ANALYSIS OF INFORMATION QUALITY CRITERIA IN A CRISIS SITUATION AS A CHARACTERISTIC OF COMPLEX SITUATIONS

(Research-in-Progress)
IQ Concepts, Metrics, Measures, and Models

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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. Characteristics of this domain include the facts that the stakes are high and the time for intervention is short. These complex situations demand for an extensive level of information as a basis to the difficult decisions an officer-in-charge has to make. But the need for quick action limits the time available for comprehensive information. Therefore, if we want to support the decision-making of an officer-in-charge 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 first, then analyzing existing models of information quality and mapping their aggregated criteria to the obtained characteristics and finally the preparation of a survey to evaluate the set through the involvement of domain experts.

Key Words: Information Quality, Information Quality Criteria, Complex Situation, Requirements of Complex Situations, Crisis Management

INTRODUCTION

Private and professional information are formed every day – they are the basis for actions and decisions [25]. They become more important within rising impact of the results of actions. On one side quick and definitive decisions are required in critical situations, on the other side extensive information to prevent incorrect decisions are needed [35].

For instance, the reinforced passenger cells of modern motor vehicles offer more protection to the passengers in case of an accident, but even professional rescue equipment may fail if the correct point of application is unknown. Due to the resulting amount of documents it is impossible to collect all needed

information for every possible incident in advance. The very idea of a complete list of all possible incidents is unrealistic because of the infinite number of variations and combinations of individual events. Even a reduction on the most common events and the use of modern digital storage media would leave the problem that the information may not be current.

In contrast the realization of an "on demand" service is not a problem due to the availability of modern mobile communication infrastructure [32]. This would give access to a variety of up to date information. 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 [23]. In 2007 the total amount of digitally generated data added up to 281 Exabyte. The prediction for 2011 assumes 1800 Exabyte [10].

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 [34], 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 ([17], [27], [8], [29]).

Even though the amount of available data can be decreased to the subset corresponding with the actual event by the use of an electronic data processing system, the remaining result set may still contain inappropriate data or simply be too large. 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 [20].

The identification of information quality criteria considering the requirements of situations that can be specified as complex situations is the first step to identify, to assess and in the future to improve data for users in complex situations. The development is described in the following.

STATE-OF-THE-ART AND BACKGROUND

First we will give a definition of what is referred to as a complex situation. The specific characteristics of complex situations will be the determining factor for the selection of the information quality criteria. An overview of the most common models of information quality completes this chapter.

Complex Situation

In our work we focus on emergency response as a specific type of complex situations. Different crisis situations and scenarios will change the importance of the different characteristics. 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 (for example that could be an accident in a chemical factory). This generates some specific conditions that are discussed hereafter.

Interagency disaster management is considered to be a very complex process [3]. To start the development of criteria for information quality in complex situation, we need a more in-depth understanding of the context in order to define the criteria for our work. Hofinger [15], Dörner [4] and Orasanu and Connolly [28] have published definitions of what they see as complex situations. If we compare their definitions we will find agreement in principle. Our consolidated definition of complex situations which seems to be the complete description in our research includes the following characteristics:

- **Interdependence, high extent**
  A complex situation is characterized by the existence of many, interdependent characteristics. The degree of complexity originates from the number of characteristics and the degree of their interdependence.

- **Dynamic**
  The situation has a momentum of its own with an accelerating tendency that causes time stress. The trend of development is important to know before deciding which actions should be taken. Therefore the completeness of information collection collides with compulsion to take action

- **Intransparency**
  Many characteristics of the situation are not or not immediately accessible.

- **Irreversibility**
  The development of the situation and results of actions taken cannot be reversed.

- **Plurality of goals**
  Various, potentially conflicting and in the beginning vague goals have to be pursued.

- **Unique situations**
  Since no standard solutions exist many options for action are possible whose availability and effects are unknown.

- **High stakes**
  Complex situations provide high risks for persons affected and rescue forces such as large-scale threats to health and life, environment and property.

The perception of these characteristics of complex situations is individually affected and therefore subjective. They are perceived properties of a situation and depend on the individual capabilities of the acting persons as their education, training, knowledge, cognition, motivation, etc. A situation can therefore be complex for one person while another person would come to a different conclusion [15].
Because of the irreversibility of decisions and actions it is not advised to solve the problems by tryout. Rather than that the action must be consciously organized to achieve a satisfying solution. Dörner lists the following stages of problem solving (cf. [18]): (1) target identification, (2) collection of information and modeling, (3) planning, (4) decision making, (5) controlling and (6) adaption [4].
The significant part for our work is stage (2) "collection of information and modeling". Considering the time stress and the limited capability of the human brain to process information [16], it is essential to identify the most important information. The most common models to describe information quality are introduced in the following section.

Information Quality

In the past a lot of researchers have defined criteria catalogues to assign the determination of information quality. Various criteria and dimensions had been identified and examined in different contexts. But only a very few of them focused on information quality in the context of complex situations, especially in the domain of crisis management (e.g. [1], [2], [7]).
As Shankar and Watts [33] emphasize, criteria of information quality vary with the context in which they are used. Hence, to achieve a criteria catalogue in the case of complex situations, we have to analyze the existing ones. We present some of the existing frameworks in this section with the intention to build a base for the definition of the potential criteria to determine information quality in complex situations. Our list does not claim to be exhaustive, we intend to give an overview of the most cited frameworks and want to show the general overlaps.
The authors in [37] developed a set of 15 information quality criteria under intensive embracing of answers from participants of arranged surveys. The authors have derived a criteria catalogue, which contains the most important criteria to assess information quality from the perspective of users. By analyzing existing frameworks [6] generated a model with 16 criteria for information quality. The

analysis was done by literature research and empirical studies. [19] focus in their framework on the quality of the structuring of information. They analyze the management of information in organizations and develop overall 14 criteria. Redman [31], an early leader in the information quality community [11], emphasizes 20 criteria for companies to manage information quality systematically. English [5], one of the pioneers and thought leaders in the IT-driven information quality field [11], developed a framework with 15 criteria. The set primarily focuses on information in databases from a management point of view. The catalogue acts an important role in the literature and research and hence it has been included in the further development. The 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.

During the processes of complex situations, like crisis response, information is considered to be one of the essential needs of relief workers [14] and poor quality of information can be disastrous for both the workers and victims [7]. Concerning crisis response Gonzales [12] points out eight criteria of considered literature to define information quality, but these criteria were not validated by end-user.

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 MobisPro[1] tries to assist the persons in charge in the decision process by supporting the stage of information 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. In this way the persons in charge will be offered a wider range of information as a basis for their decisions and actions without losing time for information retrieval or sifting.

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 have a model of information quality. As we have seen in the previous chapter there are a lot of models determining information quality but they do not focus on specific characteristics of critical situations. Currently there has been very little research in this special area of information quality [2].

Therefore we would like to present our work on establishing a set of information quality criteria in the special area of complex situations which then will be validated by domain experts.

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[1] Mobis Pro is a current German research project, which is coordinated by our institute. The system aggregates different data sources and provides necessary information to the officers-in-charge. Here you can find more information: http://www.simobit.de/de/140.php and http://www.mobis-pro.de/. If you are interested in detailed English information, please contact the authors.

APPLIED METHOD

The following section describes the derivation of the criteria to assess information quality in complex situations. It starts with determining requirements for information in complex situations. Then the criteria of the above mentioned frameworks are clustered into groups with similar impact. These clusters are mapped to the characteristics of complex situations to identify the required criteria.

Requirements on information in complex situations

The first step in defining a set of criteria for the assessment of information quality in complex situations is to find out which requirements must be met by information objects in this particular case. Therefore we analyze the definition of complex situations given before and derive necessary requirements.

- **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**
  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 or competing 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 **complete** 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**.

A general requirement on any information is that it is **relevant** to the specific situation. The next step would be to evaluate if a relevant information would make a difference in the situation assessment. If not,

it would be dispensable. The problem is that this would require detailed knowledge about the person assessing the situation. As mentioned above in the definition of complex situations the grade of complexity depends on the individual person and their background. The same applies to the question whether an information makes a difference or not. It depends on the knowledge, training, motivation etc. of a specific person and the uniqueness of the actual situation. 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.

So we can summarize that information in complex situations should be accurate, adequate, clear, complete, objective, relevant, reliable, timely and valid. This thesis is supported by the work of Wilensky [38] and literature in the field of military operations (cf. [21], [39], [36] and [22]).

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 situation.

Development of the Criteria-Set

The development of the potential information quality criteria catalogue was made stepwise. In a first step the criteria of the existing frameworks were clustered according their definition of information quality. Some of them are correlated (cf. to [30]), so the number of criteria can be decreased. For instance, the *Accuracy* depends on the *Precision* and *Granularity*. Every cluster is named by one criterion which is included and describes the other criteria in the group. Furthermore every criterion in a group is assigned to the author who listed it originally to show that the remaining clusters were meaningful in past research. We want to give an overview of general criteria to assess information quality as independent from every individual as possible. The result of this clustering is pictured in Table 1.

	Eppler, 2003	Wang & Strong, 1996	English, 1999	Königer & Reithmayer, 1998	Redman, 1997
Cluster 1: Clarity	•		•		•
Ease of understanding		•			
Comprehensiveness	•				•
Interpretability		•		•	•
Understandability				•	
Consistency	•	•		•	•
Homogeneity					•
Equivalence			•		
Conformance			•		
Cluster 2: Objectivity		•		•	
Naturalness					•
Cluster 3: Validity			•		
Correctness	•				
Rightness			•		

Cluster 4: Believability		•			
Reputation		•			
Traceability	•				
Trust				•	
Integrity			•		
Cluster 5: Accuracy	•	•	•		•
Precision			•	•	
Granularity					•
Cluster 6: Value-added		•			
Cluster 7: Relevance		•		•	•
Essentialness					•
Identifiably					•
Appropriateness				•	•
Content				•	
Cluster 8: Accessibility	•	•	•	•	
Obtainability					•
Existence				•	
Cluster 9: Redundancy			•		•
Nonduplication			•		
Cluster 10: Usability			•		
Flexibility					•
Efficiency					•
Applicability	•				
Interactivity	•				
Convenience	•				
Cluster 11: Timeliness	•	•	•	•	
Currency	•				•
Cluster 12: Completeness		•	•		•
Cluster 13: System					
Robustness					•
Maintainability	•				
Speed	•				
Security	•	•		•	
Cluster 14: Conciseness	•			•	
Appropriate amount of data		•			
Concise representation		•			

Table 1: Cluster of information quality criteria

One group is named "System" because the criteria deal with the functionality of the system and do not look at the quality of the content of a single information object (cf. also [26]). We want to focus on the

most important criteria to determine information quality and criteria like *Speed* do not point at the information quality of a single information itself; the criteria have to be fulfilled forehand by the system and are components of the functional requirements. Likewise the cluster *Usability* focuses on the usage of the information system and the *Accessibility* is a precondition to receive information. Of course information needs to be accessible to provide any use at all, but this is more of a prerequisite. And since we will use the criteria set to define the information object a user of an IT-system received, also this requirement already has to be fulfilled forehand. Hence, from this point of view we eliminate these groups of criteria from the list. 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. Moreover, 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.

The before-mentioned frameworks were clustered and furthermore in a second phase the adaptability to complex situations of the remaining nine criteria were analyzed. To achieve a definition of information quality it is not enough just to identify the common items of the existing models because as mentioned before the criteria depend on the used context [33] which has to be taken under account accurately. Therefore the requirements we identified before are related to the preselection of information quality criteria we found out. Of course, 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 that something has to be enough to meet a purpose and 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 (as you can see in Table 2).

Information quality criterion \ Characteristics of complex situations	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	X	
Clarity	X		X		X		
Validity				X			X
Timeliness		X			X		
Objectivity					X		
Redundancy							

Table 2: Mapping of information quality criteria to characteristics of complex situations

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 have an impact on complex situations. The *Redundancy* did not get a flag because we did not identify a relation to any of the characteristics of complex situations. The nine remaining criteria and additionally the *Relevance,* which we identified as a fundamental criterion which do not need any additional dependence, are defined below for the adapted context.

Our result fits to the criteria [12] use in their work: *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.

Definition of the criteria

The identified set of information quality criteria we found out is defined for the context of a crisis situation and the need to cover the specific criterion is given. The collection includes nine criteria.

- **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 [24].

- **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.

- **Believability**
  Believability complies with the perceived truth of information from the perspective of a receptor [13]. But this truth has not necessarily to go along with the objective reality.

- **Completeness**
  Completeness defines if an issue is covered broadly within an information object and possibilities for further information are given.

- **Clarity**
  The possibility of correct understanding and interpretation of information is meant by the criterion *Clarity*.

- **Validity**
  The criterion *Validity* is largely synonymous with logical truth and free of errors.

- **Timeliness**
  Timeliness declares if information is outdated or as up-to-date as required.

- **Objectivity**
  The criterion *Objectivity* describes the judgment based on observable phenomena. Furthermore how uninfluenced information is by emotions or personal prejudices.

- **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.

DESIGN OF THE EMPIRICAL STUDY

We achieved nine criteria to define information quality. Even if our result relates to criteria defined by other researchers [2], 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 research projects at our institute at the end of the year 2010 an interview will be conducted with several experts of crisis management. During the questions their estimation of the importance of the miscellaneous information quality criteria will be collected and analyzed. In that process indicators which represent each criterion will be questioned. These statements help to understand how the users define each criterion and will later on help to develop solutions to support the assessment of information.

We refer our question to the work of [9] where a survey was conducted in-depth to analyze the importance of information quality criteria of wiki used in organizations.

In this section we present the focus group of interest and the design of the intended questionnaire.

Focus group

In order to receive qualified feedback on our criteria set, we need a group of people familiar with decision-making in complex situations. For instance, this could be firefighters that 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 experience as officer-in-charge
- Knowledge about operational tactics and procedures
- Recognized qualification as platoon leader at least
- Leadership skills
- Proven capability of rational judgment

The questionnaire

In our planned questionnaire firstly we want to analyze if a low information quality influences the workflow of the users (Figure 2). Thereby the goal is to strengthen our motivation to continue the research in the domain.

Would low information quality influence your work process?

◯ very high influence   ◯ high influence   ◯ weak influence   ◯ no influence

Figure 1: Influence on the workflow

Following we want to find out, the main interest, how the end-users define information quality. We will suggest the defined criteria to the participants and request their importance on the basis of a four-level

Likert scale (cf. to Figure 3). The criteria are listed randomly and do not have an impact on the weighting. Each criterion will be asked separately together with an exploration of appropriate indicators which can be gathered in cooperation with the experts. We know that the criteria are not independent but we aim at gathering statements about every criterion and its indicators. The challenge is to enable the interviewed person to focus on every single criterion as effectively as possible.

How important are in your opinion the following criteria concerning the assessment of information quality?

	very important	important	less important	not important
Accuracy	○	○	○	○
Conciseness	○	○	○	○
Believability	○	○	○	○
Completeness	○	○	○	○
Clarity	○	○	○	○
Validity	○	○	○	○
Timeliness	○	○	○	○
Objectivity	○	○	○	○
Relevance	○	○	○	○
	1	2	3	4

Figure 2: Classification of information quality criteria

Besides we challenge if further criteria belong to the definition than the suggested and encourage the participants to itemize further criteria which seem for them to be important to assess the information quality (cf. to Figure 4).

Is in your opinion a criterion missing in the list?
☐ no
☐ yes _____

Figure 3: Further criteria

These questions show an excerpt of the survey we plan to conduct during the upcoming evaluation phase of the research projects[2]. We want to have the set we identified validated by end-users and where appropriated we will modify the collection of criteria. Furthermore we expect an assemblage of indicators

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[2] First results could be available at the conference in November 2010.

for every criterion.

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 the domain of emergency response and the paper starts with 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 first steps towards a survey to question domain experts are presented. Through that method real end-users of complex situations 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 complex situations and offer the possibility to assess the information. The intention is that correct information can be delivered at the right time.

We expect answers 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. Otherwise a next step would be to modify the set of criteria. Modification could imply to work on singular criteria or maybe to diminish the collection of criteria. 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 complex situations.

Furthermore 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. Ideas for that could be the length of text, the creation date, 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 maybe a validation with experts has to be attached.

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