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Amount and Utility of Information Values: Two Cases of the Most Misunderstood Quality Attributes

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ABSTRACT

This is a comparative technology-independent case approach to theory-based views of operations quality requirements for data and information values. Two contrasting cases illustrate the intricate relationship between the amount of information as defined by Shannon and Weaver and the utility value of information as defined by Kofler. Simple examples illustrate the role of quantity and utility value of information in decision-making within business environments. They are discussed by referring to the ontological, evolutional, and teleological frameworks proposed for assessing operations quality of data/information values.

INTRODUCTION

This is a contribution to the discussions on different approaches to quality of data and information values. Liu and Chi (2005) categorized different approaches as intuitive, empirical, and theoretical. Initially, the intuitive, and the empirical approaches dominated, but they lack theoretical foundations on how DQ/IQ attributes are defined and grouped. This is a comparative technology-independent case approach to theory-based views of the quality of data and information values. The presented cases stay exclusively within the theoretical approaches that yield results of a more lasting validity. They derive attributes of information quality from established theories. Two cases illustrate and discuss the controversial **amount of information** as defined by Shannon and Weaver (1949) and the **utility value of information** as defined by Kofler (1968). Other dimensions of data/information quality are discussed as needed by the context by referring to three proposed theoretical frameworks: the ontological approach limited to the some intrinsic quality dimensions defined by Wand and Wang (1996), the evolutional theory-specific approach defined by Liu and Chie (2002), and the teleological operations research-based and content-focused approach as proposed by Gackowski (2005b).

The main contributions of this paper are:

- A demonstration of the advantages of the theoretical approaches to identifying the major data/information quality requirements
- Presentation of theory-specific approaches to quality by using two contrasting cases when:
  - The amount of information is important in defining its utility or payoff, and when
  - A huge utility value or payoff hinges upon only one bit of the amount of information
- A comparative discussion of other related quality dimensions as needed.

OVERVIEW OF SOME THEORY-BASED VIEWS OF QUALITY

1. In 1949, within the **mathematical theory of communications1**, Shannon and Weaver (1947) defined the amount of information $\mathbf{A_I}$ transmitted as a function of its probability $\mathbf{p_I}$ that is: $\mathbf{A_I = -log_2\ p_I}$. The formula yields a number that indicates the rarity or the surprise effect associated with an object, event, or state represented by the received signal or value. Other attributes of information encoding can be derived from this one such as encoding capacity of communication channels or data fields, absolute and relative information encoding efficiency, absolute and relative redundancy, etc. It enables calculation of cost effectiveness of storing and processing of data and information. Two decades later, Mazur (1970) developed a generalized **qualitative communication theory** that does not require the assumption of probabilities and yields the same results, thus providing the ultimate proof of its validity. (In science, use of probabilities indicates that the internal mechanics of the phenomenon is not yet fully known.) How abstract the definition of the amount of information may sound, it plays a direct role in news services and news media2 such as press, radio, and TV.
2. In 1968, in **information economics**, Kofler (1968) defined the utility of an information value as the difference between the utility value of results of operations while acting with and without it. The assumption is that decision-makers, while making decisions and acting accordingly, use some data **D** known to them. An incoming piece of information **I** may change the decision situation from what they know. The change is represented by the transition from state **D** to state **D + I**. Then, the ***utility value of an information value V(I)3*** or its impact on business results is the difference between the **utility value of results** $\mathbf{V_R}$ of business operations while acting with $\mathbf{V_R(D + I)}$ and without it $\mathbf{V_R(D)}$. It can be calculated only under the assumption that *the results of business operations can be assessed*, not necessarily in monetary units. The same formula covers the utility value of a lost piece of previously available data value that significantly impacts the outcomes. From this definition, other related attributes can be derived such as its procurement cost, net utility value, and its simple and expected cost effectiveness. Most authors of MIS textbooks do not pay attention to these attributes or pay lip service only. It amazes that Alter (2002, p. 162) ironically describes this pragmatic definition of utility of information value as "more elegant than practical." Utility value of any data or information value should be considered from either side of the supply chain – the providers and the consumer. The benefits for both sides are equally important for lasting business relations. One should not overlook, however, that the provider of information is always in a stronger position than the consumers, hence, the latter may deserve more protection, although their perspective are not necessarily more important or critical.
3. In 1996, based on **ontological foundations**, Wand and Wang (1996) defined four data quality dimensions (complete, unambiguous, meaningful, and correct) intrinsic to the design and

operations of information systems. They were derived by analyzing the requirements for faithful mapping of states of the real world into the states of information systems. Within the confines of the assumptions used4, “those attributes have crystal-clear definitions and theoretically sound justification, but they constitute only a small subset of known attributes leaving the rest unspecified” (Liu and Chie, 2002). They are preconditions of accurate representation of reality, hence preconditions of accuracy and precision of data values, which again are contributing factors of credibility of data or information values. The defined quality dimensions were clearly explained as derived from deficiencies in the design and operations of information systems. There is, however a problem associated with this excellent contributions. They were clearly defined as intrinsic to the design and operations of information systems, but later mislabeled as intrinsic data quality dimensions. They are continuously cited and accepted as such.

4. In 2002, in an **evolutional and theory-specific approach** to data quality, Liu and Chi (2002) try to overcome the weaknesses of the product analogy used in empirical studies of DQ/IQ and the narrowness of the ontological approach limited only to a few quality dimensions intrinsic to system design and operations. The authors claim that data have meaning only through a theory. As data evolve through the stages of the data evolution life cycle (DELC), they undergo a sequence of transformations and exist independently as different morphons (**captured** data; **organized** data, **presented** data, and **utilized** data). Each transformation introduces independent errors such as measurement errors during data collection, data entry errors during data organization, interpretation biases in data presentation. Different theories apply to different stages of the DELC; hence, different definitions to measure the quality of those morphons are needed. Instead of a single universal concept of data quality, four hierarchical quality views are used for data collection, organization, presentation, and application.
5. In 2005, anchoring the concept of data/information quality in **operations research**, **management science, and decision science,** Gackowski (2005b) proposed a theoretical technology-independent teleological operations-based and content-focused framework of operations quality of data and information values. This approach makes possible the definition of:

- A universal taxonomy of the entire universe of quality requirements for data and information values by the type of their impact on operations into direct and indirect ones, the direct into primary and secondary ones, and the primary into universal ones and task-specific ones
- Sufficient conditions for defining task-specific usability of single data/information values and for task-specific effective operational completeness of sets of usable data and information values with a clear distinction of *only effective* and four additional mandatory requirements for also *economically effective completeness*
- An economical examination sequence of the direct primary universal quality requirements
- Presently seven universal principles governing all operations quality requirements.

CASES WITH SELECTED THEORY-BASED ATTRIBUTES OF QUALITY

Some Basic Terminology

In discussing the theory-based attributes of data/information values, one must make a rigorous distinction between data and information values that in other situations might not be required. Here, this distinction is made within the context of decision situations. Decision makers and acting agents already know some aspects of the situation, but other may yet remain unknown to them. Within this paper, ***data5 values*** represent aspects of reality that are known, given, or assumed true. ***Reality*** encompasses business organizations and their environments. Within reality, one distinguishes ***entities***, which are objects or events represented symbolically by their identifiers and values of their attributes. ***Information values*** represent things, events, and unknown states that are yet to be acquired, which change the decision situations per se, and/or the actions that implement the decisions, and/or the results of operations. From the viewpoint of the theory of communications, any representation of something known contains or conveys zero (0) bits of the amount of information – the low extreme of Shannon’s equation. Shannon’s formula of the amount of information $\mathbf{A_I = -log_2\, p_I}$ associates $\mathbf{A_I}$ bits of information with any symbolic representation of reality that is yet unknown as a function of its probability $\mathbf{p_I}$. The amount of information measures the rarity or the surprise effect associated with the object, event, or state. Thus, at the other extreme, symbolic representations of objects, events, or states, which are very unlikely, with probability $\mathbf{p_I}$ close to zero, is associated with nearly an infinite amount of information for their recipients. ($\mathbf{A_I = -log_2}\ 0 = \mathbf{-\ log_2}$ (1/**”) = log**$_2$ •H•” [bits] – the high extreme of Shannon’s equation).

Some in the field prefer “known information” vs. “unknown information” instead of data values and information values. In the light of the communications theory “known information” is a contradiction in adjective such as a solid liquid and as such unacceptable in rigorous parlance. In operations, explicit vs. tacit is considered universally only when testing interpretability of data and information values during their acquisition. In indirect informing, it is also a factor of presentation interpretability of values by their users. To them it may or may not be. Encoding does not imply explicit information. It may be encrypted. Under no circumstances, any amount of information should be considered useful; it may be or not. Within the model of operations quality, usability6 and usefulness7 of any data/information value are clearly defined. This approach to quality is simple, devoid of any lofty fuzzy considerations alien to decisively acting decision-makers in massive business, public administration, and military operations (Gackowski, 2005b).

It is easier to grasp abstract concepts when examined within a broader context of their use. In operations:

- *Data values* represent aspects of reality that are *given, known*, or assumed true.
- *Information values* represent aspects of reality that are *unknown* and must yet be obtained.
- Data and information values are *disjoint* sets of values (with no overlapping elements).
- Available data values <u>never</u> change operations; their usefulness has been already discounted.
- Any obtained information value, if of significant impact or relevance, <u>always</u> changes the operations situation qualitatively and quantitatively, and/or the necessary actions, and/or the results.
- All values of quality attributes of data and information values share the same multidimensional space, but *differ substantially*; usually they are at the <u>opposing ends</u> of their respective spectra.
- Data values are an important part of operations completeness, but they never increase it. An incoming information value, if only of significant impact and useable, <u>always increases task-specific operations</u> completeness of data/information values.

MIS textbooks are confusing student minds with scientifically untenable definitions such, as “information is processed data.” No amount of high-speed data processing will yield information out of known values; it may derive another data value from available data values. This is a deterministic process, with no room for any uncertainty; hence no amount of corresponding information that always changes the corresponding decision situation. Data mining may yield information. Data mining, however, is not data processing but a one-time knowledge acquisition process of discovering new patterns in large data collections - a research result that to be interpreted by researchers not users. Discussions of operations quality of data and information values require a corresponding quality of the vocabulary used.

The following cases illustrate the theoretical aspects of the amount and the utility value associated with information values obtained from the outside world.

CASE 1 - AMOUNT OF INFORMATION AND OTHER IQ DIMENSIONS IN NEWS MEDIA

This is a business case when a *large amount of information translates into high utility value of an information value*. Within communications theory, the amount of information is used mainly for calculating the capacity of communication channels and efficiency of encoding. However, it also measures an important aspect of news for news media. Generally, nothing known makes good news. It has to be extraordinary, rare, and unlikely for being considered interesting news. For the news media, the more unlikely an event is the more useful it is for the publisher. Reporting of rare events increases ratings, circulation, and visibility. It attracts high-paying advertisers. In addition, to rarity of events, the higher the general appeal of the subject for media consumers, the higher its utility value is. Its impact on business results of media may be very high.

When information acquisition processes yield only values already known no one feels informed. They do not change the outcomes of business operations. Users received zero amount of information of zero utility value. There must be at least some amount of information to carry the utility value. Between the two, there is only a **qualitative** relationship, but **no direct quantitative** relationship. No trade-offs are possible either. The formulas that define the amount of information and the utility value of information are completely independent and derived from different sets of assumptions. No direct or intrinsic relationship between the two dimensions exists.

The teleological view emphasizes the impact an information value makes on business results. In a news service, however, there are also other important universal direct primary quality requirements associated with a tangible utility value for publishers. Information values must also be **operationally timely available** with the exclusion of other competing actors; otherwise, they lose or substantially diminishes their utility value. Everybody agrees that availability of data or information is a serious issue. When economy matters, it must also be economically timely available.

Inconsistent with the terminology of certified public accountants, several authors interpret timeliness as timely updated, as an aspect of information aging. "Currency" better conveys this meaning. Nevertheless, timely availability has at least three aspects. Therefore, one needs to qualify these terms too. In this case, the information value must be **timely and exclusively available.** In other words, it has to be of restricted availability. This indicates that at least some quality dimensions currently considered simple attributes, are in reality multifaceted attributes. The labels assigned to quality dimensions should reflect such facts. More examples follow.

In news media, there is an unending race for **exclusively operationally timely available** information values. The most frequent casualty of this race is its **credibility and completeness**. Even worse, credibility of news is frequently compromised by a strong dose of political bias by media owners, editors, and the journalists themselves. Under the pressure of sensationalism8 or political expediency, e.g. to be the very first to report something unusual, there is not much time and interest in checking for its veracity and other mitigating circumstances, when mudslinging pays off. Even worse, the pressure to sensationalize the news literally leads to inventing news, thus to *disinformation*. Many journalists succumbed to the pressure to attain the highest utility value for them personally and for the editors at any cost, even when later it becomes detrimental to their personal and company's reputation9.

Neither credibility nor completeness is fully attainable. Both are measured by a continuum of degrees [0-100%]. If 100% is not attainable, there has to be at least an acceptable minimal level of credibility that triggers action. Any level of credibility that is equal or above this minimal level is the **actionable level of credibility**. Thus, one needs again qualified terms such as **actionably credible** and **effectively operationally complete**. Both are universal requirements not only in news services. From the external view, they are well defined, but from the decision-makers' view, they are highly subjective, for they will be different for decision-makers of different personalities and in different situations.

Alas, the evolutional theory-based approach (Liu and Chie, 2002) omits completely the issue of the amount of information an information value conveys as defined in the communications theory and the issue of its utility value as defined in information economics.

This case illustrates the first principle or the **law of relativity** of *all* operations quality requirements, which in its full extent is recognized only in the teleological approach to quality (Gackowski, 2005b). There is no room for intrinsic quality requirements. Only under specific circumstances, a large amount of information as defined by Shannon and Weaver (see the last formula in previous section) translates into a high utility value for the publisher due to its attractiveness to the mass media audience. To this effect, however, it must be also operationally **timely available (**the third direct primary universal requirement) to a single publisher. **Restricted availability** is a situation-specific mandatory requirement otherwise, competition reaps profits. Disinformation violates **credibility** (the fourth direct primary universal requirement). It may yield a one-time gain, but it may ruin the publisher in the end as a failed or biased audit of ENRON ruined Arthur Anderson.

CASE 2 – AMOUNT AND UTILITY VALUE OF AN INFORMATION VALUE IN BUSINESS

This case represents the other extreme in the relation between the amount and the utility value of an information value. This is a historical business case when *enormous business opportunities hinged on a single variable of only two or possibly three values that represent the outcome of an event*. It demonstrates also, how limited the present ways of thinking about quality requirements are.

In 1815, in one of the 20 most decisive battles in world history, the British in alliance with Prussia faced Napoleon's last-ditch effort to change the course of history, not only in Europe. Innumerable business opportunities, among them the pricing of assets (deposits, stocks, bonds, real estate, etc.) of the Rothschild's bank in London, hinged on any decisive outcome of the Battle of Waterloo, Belgium. The outcome may be represented by a binary variable, which cannot yield more than one bit of information - the maximum amount of information possible in this situation. If one takes into account three options: an outright victory, outright defeat, or an inconclusive outcome, the maximum amount of information cannot exceed 1.6 bits according to Shannon. The actual amount of information was less, for by historical experience the outcome of battles waged by Napoleon was not 50/50. Most people still favored Napoleon. At that time, a decisive outcome would change the pricing of most assets in Britain. Rothschild decided to find the outcome as the first businessman in London. He sent observers to Waterloo equipped with carrier pigeons to be dispatched with the encoded result10.

The informational model of the situation consists of one variable of unknown value that has to be acquired. In this case, however, the amount of less than 1.6 bit of information is associated with an enormous utility value. Rothschild was a shrewd businessman, too. Once he received the valuable information about the victorious outcome of the battle, he started selling assets. It sent all prices into a tailspin. Later he started buying everything at depressed prices by concealed representatives, thus multiplied his fortune.

This is a classic case when utility value of enormous magnitude is associated with about one bit of the amount of information. This information, however, had to be of proper quality with many requirements attached to fit its use. The outcome of the battle must be accurately interpreted, encoded, transmitted, received, properly interpreted by the receiver, and finally shrewdly acted upon. All this was uncertain, as it usually is when stakes are high. Even redundancy had to be added, e.g. many observers deployed, many encoding schemas used, many carrier pigeons dispatched for some might perish. The information might have arrived in a not interpretable form. Many things might have gone wrong. The requirement of exclusivity applies here, as well; hence, all types of security precautions had to be taken.

The first conclusion from this case is that the teleological approach (Gackowski, 2005b) illuminates immediately the potentially most important quality requirements that must be considered for a successful acquisition. This research, even in its incomplete form, without the map of mutual interdependencies among all quality dimensions, provides a quality analyst with an insight what is important and mandatory versus what is secondary without resorting to survey-based research. The latter is practically infeasible with high-stake business opportunities. The teleological view does not exclude brainstorming sessions with experts.

Similarly, the recommended sequence of examination of the universal direct primary quality dimensions within the teleological view turns out to be helpful, too.

- First, whatever information arrives, whether from the battlefield or anywhere else, it must be **acquisition interpretable**. It is the first universal direct primary quality requirement.
- Second, it must be of **significant impact** on the desired business results. For instance, an indecisive outcome of the battle would probably be of no practical use. It is the second universal direct primary quality requirement.
- Third, the information must be not only available, but also **exclusively** and **operationally timely available**, e.g. sufficiently in advance so that any required action can be triggered successfully before anybody else becomes aware of the same opportunity. It is the third universal direct primary quality requirement. It also suggests that pertinent **security measures** for preventing information sharing must be taken as prudent precautions. Here, **exclusivity** is also mandatory; otherwise, its impact would be nullified or unacceptably diminished. It is not, however, an example of a universal but a situation-specific quality requirement.
- Fourth, it must be **presentation interpretable**, since here, the use of information is separated from its acquisition, and indirect informing takes place as defined in (Gackowski, 2005a). This one, however, is also not a universal requirement for it applies only to indirect informing.
- Fifth, it is desirable that the information is not simply credible but **actionably credible**; otherwise, it would be foolish to act upon it. Of course, what constitutes actionable credibility must be operationally defined within the context of a specific situation, for instance, when received from two independent sources that are experienced enough to correctly interpret the outcome of the battle, and sufficiently trustworthy to rely on them. It is the fourth universal direct primary quality requirement.
- Sixth and last, it also must be **task-specifically effectively operationally complete** that in this simple case is not a problem. The latter requirement within the teleological approach to quality represents the fifth and last universal direct primary quality requirement for a set of usable data or information values.

If any one of the five (here six) direct primary mandatory dimensions of information quality could not be met, the potential business opportunity is lost. This precludes considering the remaining quality requirements. When it comes to the direct secondary quality dimensions, they usually affect only the economy of effective use of information. In a case of high stakes, cost considerations are rather tertiary. The teleological view facilitates examining data/information quality derived from various theories and used in different situations. It helps to focus the examiner's attention on only 5 – 9 direct quality requirements out of the seemingly unmanageable plethora of 179+ quality dimensions11 initially identified in the empirical study by Wang and Strong (1996). In stark contrast, like the evolutionary approach by Liu and Chie (2002), they encompass neither the amount nor the utility value of an information value derived from the corresponding theories. It demonstrates again how unreliable can become otherwise useful empirical studies. By ignoring these important factors, both approaches do not provide any hints as to how much attention to pay to different information values, while collecting, storing, presenting and using them.

CONCLUSIONS

This paper shows in two contrasting cases of data and information quality (viewed from theory-specific perspectives) the intricate relationship of the amount of information conveyed by and its utility value in operations – the two most misunderstood theory-derived quality attributes of information. Information systems do much more than only represent the real world as pure data processing systems do. If well designed, information systems assist in changing business results for the better. In business environments, the *teleological* perspective should be the dominant one.

Once the only 5 - 9 direct operations quality requirements have been identified, the next important step is to map their functional dependencies on the remaining plethora of the 170 + the not yet identified indirect quality attributes, develop an examination algorithm and construct an intelligent operations quality analyzer of data and information values within their context-specific use in operations in business, public administration, and military.

The internal view is restricted to the design and operations of data and information delivery and distribution systems, never to data and information values per se. This is obvious, but still it is very far from being generally accepted.

Some ask how to measure quality within the context of operations. This question alone implies three things that: (a) such a measure can be developed, (b) may have any useful application, and (c) the more of it the better. One could say a detail answer to this question exceeds the boundaries of this paper; however it is simple and shocking. Shocking when one takes into consideration how much effort, time, and resources have been spent on developing and applying different metrics of quality. Here is the answer with the corresponding arguments.

1. First, by the law of relativity, operations quality requirements are determined by the purpose and circumstances of operations they are used for. It pertains to all representations of the states of the real-world (data, information, and rules of reasoning). This implies an absolute *individuality* of quality requirements for each data or information value as a function of task-specific purposes and circumstances. This alone precludes any *composite measure* of operations quality requirements. Within the realm of operations quality, attempts of developing such metrics are futile.
2. Second, the quality of data and information values is a vector in a multidimensional space of 179+ potential quality attributes. One should define each of them in a manner that facilitates measurability. Nevertheless, they are interdependent, and we do not possess reliable exchange or trade-off rates for these attributes. It is unlikely we ever will. Hence, *quality* viewed this way cannot be reduced to a common scalar value12; it *cannot be summarily measured*.
3. Third, the operations quality knows only five to nine direct quality requirements. As mandatory, they make trade-offs impossible. They must be met, hence no quantification is possible.
4. Fourth, one may ask what purpose such a composite measure may serve. To reduce the problem ad absurdum, let's assume trade-offs among quality dimensions are possible and a composite measure calculated. Results of operations, especially their cost effectiveness, are certainly a function of specific quality dimensions, but not of quality in general. Most people intuitively tend to think that improved quality of data and information value improves the results of operations. It may, but not necessarily. Not even a single attribute of quality monotonically increases operations results, then the same holds true of their composite

measure. All quality attributes must be applied at their optimum levels to obtain the best results of operations. An unchecked effort to deviate from the optimum level of any quality aspect is counter-productive - see more detail discussion in Gackowski (2006). The economic law of diminishing returns applies here fully. In other words, no aspect of quality should become an end on its own merit. Each one should be fine-tuned from the perspective of maximized cost effectiveness of products, services, and operations. Operations are a granular network (graph) of elementary activities use resources (among them data and information values). It does not preclude optimization of aspects of operations quality, but it does preclude the development of any composite measure of operations quality of data and information values that would make sense and be applicable.

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ENDNOTES

1 The theory deals with the **quantity of information** and problems arising in transmission of messages, which usually consist of one or more values.

2 This measure is important not only in analyzing the efficiency of information transmission, but also carries a practical and monetary weight in news media. The anecdotal saying: "dog bites man does not make news, but man bites dog makes news" illustrates the above statement.

3 For instance, the utility value of special information service on road conditions.

4 "**The Internal View assumptions**: Issues related to the external view such as why the data are needed and how they are used is not part of the model. We confine our model to system design and data production aspects by excluding issues related to use and value of the data" (Wand and Wang, 1996) (emphasis added).

5 From datum – facts considered to be given, true or propositions used to draw conclusions or make decisions

6 A data or information value becomes usable when it jointly meets all its universal and situation specific mandatory quality requirements. Usability does not imply effective usability; it is a necessary requirement only (Gackowski, 2005b).

7 A usable data or information value can become operationally useful only as a member of an operationally effectively complete activity-specific cluster of required usable data or information values (Gackowski, 2005b).

8 May not be liked, but it is a driving concept of many media outlets, and it is of high utility value to publishers

9 Note: CBS's far reaching debacle with the credibility of their reporting during the last presidential election campaign.

10 As historical reports show, at those times one could watch a battle without being unduly harassed as a non-combatant and non-participating observer.

11 No other approach, model, or framework does it. None of the known approaches to quality defined a universal taxonomy, identified universal quality requirements with an economic sequence of their examination, and defined at least seven universal principles, which govern all aspects of operations quality of data and information values.

12 As for instance, the value of products and services rendered are reduced to one value of the GNP (gross national product)