

Information Quality Criteria and their Importance for Experts in Crisis Situations

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ABSTRACT

In the past a lot of researchers have defined criteria to determine information quality. Various criteria and dimensions have been identified and examined in different contexts. But very few of them focused on information quality in the context of complex situations, especially in the domain of crisis management. These complex situations demand for an extensive level of information as a basis to the difficult decisions an officer-in-charge has to make. Therefore, if we want to support the decision-making of the leading officers through an at least semi-automated process, we need first of all to find a set of criteria to assess the information quality considering the special requirements of such complex situations. In this paper we describe our approach of defining a criteria set by identifying the characteristics of complex situations, then we analyze existing models of information quality and map their aggregated criteria to the identified characteristics and finally first results of interviews to evaluate the set through the involvement of domain experts are presented.

Keywords

Information quality, information quality criteria, crisis situation, requirements of crisis situations, crisis management, expert validation.

INTRODUCTION

Information is the basis for actions and decisions – whether in professional or private life (Müller, 2001). Information becomes more important with the rising impact of the results of actions. However, complete information is not the sole criterion in real life decisions. On one side quick and definitive decisions are required in critical situations; on the other side extensive information to prevent incorrect decisions are needed (Strohschneider, 2007). This applies especially to the work of fire fighters and rescue organizations.

Since modern mobile communication infrastructure is largely available (Rohrer, 2009), essential information can be accessed in situ if necessary. The problem is the amount of online accessible data and its exponential growth. In 2002 approximately five Exabyte of new data was produced on the media print, film, magnetic and optical storage (Lyman and Varian 2009). In 2007 the total amount of digitally generated data added up to 281 Exabyte. The prediction for 2011 assumes 1800 Exabyte (Gantz, 2009).

The challenge is to filter the relevant information from the entirety of data. Considering the fact that time pressure which is typical for complex situations (Shankar and Watts, 2003) limits the possibilities to perform an extensive search, the use of an electronic data processing system is indicated. Several research projects have addressed this matter (OASIS, 2005; Freßmann, 2007; Peinel, Rose and Berger, 2007; Japs and Prödel, 2009).

But the identification of relevant data for a specific situation is just the first step. Due to the fact that not every data contributes to the satisfaction of information needs in equal measure a rating of the data received from an IT-system is necessary to either eliminate data of lower value or to sort the result set (Kreitel, 2008). In order to support the situation assessment in critical situations (e.g. firefighting, rescue operations, etc.) we developed an

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IT-system that is capable of identifying relevant information and sort them according to their overall information quality. The development of the information quality criteria necessary for the rating of the individual data objects is described in the following.

BACKGROUND

First we will explain our definition of what we refer to as a complex situation. The characteristics of this definition of a complex situation will determine the information quality criteria used to assess the individual data objects. In the second part of this chapter we will give an overview of the most common models of information quality that build the basis for our specific set of criteria.

Complex Situations

“Complex situations” is a broad term that covers a multitude of possible situations. In our work we focus on emergency response as a specific type of complex situations. Therefore, if we talk about a complex situation, we refer to the type of scenario an officer-in-charge of a fire brigade would accomplish (e.g. an accident in a chemical factory).

To start the development of criteria for information quality in such situations, we need a more in-depth understanding of the context in order to define the criteria for our work. Hofinger (Hofinger, 2007), Dörner (Dörner, 2006) and Orasanu and Connolly (Orasanu and Connolly, 1992) have published their definitions of complex situations in the above mentioned context. Our research showed that there is agreement in principle throughout the definitions. Therefore we developed a summarized and consolidated definition which seems to be the complete description for our research. It includes the following characteristics: Interdependence and high extent, dynamic, intransparency, irreversibility, plurality of goals, unique situations and high stakes.

Information Quality

Information Quality has been in the focus of numerous researchers and various criteria catalogues have been defined. But only few of them focused on information quality in the domain of crisis management and the critical situations encountered here. (Fisher and Kingma, 2001; Bharosa and Janssen, 2008; Bharosa, Van Zanten, Zuurmond and Appelman, 2009).

Since the criteria of information quality vary with the context in which they are used (Shankar and Watts, 2003), we analyze and evaluate the existing criteria catalogues according to their applicability in complex situations. On this basis we develop a new set of criteria that fits to the special conditions of complex situations within the domain of crisis management.

The most cited frameworks on information quality include the work of Wang and Strong (Wang and Strong, 1996), Eppler (Eppler, 2003), Königer and Reithmayer (Königer and Reithmayer, 1998), Redman (Redman, 1997) and English (English, 1999). This list does not claim to be exhaustive, but from our point of view they represent the most acknowledged work in the field of information quality with different perceptions of the theme. These five mentioned frameworks build the base in our further development and the criteria will be aggregated in different clusters to gain a summarized set of information quality dimensions adapted for crisis situations.

RATIONALE AND PURPOSE

As stated above the complexity of a situation is determined by the number of its characteristics and the degree of their interdependence. Problem solving in such a complex situation requires reliable information to make decisions and to act effectively. Since the subjects of our field of application are non-police civil protection officers and their operations, the situations we concentrate on, are complex and mainly critical. This implies that the actors in our scenarios have to make vital decisions under time stress. Therefore they cannot spend plenty of time searching for all the required information. Instead, they have to act expeditiously to prevent more damage. This might involve that decisions are made on the basis of assumptions and estimates, not on data and facts.

At this point an information system for crisis management like the solution in the German research project MobisPro¹ tries to assist the persons in charge in the decision process by supporting the stage of information

¹ See: <http://www.mobis-pro.de/>.

collection. It gathers all data from connected databases that contain information that are related to the current incident. However, simply presenting the data without some sort of filtering, ranking or rating would not be useful enough. The large quantity of data would result in an information overload, leaving the user alone with the problem to sort out the most important information. The problem of getting access to this information would only be transferred into a problem of sifting the information.

So if we want to realize information support through electronic data processing in a critical situation, we need to find a way to filter and sort the result set of the computerized search to improve the delivered results. This can be done if we develop a method for calculating an information quality score which allows us to compare the individual information objects with one another. If we realize this through the help of an information system we can only consider parameters that lie within the system boundary. For instance, a value that depends on specific information about the user of the system is incalculable because we have no data on future users. Therefore our framework will concentrate on criteria that are inherent to a single information objects. Calculating an information quality score out of these inherent parameters for ranking the result set, will allow the system to offer the persons in charge a wider range of information as a basis for their decisions and actions without losing time for information retrieval or sifting.

METHODOLOGY

In order to filter less relevant information or to sort different pieces of data depending on their significance to the current incident, we need to find criteria that are capable of describing the specific aspects of information quality of complex situations. As we have seen before there are a lot of models determining information quality but they do not focus on complex situations that occur during crisis management. Currently there has been very little research in this special area of information quality (Bharosa and Janssen, 2008).

The first step in generating a set of criteria for information quality in complex situations is to determine the requirements of such scenarios. Therefore we analyzed the definition of complex situations mentioned above and derived the following necessary requirements (Friberg, Prödel and Koch, 2010):

- **Interdependence, high extent**

In a situation that is characterized by many interdependent parameters, information should be **complete** and **clear** to deal with all the different facets of the problem and to prevent misinterpretation. The more **accurate** an information object is, the better it will help to clarify the situation. Despite that to avoid information overload it has to be **adequate**.

- **Dynamic**

In a dynamic situation that is subject to constant alteration, information must be **timely** and **adequate** to provide benefit and to not be overtaken by the events.

- **Intransparency**

Many characteristics of intransparent situations are not or not immediately accessible. Therefore intransparency can only be resolved by **clear**, unmistakable information that is derived from **reliable** sources. Different sorts of information would only lead to more confusion.

- **Irreversibility**

The fact that once an action has been taken it cannot be reversed demands for a thorough analysis in advance. The decision making has to be made on **reliable** and **accurate** information that are **valid**. Furthermore information should be **complete** to avoid omitting any fundamental aspects.

- **Plurality of goals**

To pursue shifting goals the information should be **timely**. To avoid problems that are created by ill-defined goals the information should be **complete** and **clear** to enable the person responsible to adjust the goal-setting. Furthermore to prevent any bias in the decision making, the information has to be **objective**.

- **Unique situations**

Unique situations call for **accurate** and **clear** information from **reliable** sources to allow realistic assessment and consequential decision making. Otherwise the manifold options for action could not be evaluated to full extent.

- **High stakes**

Due to the large-scale threats to health and life, environment and property that emerge from complex situations the information has to be **accurate** and **valid** to keep the remaining risk as low as possible. Furthermore the information must be **reliable**.

This thesis is supported by the work of Wilensky (Wilensky, 1967) and literature in the field of military operations (cf. Le Fevre, 2003, Wolstenholme, Henderson and Gavine, 1993, Vego, 2007 and Leonard, 2004).

The next step is to look which information quality criteria are able to assess the before mentioned requirements and hence have an influence on the assessment of information quality in complex situations. If we look at the five frameworks of information quality mentioned above we get a total of fifty different criteria. But some of them are correlated (cf. Pipino, Lee and Wang, 2002), so we can combine them in clusters of criteria with the same focus. For instance, *Accuracy* belongs to *Precision* and *Granularity*. We named every cluster by one criterion which is part of the cluster and which describes the entirety of the criteria in its cluster the best. Thus we were able to aggregate the fifty individual criteria in fourteen clusters: Clarity, Objectivity, Validity, Believability, Accuracy, Value-added, Relevance, Accessibility, Redundancy, Usability, Timeliness, Completeness, System and Conciseness (Friberg et al., 2010). From this list we eliminated System and Usability because these criteria focus on the usage of the information system and not the information quality of a single information object itself. Likewise Accessibility was excluded because it is a prerequisite that needs to be fulfilled beforehand otherwise an IT-system could not use the information. Of course, they are not to neglect because if they are not implemented even information with the highest information quality might not be detected by the receptor. They are just functional requirements that we do not focus on in this work. Finally the criterion Value-added is not included in the potential set of information quality criteria because it is very subjective and depends strongly on the user. To assess the added value of information we have to know a lot of the individual for example about his prior knowledge. Since we cannot create a complete model of every possible user of our IT-system with their complete backgrounds and every possible situation, we cannot proceed past the question whether the information has any relevance at all. This leaves a total of ten criteria at last which are defined concerning the conducted context:

- **Accuracy**
Accuracy defines if given information correctly represents the reality and how close something is to the true value. A lack of information will turn into large amounts of imprecise information (Manoj and Baker, 2007). Accurate information will strengthen the preciseness and leave less uncertainty.
- **Conciseness**
The criterion *Conciseness* describes the terseness of an information object. The intent always has to be identifiable, but a rambling description can decrease information as well. Information gets adequate by fulfilling the criterion.
- **Believability**
Believability complies with the perceived truth of information from the perspective of a recipient (Gräfe, 2005). By fulfilling the criterion information is reliable and credible.
- **Completeness**
Completeness defines if an issue is covered broadly within an information object and possibilities for further information are given. Complete information will not leave any uncertain areas in an information object.
- **Clarity**
The possibility of correct understanding and interpretation of information is meant by the criterion *Clarity*. Clear information will strengthen the interpretation of an information object.
- **Validity**
The criterion *Validity* is largely synonymous with logical truth and free of errors. Valid information is completely true and you can build on it.
- **Redundancy**
Redundancy means the duplication of information. Hence, redundant information already existed before.
- **Timeliness**
Timeliness declares if information is outdated or up-to-date as required. Timely information comes in time and will not deliver delayed information.
- **Objectivity**
The criterion *Objectivity* describes the judgment based on observable phenomena, furthermore how uninfluenced information is by emotions or personal prejudices. Objective information delivers a neutral

feedback to the recipient.

- **Relevance**

Relevance summarizes all information being meaningful from the point of view of a user. Hence, the criterion judges, if information has the potential to answer satisfactorily to a request. Relevant information can vary from every request and is subjective.

To complete this step of mapping the information quality criteria to the characteristics of complex situations we need to find out which of the requirements we identified before are related to the preselection of the ten information quality criteria. Obviously, complete correlates with Completeness, clear with Clarity, accurate with Accuracy, timely with Timeliness, valid with Validity, relevant with Relevance, and objective with Objectiveness. Furthermore we put adequate on a level with Conciseness and reliable with Believability. The definition of adequate is the quality of being able to meet a need satisfactorily and thereby to fulfill an appropriate amount of data. The Believability is described among others through reliable information. According to these allocations we have mapped the characteristics of complex situations to the criterion of information quality (cf. Table 1). The Relevance which we identified as a fundamental criterion does not need any additional dependence to other requirements, but is included in our final set.

In Table 1 the beforehand merged information quality criteria are mapped to the dimensions of complex situations. The criterion which has an influence on a certain dimension of complexity (cf. to the requirements of complex situations) is checked in the corresponding cell. Hence, rows without a flag do not seem to correlate with the characteristics of complex situations. The Redundancy did not get a flag because we did not identify a relation to any of the characteristics of complex situations.

Characteristics of complex situations \ Information quality criterion	Interdependence, high extent	Dynamic	Intransparency	Irreversibility	Plurality of goals	Unique situations	High stakes
Accuracy	X			X		X	X
Conciseness	X	X					
Believability			X	X		X	X
Completeness	X			X	X		
Clarity	X		X		X	X	
Validity				X			X
Timeliness		X			X		
Objectivity					X		
Redundancy							

Table 1. Mapping of information quality criteria to characteristics of complex situations

Our result fits to the criteria Gonzalez and Bharosa use in their work (Gonzalez and Bharosa, 2009): Accuracy, Completeness, Timeliness, and Relevance are also defined. Quantity is defined as we use Conciseness, Format and Consistency apply to Clarity and Security confirms Believability and Validity. So there is high potential that our identified set of information quality criteria reflects the needs of end-users in the domain of complex situations.

Because our resulting set of information quality criteria consists of more than one criterion we are facing the problem that information quality scores of individual information objects will be a composition of multiple characteristics. Since we cannot assume that all the criteria will have the same priority for the decision maker, their influence on the information quality score will vary. Therefore we need a methodology that allows us to weight the specific criteria. Multi-criteria decision making models (MCDM) provide the ability to evaluate a

finite set of alternatives with respect to multiple criteria. The most common models include the multiple attribute utility theory (MAUT), the multiple attribute value theory (MAVT) and the analytic hierarchy process (AHP) (Choo, Schoner and Wedley, 1999). Since we assume mutual independence of our criteria, we can use the less complex additive form of the MAVT. So we will use an additive scoring model to calculate the information quality score (IQS) of an individual information object (io_j):

$$IQS(io_j) = \sum_{i=1}^N w_i v_i(s_{ij})$$

With:

N: number of criteria

w_i : weight for criterion c_i

v_i : value function for criterion c_i

s_{ij} : score of information object io_j for criterion c_i

The weight represents the importance of the criteria in the users' point of view, while the value function normalizes the scores of the different criteria to a comparable level. The determination of the individual weights of the specific criteria will be derived from interviews with experts in the domain of crisis management. With these interviews described in the following section, we are pursuing two targets: first, we want to validate the correctness of our result set and second, we want to establish a ranking of our criteria (i.e. to identify the individual weights of the specific criteria).

VALIDATION

We achieved nine criteria (eight out of the mapping and additionally the Relevance as a fundamental criterion) to define information quality. Even if our result relates to criteria defined by other researchers (e.g. Bharosa and Janssen, 2008), we have to validate our results by persons familiar with complex situations. They are the real end-users who will benefit from the assessment and declaration of the information objects. During the evaluation phase of several research projects at our institute we have started to conduct interviews with several experts of the crisis management. These experts were fire fighters in leading positions in a huge city of Germany and furthermore emergency manager of a subway station.

During the questions their estimation of the importance of the miscellaneous information quality criteria were filmed, recorded and analyzed.

In that process indicators which represent each criterion will be questioned. These statements give information about how the users define each criterion and will help to develop solutions to support the assessment of information. We refer our question to the work of (Friberg and Reinhardt, 2009) where a survey was conducted in-depth to analyze the importance of information quality criteria and their indicators of corporate wikis.

In order to receive qualified feedback on our criteria set, we need a group of people familiar with decision-making in crisis situations. For instance, fire fighters who have acted as officer-in-charge. In this position you need to be able to make quick decisions on sparse information while being responsible for the health and life of your team and the involved civilians.

So we can define the following requirements for the participants of our study:

- Multiple years of experience as the specific expert
- Knowledge about operational tactics and procedures in the specific organization
- Recognized qualification
- Leadership skills
- Proven capability of rational judgment

The conduction of the interviews

Through the interviews with the experts we want to find out how they define information quality in their specific field of expertise.

We present and define the nine identified criteria to the participants on moveable cards by explaining every criterion in detail. The criteria are presented randomly. In the beginning each criterion is defined by the interviewer to the experts to guarantee the same basis for every participant. Afterwards the task for the persons is to sort the cards in three groups. The groups are called “very important for my work”, “less important for my work” and “not important for my work”. After the sorting the criteria in the first group shall be arranged according their prioritization.

The participants are requested to comment their sorting (“think-aloud”) and to ask if anything is unclear. The final sorting is recorded for the analysis.

The sorting within the groups is weighted in the analysis. Criteria in the first group get four points, the “less important”-group gets two points, and “not important” gets zero points. If the criteria are arranged according their prioritization, we distribute the available points. Otherwise every criterion in the same group gets the same points. Finally, all numbers are summarized and hence, the highest result presents the most important criterion and the lowest number the least important criterion.

Besides, we scrutinize if further criteria belong to the definition of information quality than the suggested ones and encourage the participants to specify further criteria which seem to be important from their perspective to assess the information quality. We finished the interview by asking for possible indicators to measure and assess these criteria.

First Results

Until now (March 2011), 16 interviews were conducted. In the next weeks and months further interviews will be realized.

In Table 2 the results are shown with the gathered points during the sorting. It is recognizable that often many criteria got four points or at least are sorted into the first “important” group (every criterion with more than two points). Few criteria are classified into the last group “not important”, often the reason was the expectation of the fulfilling of that specific criterion and hence the person does not require an assessment.

Person	Believability	Clarity	Conciseness	Accuracy	Completeness	Relevance	Timeliness	Validity	Objectivity
1.	4	2	2	4	2	4	4	2	4
2.	4	4	4	2	2	4	4	0	4
3.	2	2	4	4	4	4	4	2	2
4.	4	4	4	4	4	0	2	0	4
5.	0	0	0	4	4	4	4	2	0
6.	4	3	3	3	1	1	0	0	4
7.	2,5	3,5	3	4	2	2	0	2	0
8.	1	4	3,5	3	3,5	0	2,5	2	1,5
9.	3,5	2,5	2	2	2	3	2	2	4
10.	0	4	4	4	1	4	2	2	3
11.	0	4	4	4	0	3	3	0	0
12.	1	4	4	2	2	2	4	1	1
13.	0	4	4	4	4	2	2	0	2
14.	2	3,5	2	2	2,5	2	4	3	4
15.	4	4	4	4	0	4	4	4	4
16.	0	4	4	0	2	4	4	1	2
Total:	32	52,5	51,5	50	36	43	45,5	23	39,5

Table 2. Sorting during the interviews

In figure 1 you can see the first distribution of the presented information quality criteria. We summarized the gathered points of all criteria and hence we reached a percentage distribution. After the conducted interviews *Conciseness* and *Clarity* are the most important criterion, followed by *Accuracy* and *Timeliness*. The *Validity* seems to be the least important criterion.

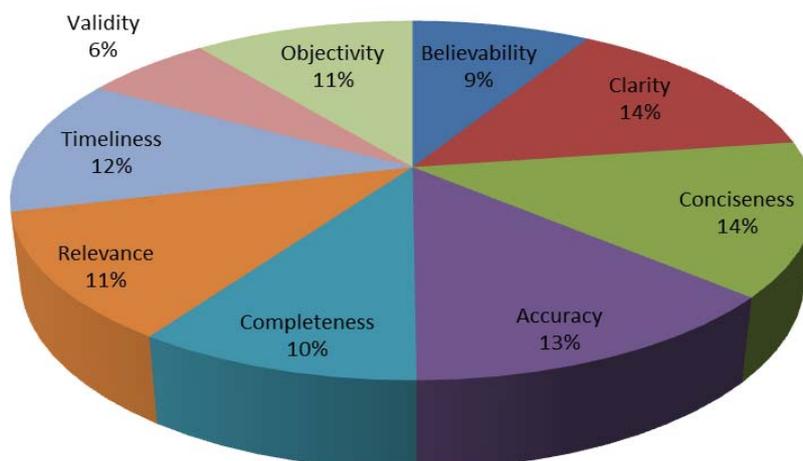


Figure 1. Distribution of the information quality criteria

An additional criterion was named very rarely in the interviews; “Security” was mentioned twice. The persons confirmed a complete set of information quality criteria.

Furthermore indicators for every criterion to assess it (i.e. creation date for Timeliness) were questioned. Suggestions towards specific indicators were just named rudimentally.

CONCLUSION AND OUTLOOK

In this paper we describe the approach of defining a set of information quality criteria. Our work focuses on information quality in crisis situations and the paper starts by identifying the characteristics of complex situations. We analyze existing frameworks of information quality and then we map the clustered criteria to the obtained characteristics. Finally, we present the process of the conducted interviews with domain experts. Through that method real end-users of complex situations (leading positions of fire departments and emergency manager of a subway system) are involved in the evaluation of the set of information quality criteria. The motivation for us to start this work was to minimize the information overload for users especially in the domain of crisis situations and offer the possibility to assess the information. The intention is that correct information can be delivered at the right time.

Until now we received 16 answers of experts and we expect further results of several experts in the domain of emergency response during the upcoming months. These ratings will give us feedback if we have identified the correct criteria to assess the information quality in a complex situation. Hence, it is important to work together with more experts to get valid results of the importance and prioritization of the information quality criteria. This will enable us to determine the individual weights of the specific criteria in our information quality score formula. The value function and calculating a score for each criterion is further work in progress.

In the future it will be of great interest to analyze dependencies between the criteria. Maybe there is a relation between for example Believability and Objectivity.

Furthermore the adaption to other domains has to be taken under account. The feedback of end-users of several complex domains can possess the statement that the set of information quality criteria is valid in the domain of crisis situations. Maybe the set is not complete for every organization and we identify a core set which has to be adapted.

Moreover, a target is to scrutinize the indicators having an influence on each criterion otherwise it would not be possible to assess the criteria, especially automatically or semi-automatically in an IT system. Ideas for that could be the length of text, etc. A motivation is to collect these indicators dedicated for every criterion of the identified set. These indicators have to be analyzed and refined in detail afterwards and a validation with experts of a first prototype has to be attached. As the participants of the interviews just mention potential indicators rudimentally, it could be an improved approach to propose some indicators to the people to get a confirmation and extension.

An interesting aspect would be the result of foreign countries, because these interviews were conducted in Germany and maybe the influence of another culture would change the results of the experts.

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