Measuring Information Value: key information properties and approaches to assessment

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Research Highlights:

- Information can be evaluated through the assessment of seven key characteristics.
- A distinction can be drawn between characteristics and the attributes which contribute to them.
- These characteristics are integrated in a novel interpretation of a general model of value.
- The value model provides the basis for a practical assessment of information value.
- Three distinct modes of assessment have been identified.

Measuring Information Value: key information properties and approaches to assessment

1. ABSTRACT

The principled evaluation of information is necessary if good decisions are to be made in its management, yet there is little support for the evaluation process. This theoretical work sets out to explore and define the properties of information necessary to enable its evaluation. These consist of *Accuracy, Trustworthiness, Usability, Currency, Benefit, Cost* and *Relevance.* In exploring these properties a model of information value is introduced which is then elaborated and underpinned by the development of a model of information use impact. This theoretical analysis supports the authors' earlier work in which a framework for information evaluation is set out (Darlington, et al., 2008) in the context of information evaluation for engineering enterprises and provides the basis for understanding how practical evaluation may be undertaken.

2. INTRODUCTION

It is argued that the principled evaluation of information is necessary in order to support good decision-making in the through-life management of information. Yet there is little practical support for making judgements about the relative worth of information in the context of everyday business activities; this in spite of the fact that a number of authors have attempted to develop an understanding of what loosely constitutes information value from perspectives as diverse as supply chain management, Value of Information Analysis (VOI), management decision-making support, IT applications evaluation and information provision in libraries (Zhao, 2007). Zhao et al.'s comprehensive review (and associated wide-ranging discussions by them with a wide variety of researchers, IT specialists, archiving specialists and information and knowledge managers) shows that the evaluation of information is an under-researched and incompletely understood area.

A prerequisite of evaluation is an understanding of those aspects of information which define its characteristics or qualities and thus contribute to its value or worth, and what attributes or properties influence these characteristics and how they might be measured. At the same time, to ensure a firm foundation for developing evaluation methods and tools, it is also necessary to achieve a normative definition of the terms that are used to describe information and its characteristics. Hitherto, this understanding and normative definition has been largely incomplete.

The authors in previous work (Tang et al., 2007) collate and identify – from the literature and their own empirical work in both engineering and construction companies – the characteristics of information associated with the evaluation of information that a wide cross-section of evaluators believe are most important. From this has been developed a probabilistic model of information value based on an aggregation of characterizing values (Tang et al., 2008). The seven key characteristics identified – that is, those that feature most notably in the literature and are referred to repeatedly by participants in the empirical work – are *Accuracy, Trustworthiness, Usability, Currency, Benefit, Cost* and *Relevance*. In addition the importance of 'impact' and its relationship to benefit is dealt with.

The chief motivation for the work reported here is to provide support to the process of information evaluation, particularly in engineering and construction enterprises. Ideally, this should be achieved using semi-automatic or automatic means. It should be emphasised here that although the work reported in this paper was undertaken in the context of developing a means of information value assessment for parts of the engineering industry, much of that which follows can be seen to be of general applicability and interest.

The characterizing terms introduced above have been found to be susceptible to variations in usage and interpretation, which themselves may vary according to the context in which the terms are used; dealing with this variation is one of the goals of this paper. In order to achieve this it necessary first, amongst other things, to provide *normative definitions* of the terms used, based on a clear understanding of the underlying concepts. In this paper the authors explore the concepts and propose appropriate definitions.

In Meadows & Yuan (1997) the following pragmatic view expressed by Felix Cohen (Cohen, 1950) is quoted:

> *Once we recognize that a definition is, strictly speaking, neither true nor false but rather a resolution to use language in a certain way, we are able to pass the only judgment that ever needs to be passed on a definition, a judgment of utility or inutility.*

It is in this spirit of pragmatism and utility that the definitions are proposed here by the authors.

In this paper an analysis of the adopted terms is provided together with the resulting definitions and indicators for each. In exploring these properties a model of information value is introduced which is then elaborated and underpinned by the development of a model of information use impact. In addition three means of assessment are introduced which allow evaluation to take place at different levels of abstraction, referred to as first-order (or direct), second-order (or indirect) and third-order (or associative) assessment.

In the first instance, however, it is necessary for clarity to introduce the reader to some key terms related to information evaluation

2.1 Key Elements in Information Evaluation

For clarity, before treating the key characteristics of information, a number of definitions and descriptions are given here of associated concepts which are closely related to the process of information evaluation which help to clarify and consolidate the understanding of terms and thus facilitate communication.

In introducing the terms used throughout this paper it should be observed that from a theoretical standpoint a distinction must be drawn between those things which are the properties of information *in the abstract sense* and those things which are the properties of *the physical representations or proxies* of information. The two things turn out, for practical purposes, to be inextricably linked, thus the future discussion will be generally applicable to both. The proxies of information are wide ranging and are referred to as

information entities and include information fragments, information objects and information systems (as defined in Darlington et al., 2008); these entities being the practicable subjects of evaluation. An example of the link between information and its proxies is 'trustworthiness'. Trustworthiness is a characteristic which legitimately can be associated with information in the abstract, but equally it would be entirely appropriate to ask whether this document or that were trustworthy, standing as a proxy for the information contained therein.

2.2 Information Value

The authors have adopted the following definition for information:

'The outcome of an assessment of the trade-off between what is given to have information and the benefit to be gained from having it.'

This definition has been derived from earlier treatments (see below) and is the outcome of analysis presented in this paper, the culmination of which occurs in Section 10. Because the term is of key importance to this paper, the definition is introduced at this early stage to aid the reader.

The adopted definition takes a stakeholder-centric view of information value, which recognizes that each stakeholder will have their own perspective on what constitutes value in information. As such the variables chosen in any evaluation will be context dependent. It should be understood that the stakeholder may be an individual making an evaluation on their own account or an individual acting as proxy for a larger group.

The definition given has its roots in the conventional means of representing and also arriving at an estimation of value, this being:

Value = Benefits/Cost

This representation was reformulated by Thompson, et al. (2003) as:

Information Value = what you get/what you give
(where the oblique is interpreted as a trade-off).

Subsequently Mills, et al (2006), reformulated this trade-off as being between the gain (what you get) – that is benefits minus sacrifices – and resources (including such things as monetary expenditure, time and so on). Resources can be thought of as being quantitative, whereas benefits and sacrifices can be thought of as being both quantitative and qualitative depending on the circumstances. It is the Mills, et al. reformulation that has been adopted here as an expression of Information Value.

The constituents elements of these *benefits, sacrifices and resources* are identified and explored in following sections of the paper. In particular the assessment of impact – which directly relates to benefit – is explored in some detail. However before proceeding it is necessary to introduce and define a further two key terms, namely information characteristic and information attribute. which are collectively referred to as information properties.

2.3 Information Characteristic

An *information characteristic* is a feature or quality of information, the strength of which affects its value. It is a distinguishing quality or property which may not be readily measurable in the conventional sense, although it might be possible through scrutiny to make a judgement, as will be discussed in subsequent sections. It is this element of judgement that makes measurement difficult. Examples of such qualities might include trustworthiness, clarity, authority, usability, and so on. The authors will present their list of seven characteristics.

2.4 Information Attribute

This is an aspect of a characteristic, the strength of which affects the strength of the characteristic, or provides a datum about the information. A characteristic may be contributed to by one or many attributes. Examples of information attributes include such things as the name of the author, the fact of having been approved through some approval process, the fact of having been generated according to a formal procedure, the number of pages of the document in which the information is found, etc. These things, taken together, could suggest that the information entity to which they refer or the information which can be found therein is, for example, characteristically *authoritative*.

It should be noted that some attributes, which are the property of a proxy to information (for example a document) contribute to the strength of a characteristic of information in the abstract. So for example, the fact that a formal structure (sections, indices, and so on) is manifest in the text of a document will actually contribute to the quality of 'understandability' of the meaning of the information.

It can be said more generally that information as an abstract entity can inherit properties of its information proxy. This reinforces the view that the properties of information and its proxies are inextricably linked.

It can be seen, then, that an attribute is a *directly* or *indirectly* measurable or retrievable property or verifiable fact about information or its proxy which may contribute to the definition of a characteristic and the value of which may affect that characteristic (see Section 11, for a discussion of types of assessment).

It can also be observed that there are two types of attribute:

- *Intrinsic attribute*: an essential or inherent part or property of a thing, e.g. length, language, typeface, style, but also more abstractly, readability index score, usability index score, etc.
- *Extrinsic attribute*: arising or originating from the outside, e.g. frequency of use, currency, author, etc.

2.5 Characteristics vs Attributes

It is interesting and important to reflect on the difference between information *characteristics* and information *attributes*. Characteristics are seen to be dependent on the value or state of one or more contributory attributes or on the value of other contributory characteristics. They are themselves not directly measurable because of their qualitative nature. Attributes, on the other hand, seem to be simpler, atomic, entities, which are contributory to characteristics and are more directly measurable. This

is important since for the purposes of modelling information evaluation computationally, all 'properties' of information must be quantified in some way, including characteristics.

The term 'property' will subsequently be adopted to cover the concepts of both Information Characteristic and Information Attribute and is used where differentiation is neither required nor desirable.

2.6 Information Property Metric

This is the unit and scale used for indicating the quantity or quality strength of the property. For intrinsic attributes the metric tends to be conventional, that is to say, for example, length would be assessed in terms of number of words or number of pages. For extrinsic properties the metric may be more arbitrarily chosen, principally based on its utility. For example, dates of publication (an attribute) might be grouped into appropriate sets (say, before or after an event, or according to date ranges) which themselves might be ranked according to perceived utility. Likewise, the value of the characteristic 'quality' might be assessed on a scale of 1 to 10, based on the contributory properties and as a means of quantifying what is essentially a qualitative property.

2.7 Information Property Magnitude

This is a quantity or a scale (rating) or rank position which describes the value of the property according to the metric defined for that property. The term has been adopted in favour of the more natural one of 'value' to avoid confusion with the use of 'information value'.

Having defined these associated terms it is now possible to explore each information characteristic in turn. The approach taken is to explore the concept, warts and all, and then propose an approach to a definition that is both pragmatic and useful.

The key characteristics identified and treated are *Accuracy, Trustworthiness, Usability, Currency, Benefit, Cost* and *Relevance*. These are dealt with in the subsequent sections. It will be shown that conceptually some of these characteristics are quite complex and require wide-ranging consideration whilst others are essentially quite simple and whose treatment is, accordingly, short.

3. ACCURACY

What does it mean for information to be accurate? One definition (COD, 1992) is: 'conforming exactly with truth or a given standard'. The notion as expressed here conforms with the common intuition and any number of other definitions which approximate to the same thing. Yet, whilst it is good as a definition it may be problematical for the basis of measurement, since it presupposes what is 'true' is known by which a basis for comparison can be made. More helpful is the reference to 'a given standard' since, given the standard, there is some basis for comparison.

For many things there is no such thing as absolute accuracy, and indeed for many things it is not possible to express the level of precision precisely nor, for that matter, to derive a rule which computes 'accuracy' except as a function of the chosen inputs. In

particular, whilst it might be possible to say that a numerical value is accurate, and be clear about what metric for accuracy is used, the same cannot be said for, for example, the content of a text passage.

Moving on, it is clearly the case that there is some relation between accuracy on the one hand and precision on the other. Paradoxically, the greater the level of precision required, the less likely is some statement (numerical or otherwise) to be actually true. So, it would seem that to be *accurate* is to be true at an (implicitly or explicitly) agreed level of *precision*. This raises the question as to whether there is, in practical terms, a useful difference between accuracy and precision.

The terms accurate and precise are sometimes used (and definitions are common) where no distinction is drawn in meaning. However, there is a stronger interpretation of 'precise' which implies a special sort of accuracy and which is important in, for example, engineering information:

1. Sharply exact or accurate or delimited
2. Characterized by perfect conformity to fact or truth; strictly correct. (This is in respect of ideas, images, representations, expressions)

(both definitions from ((Wordnet, 2006))

The Concise Oxford Dictionary ((COD, 2006)) has *precision* defined as: 'the degree of refinement in measurement'. So, on this interpretation, *accurate* thus means 'True to some agreed refinement of measurement'.

Based on the analysis above the definition proposed by the authors for the attribute of information accuracy is:

'True or correct to a level of precision appropriate to the purpose'

Given a definition the question of measurement then has to be dealt with. Measuring accuracy directly is not possible, except perhaps in very restricted conditions (e.g. comparing numerical data directly with approved source data). Assessment of accuracy can, however, be made based on a variety of evidence of, for example:

i) adherence to a validated methodology,

ii) application of peer review,

iii) usage in critical applications,

iv) indications subsequent to information use of satisfactory outcome or performance.

According to the earlier definition then, *Accuracy* is a characteristic, the expression of which might be derived *directly* from the contributory attributes – e.g. validated method, peer reviewed, used on critical applications, proved by usage.

Furthermore it can be seen that two types of assessment are identified, these being based respectively on direct and indirect suggestive evidence. Assessment types are treated in Section 11.

4. TRUSTWORTHINESS

What does it mean for *information* to be trustworthy? It means, loosely, that the information can be relied on. For information to be trustworthy it means that assumptions about the value of some important characteristics of the information can be taken as read without individual consideration or proof. It constitutes a *belief* that the characteristics of importance in the context conform to some particular conventions and thus the information can be used with limited risk. The foundations for the belief (or the test) will be different depending on context.

The particular properties that suggest themselves as being indicative of information trustworthiness might include those such as:

i) Truthfulness

ii) Completeness

iii) Logic (the quality of the argumentation)

iv) Level of validation

v) Coherence of structure

vi) Level of expertise

And so on …

Trustworthiness of information cannot be measured directly; it is an extrinsic rather than intrinsic property inherited from the magnitude of the characteristics or attributes which contribute to it.

The above suggests that a useful definition of trustworthiness of *information* might be:

'The reliability of the information based on knowledge of its properties'

However, the risk-bearing properties of information can be derived not only from the information itself, but from extrinsic information such as its provenance (e.g. the author, publisher, sponsoring entity, etc). This brings us to considering 'Trustworthiness of Source' rather than the trustworthiness of the information itself, thereby changing the entity defined by the property.

The chain of inference for asserting trustworthiness in a document based on provenance might be expressed:

Source OK, by implication information characteristics OK, by implication information OK.

Because the elements of this chain are related transitively it is possible to leave out the middle, so if the source is trusted we don't need to measure accuracy or completeness (or any other information properties, come to that, identified above as contributing to trustworthiness of information per se) since we are relying on an assumption to carry us through. This is an example of *indirect* information assessment (introduced above and treated in detail in Section 11.2).

What, in a practical sense, does it mean for a *source* to be trustworthy? Perhaps:

i) known through experience to be reliable,
ii) of proven credentials which suggest reliability (having certifiable experience, qualifications, recommendation, etc.),
iii) being of a type that implies trustworthiness through intention (e.g. a standards body).

4.1 Assessing Trustworthiness by Association

The information required, then, to make judgements about *'Trustworthiness* of Source' is that which answers some of the following questions:

1) What is the source?
2) Is the source known and trusted?
3) Does the source have identifiable credentials: e.g. formal qualifications, publications record; acknowledge area of expertise; rank in hierarchy which reflects relevant expertise?
4) Is the source a standards or regulatory body, a professional institute, a nationally or internationally recognized authority, government, etc?

Though measuring trustworthiness of the source, it is still the knock-on trustworthiness of the information that is of principal interest, so the following secondary definition is suggested:

'The reliability of the information inferred from information about the source'

Here 'reliability' means conventionally the extent to which the information can be *relied on*.

Trustworthiness, therefore, could be assessed through association (knowing the source and knowing that it itself is trustworthy) or directly by counting or making judgements based on the values of some of its contributory attributes (qualifications, etc) applied as input to an appropriate algorithm.

5. USABILITY

The concept of usability has been widely considered in the domain of human–computer interaction and software systems. Indeed these are now well researched and maturing disciplines (see for example (Jacko & Andrew, 2003; Law et al., 2007)). Whilst some useful insights can be drawn, there has been little work done on the usability of information per se, particularly in the form of documentation and even less in more specialized representations such as the outputs of, for example, CAD systems, dynamic models, simulation, etc. Indeed, most of the work done on usability concerns recommendation on the *generation*, development and design of usable information artefacts rather than, strictly on usability *assessment*. For example, whilst Jakob Nielsen's '10 Heuristics for Interface Usability' (Nielsen, 1994) are presented as being, and indeed are, widely used as the means for evaluating the usability of interfaces, they are actually couched in terms of generative prescriptions for the design of usable interfaces. Each heuristic can, of course, be interpreted and reformulated as an evaluative statement. Similarly, Vesa Purho's (Purho, 2000) reworking of the Nielsen

heuristics to better support 'documentation' (that is, in his terms, user manuals and such like) are represented as generative prescriptions. This 'generative' approach is similar to the widely available guidelines and handbooks (Alread et al., 2002; Blico, 1982), standards (BSI, 1992; SD1000D, 2005) and so on in use for the production of better technical documentation in general. In contrast a more explicitly evaluative approach can be seen in Deniese Pierotti's (Pierotti, 2004) software system checklist which is based on a number of existing heuristic formulations.

In short, evaluation of usability of *information*, in contrast to evaluation of usability of computer interfaces and software systems, is not well supported.

Amongst the standards for usability is that of ISO 9241 (ISO, 2006) which concerns the ergonomics of human-system interaction. Within this standard can be found a normative definition for usability of artefacts thus:

'The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.'

This definition can be specialized for information itself to:

'The extent to which the information can be used to achieve a person's intended goal(s) with effectiveness, efficiency or satisfaction.'

It is this definition that the authors have coined for 'usability of information'. It should be noted that the ultimate conjunction has been changed from 'and' to 'or' since in the authors' view it is not necessary to usability that all three requirements are satisfied at the same time.

5.1 A Basis for assessing usability

The question now arises as to what it is that makes information more or less usable. Some indication is given by asking questions such as: 'is it well organized, clear, easy to find one's way round, and so on?' These are the sorts of ideas associated generally with usability.

As a starting-point from which to extend the understanding of the facets of usability of information as expressed in the definition, the authors have reformulated and revised the Purho heuristics (Purho, 2000) to provide a set of nine generative heuristics for better information usability (in contrast with better *interface* usability or better *documentation* usability). The understanding gained during development and validation of the heuristics and, indeed, by inspection of the heuristics themselves, suggests the multi-dimensional character of usability relating to the ideas conveyed, that is the information *content;* the manner in which it is conveyed, that is, the information *representation;* and the extent to which provision is made to support navigation and exploration (for which the term *navigability* has been adopted by the authors).

Analysis of the content of the heuristics, and reformulation as evaluative statements suggests that they can be classified according to one or more of a number of characteristics associated with the dimensions of *content*, *representation*, and *navigability*, as follows:

Content (the ideas and facts expressed)

- Exposition – clarity, logic, breadth, depth, audience, level of detail, etc.
- Organization – the way in which the ideas and facts themselves are organized
- Level of Detail – a reflection of the audience and the level of abstraction of the ideas and facts
- Level of Standardization – the extent to which the ideas and facts are conveyed in a way that is conventional for the subject matter or topic and for the milieu in which they are being presented.

The last two items are related to the meeting of user/reader expectation.

Representation (means of expression)

- Appropriateness of representation – concerning the choice of scale, medium, abstraction, notation, and the associated idea of,
- Heterogeneity – the diversity of representational media used
- Structure:
    - Organization
    - Extent of
    - Fidelity – the extent to which the representational structure mirrors the structure of the ideas expressed.
    - Explicitness of – the extent to which the structure is visible to or hidden from the user (e.g. that evident from headings, etc in contrast to, say, embedded metadata).
    - Embodiment – how the structure is revealed (e.g. as part of the document itself, in the form of indexes, as a metadata schema and so on).
    - Adherence to standardization – the extent to which an information entity conforms to the expectations by the user of a familiar object.

Navigability

- Support for navigation (method-based path finding, including search).
- Support for exploration

It is the nature of these dimensions that they cannot be considered to be entirely independent from one another and yet the analysis provides the basis for asking questions about the extent to which a particular information entity exhibits them and thus the extent to which information which that entity conveys might be more or less usable as a result.

As noted above, it is not just documentation which must be usable, but all information irrespective of representation. The importance of the elements identified above in making assessment of usability would be weighted according to the type of representation.

The above items lend themselves to first-order or *direct assessment* (see Section 11.1). This might be augmented by indirect assessment exemplified by such questions as ‘has the information been hallmarked according to some usability criteria?’ or, perhaps, ‘has the information been created according to some prior expectation or standard criteria, procedure, structure, etc?’.

6. CURRENCY

The relationship of the information or information entity to time is clearly of importance in information evaluation. The term 'current' conventionally implies that something is 'up-to-date' by some measure. In this sense it is synonymous with 'timeliness' as used by a number of researchers (e.g. (Ferrer & Ketzenberg, 2004; Lee, 2001; Pipino et al., 2002)). Yet the idea of *currency* in relation to information is much richer than mere 'up-to-dateness', hence the adoption here of this different term, encountered in both industry interviews and in the literature. For the confident use of information it is not always necessary that the information be up-to-date; what is important is that it is situated temporally in an appropriate way for the context. This can be seen by considering the motivation for asking the following simple questions, the answer to each of which would raise or lower the value of the information in question according to the circumstance:

- Is the information current?
- Is the information between m and n (years, months, days) old?
- Is the information obsolete?
- Was the information current at the time that is now of interest?
- Was the information current at the time it was used?

Thus the definition of 'information currency' coined by the authors is:

'Applicable at the time of interest' where 'time of interest' is the operative term.

7. INFORMATION BENEFIT

It should be noted here that 'benefit' itself strictly is neither a property of information itself nor of one of its proxies; nevertheless it must be taken into consideration if the value of information is to be properly assessed.

Analysis suggests that there are two distinct classes of benefit associated with information; that which is associated with the *provision of information* as a thing or tangible asset (Darlington et al., 2008) and that which is associated with the *use of information* as an abstract entity. Both provision and use must be considered for a full picture of information benefit to be painted.

The first class of benefit is associated with information when viewed as an asset, commodity or facility; thus it concerns benefit resulting from activities associated with the provision of information in all its material forms (that is the things that convey information). The sorts of management activities associated with information provision have been identified by (Darlington et al., 2008) as being related to motivations for information evaluation and post-evaluative actions (that is, actions which are taken as a result of understanding how they will affect the value of the information being ssessed).

These are listed in abridged form in the left-most branch of the taxonomy. Acting on such motivations or engaging in post-evaluative actions results in benefits such as increasing asset worth, reducing future overheads (for example in storage or maintenance) improving operational efficiency and so on. The evaluation of assets and their impact on company performance and value, however, is an area that has been treated exhaustively in the domain of company management – not least in the

assessment of intellectual property as an intangible asset (see (Enayati, 1995; Kossovsky, 2002)) – and it is not the authors intention to add to this huge body of work Thus, the discussion below is confined to the second class of benefit, that of information *use*.

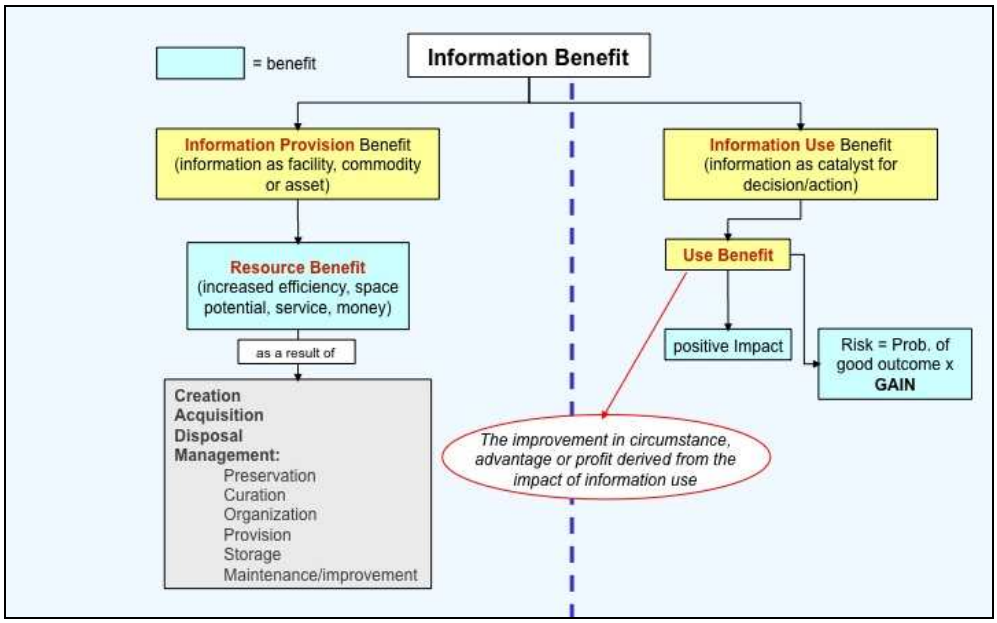

Figure 1. A taxonomy of benefits associated with information as both asset and catalyst

Once information has been provided as a 'facility' as a result of the activities discussed above, it provides the basis for *information use.* Thus, this second dimension of information benefit concerns benefit that results from using the information as an abstract entity, in all the multitudinous ways that this implies. This aspect of benefit is modelled here as emanating from the *positive impact of information use* as illustrated in the right-hand element of.

It will be seen at the end of this section that the definition of benefit will be as follows:

The improvement in circumstance, advantage or profit derived from the impact of information use

It is thus clear that the understanding of 'impact of information use' is critical to the definition of benefit, arguably being one of the key information characteristics of the seven being defined to assess information value. Impact is a complex property requiring for its full understanding a complex model. The authors' development of this understanding and of the model is treated in the remainder of this section.

7.1 Developing a Model of the Impact of Information Use

Impact in a general sense concerns ideas of influence, effect, consequence, outcomes and so on. It is important to note that – like 'benefit' to which it is a contributory factor – impact is neither an attribute nor a characteristic of information since it concerns not the information itself (which has only potential for impact when used) but the *outcome* of the *use* of information. Furthermore, in the assessment of information value the notion of impact is principally predictive, following sometimes, to be sure, from the

question ‘what have been the benefits of this information?’ but more usually ‘what might be the benefits of this information in a given context and for a given use?’

Strictly speaking the idea of impact is independent of any notion of good or bad. That is, the same outcome and influence of the use of information may be judged differently dependent on context and thus the interpretation. Because the assessment of impact is essentially predictive, consideration must be given, in principle, to both the negative and the positive impact of information use. On pragmatic grounds the authors have chosen to disregard at a theoretical level the negative outcomes of information use as being practicably unassessable in a predictive context. In addition to this, the authors assume that, in the corporate context at least, the intention of acquisition and use of information is for the accrual of benefit (i.e. positive impact); thus negative impact is represented in their models but not subject to analysis.

7.1.1 Background considerations

In considering impact, a number of sources have been explored which consider the impact of information at different levels of abstraction, e.g. (Meadows & Yuan, 1997); (Grieves, 1998); (Marshall, 1993). As will be seen, these sources in particular inform the development of the authors’ impact model.

Meadows and Yuan consider information impact directly, identifying four different types of impact – and considering the difficulty and mechanism for assessing each – these being:

- *Impact1*. A change, or the nature or magnitude of change, in the knowledge base of a subject domain of the recipient.
- *Impact2*. A change in how the recipient behaves when a decision or action is called for. An action really means a decision to take action. This is a consequence of a change in the knowledge base.
- *Impact3*. A change in how the recipient carries out a search for information, based upon preliminary results. This is a rather specialized meaning, which could fall under definition two, but is of such interest to the information processing or handling world as to justify a separate category.
- *Impact4*. A change at the organizational or societal level caused in whole or in part by the availability and use of information.

Meadows & Yuan themselves recognize the difficulty of measuring the *change* itself. For example in respect of *Impact1* they issue the caveat: ‘Impact1 can only be measured or detected by the most subtle or restrictive, and probably unreliable, of tests. It would always be difficult to tell what the impact of a particular piece of information or even set of information might be’. In a similar vein they observe: ‘Since decisions are based upon a knowledge base, not a specific message Impact2 is also difficult to detect or measure’.

It seems to the authors that this caveat applies to measuring the direct change in each of the impact types that Meadows & Yuan identify. It does, however, seem practicable to identify *where* these ‘impacts’ occur or might occur and the indirect change in terms of the *outcomes* felt in these locations and from this divine some aspect of value. The

above discussion suggests that impact has (at least) two principal dimensions, these being *location* (the context in which the information is used, and the context that is subject to the effect) and *effect* (that is, the outcome itself). These two principal dimensions are explored further and elaborated below as the basis for the authors' model of information impact which is introduced in Section 7.1.5.

7.1.2 Identifying where *impact occurs*

The idea of *location* embraces the question 'where does the effect occur?' and the question 'in what does the change occur?' From the Meadows & Yuan identification of impact types can be suggested these questions:

1. In what knowledge base has the impact occurred? (from Impact1)
2. In what domain has decision-making been informed? (From Impact1)
3. At what organizational level has the change occurred? (From Impact4)

These questions are dealt with below.

Q1. In what knowledge base has the impact occurred?

It is clear that one way that information use will have an impact is the way it will be incorporated into and change the knowledge of the user and by extension the corporate knowledge of the enterprise. In the context of business intelligence optimization (Johnson, 2008) identifies thirteen areas of knowledge common to business activities that are of key interest to 'the average enterprise'. To this list has been added the knowledge base of 'technical understanding' by the authors. Whilst not exhaustive, since knowledge areas of key interest will be dependent on specific areas of business activity, this list is indicative of the areas affected.

K_1	Product/service sales and marketing development
K_2	Strategic probabilities and futures prediction
K_3	Understanding competitor activities and strategies
K_4	Internal knowledge management
K_5	Corporate intelligence development
K…	Intellectual property exploitation and protection
K…	Mergers, acquisitions, alliance and investment support
K…	Long-term market prospects
K…	Counter-intelligence & information security
K…	Legislative and regulatory activity
K…	Business issues
K…	Executive decision support
K…	Competitive strategy planning
K…	*Technical understanding*
K_n	

Q2. In what domain has decision-making been informed?

Decision making and the impact information has on this process has been widely explored; indeed the literature on the topic and the diversity of exploration seems almost limitless (see for example (Plous, 1993) for the psychology of decision-making; (Laudon & Laudon, 1998) for the management and delivery of information for decision making; (Edwards et al., 2007) for an overview of decision analysis; (Grieves, 1998) for outcomes of information use in decision making.

Fundamentally, however, the purpose of information, apart from the promotion of learning and knowledge augmentation, is to support decision-making through the reduction of uncertainty ((Machlup & Mansfield, 1980) and to support problem solving.

Direct measurement of the outcome of decision making occurs within an enterprise related, amongst other things, to the organizational model upon which the business is structured. A number of such structures have been identified and are used widely as part of management. They include functional, product, divisional, project, and matrix structures and so on (Cleland & Ireland, 2002). Irrespective of the actual structure along which an enterprise is organized it can be said that such a structure will decompose the enterprise into *domains*. For the purpose of this exposition, and as exemplified in the resulting model, the *functional* structure, so widely encountered in engineering enterprises, is considered. Structures of other types could easily be substituted.

Q3. At what organizational level has the change occurred?

The idea of organizational level can be interpreted in a number of useful ways, for example in relation to domain as discussed above. However, for the purposes of provision of information, (Curtis & Cobham, 2002) identify three levels of *managerial* activity which are important. These activities, which can be said to coincide with levels of organization within an enterprise, are strategic planning; tactical planning and control; and operational planning and control. Each level is distinguished by different information requirements in terms of continua of information detail, source, content, degree of frequency, certainty and so on, as illustrated in Figure 2.

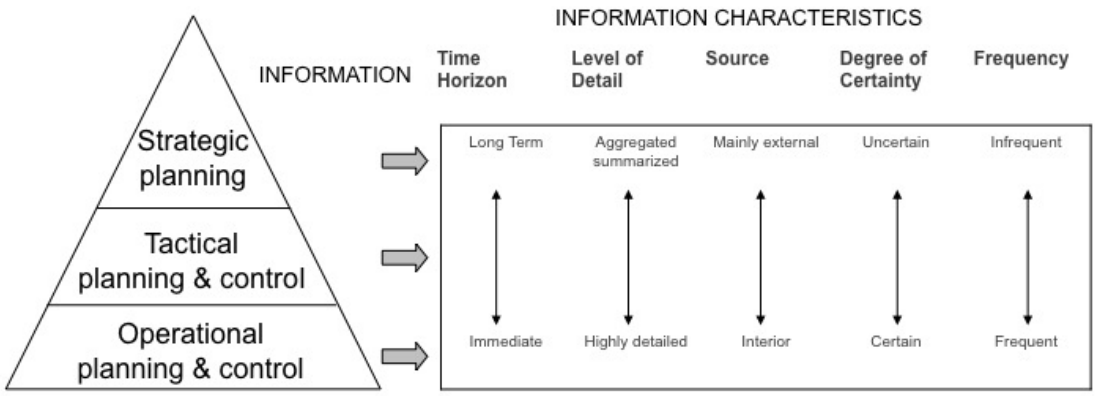

Figure 2. Curtis & Cobham's (2002) analysis of information characteristics for managerial decisions (reprinted with permission of Pearson Education).

To these three managerial levels can be added that of knowledge management, an enterprise activity that has in recent years become identifiable as a separate area of management activity and in itself a distinct organizational level. (Laudon & Laudon, 1998), for example, identify different information systems in operation which serve different operational levels and support different management levels within a company. Included amongst these is the knowledge-level information system supporting knowledge and data workers.

Together these elements constitute what the authors refer to as the *Locus of Impact.*

7.1.3 Understanding the outcome of information use (or identifying how *impact occurs)*

The second of the two principal dimensions of impact concerns the outcome of information use, as introduced earlier in this paper, together with the suggestion that the measurement of outcomes might be profitable for practicable information evaluation. (Reid et al., 1998) crystallize observations made during their researches 'that any attempt to value information within an organization had to be looked at in the context of the *activity or decision* it affected'.

Meadows and Yuan identify their Impact2 and Impact3 as concerning changes in behaviour, that is to say, the resulting outcome in terms of the action taken. At the same time, they observe that 'Clearly, what is important about impact is the selection and definition of the variables affected'. Some of the possible variables to which they allude as a result of such actions, but which they themselves do not identify, can be seen in related work on information impact that is reviewed by Grieves (1998) (including Reid, et, al. cited above) these being a series of investigations of the impact of the use of information on decision making in five sectors including that of the business activities of banking, insurance and pharmaceutical companies. These five pieces of separate research used a core set of information use outcome indicators developed in earlier research by (Marshall, 1993) which were classified according to their involvement in the information's quality, the cognitive effect; its value for decision making and the influence exerted by information use, and which were the basis for a questionnaire which formed the principal data-gathering tool for the cited research.

In addition to these, the concept of the *avoidance* of negative consequences as a result of information use is introduced including: prevention of loss of time; prevention of loss of money or waste of resources; prevention of poor business decision, etc.

7.1.4 Characterization of Outcomes

Clearly, all of the items referred to above can be considered in some sense to be related to impact outcomes. Each of the outcomes identified in this work suggest others which are specialized to particular activities outside those characterized by the areas investigated. The outcomes identified, and those that might be usefully considered for more specialized activities (for example, for the engineering domain) provide, together with the locus of impact, the basis for the model presented here.

The analysis given above suggests to the authors that a progression of outcomes exists, at progressively higher levels of abstraction and at greater degrees of chunking. away

from the cognitive outcome toward the ultimate effect or outcome. The progression is illustrated in Figure 3.

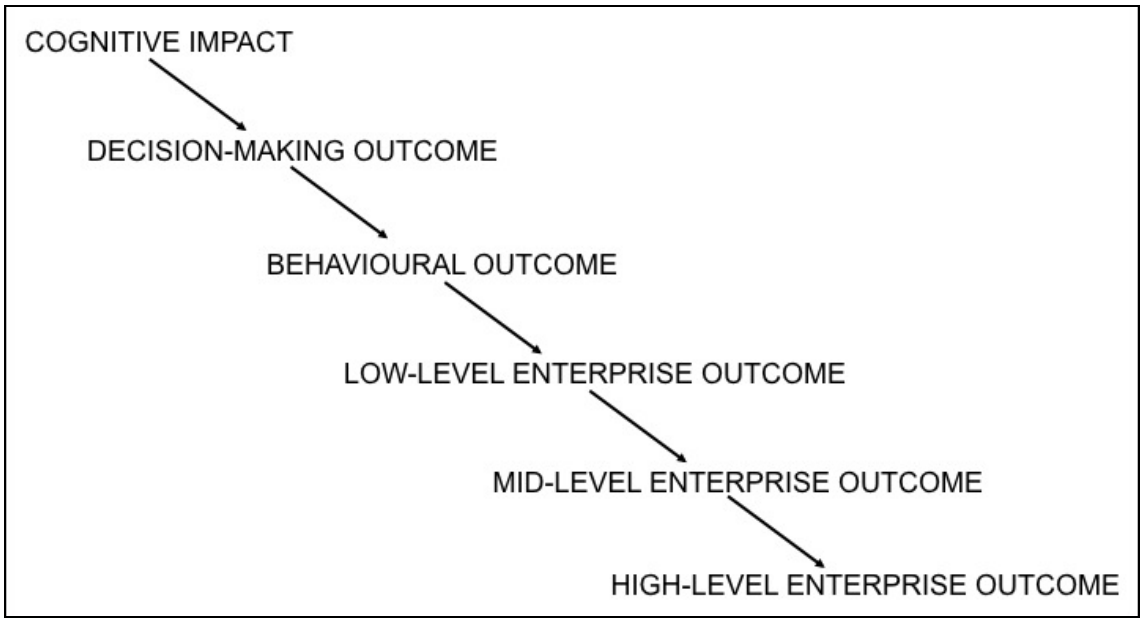

Figure 3. A progression of information use outcomes

Indicators of information impact which elaborate on this progression, gathered from a number of sources (included those cited above, and from, e.g. (Menou, 1993) (Navigant Consulting, 2005)) and augmented by those of the authors, are shown in tabular form in Table 1. This treatment reiterates the idea, introduced above, of a chain of events leading from information use, through outcomes of use, to information use impact and is broadly in line with the impact types identified by Meadows and Yuan.

The treatment given in Table 1 embraces the idea of outcomes only with respect to the entity which uses the information, in this case the enterprise. In reality, however, the impact of information use extends in a potentially infinite chain of outcome events moving outside the user entity into the world as a whole, becoming in general more tenuously related to the original information user as the chain extends. This is alluded to in Meadows & Yuan's (1997) Impact4 in their reference to 'societal'. At the same time, some of the impact can be seen to be local to yet independent from the original user. Whilst recognizing the extended picture developed above, the authors have chosen to limit their detailed analysis of outcomes to those which occur internally or, whilst external, are of interest as a result of direct association. An example of this could include not only an enterprise's customers, but other stakeholders such as those in the supply chain, and so on.

This brings the discussion to one further consideration, that being the scope of influence, which is discussed in the following section.

COGNITIVE OUTCOME	DECISION-MAKING OUTCOME	BEHAVIOURAL OUTCOMES	LOW-LEVEL ENTERPRISE OUTCOME	MID-LEVEL ENTERPRISE OUTCOME	HIGH-LEVEL ENTERPRISE OUTCOME
	Positive Outcome	Improved efficiency	**Positive Consequences**		
	Provide basis for decision	Improved effectiveness	Cost saved (one-time, recurring, fixed, variable, etc)		
	Decide a course of action	Better (operational, tactical, strategic, knowledge) planning	Time saved	Customer satisfaction increased	
	Decide on next step		Productivity, efficiency Improved	Enterprise productivity increased	Productivity gains
	Exploit a new opportunity	Improved decision-making	Quality of work, product, service improved	Strategies enhanced	Process improvement
Refresh memory or detail or facts	Provide basis for approval	Improved knowledge sharing	timeliness of action improved	New products or services realized	Financial results improved
Substantiate prior knowledge or belief	Handle an emergency	Improved learning	Value added	Financial results improved	Planning improvements
Provide new knowledge	Handle decision-making differently	Enhanced problem solving	Schedule met	ROI increased	Company asset value increased
Add a new dimension to existing knowledge	Increase in confidence	Positive behavioural change	Turn-over increased	Market share increased	Waste reduction
	Make better-informed decision	Enhanced judgement	Cash flow increased	Waste reduced	
	Avoidance of Negative Outcome	Prevention of negative outcome	Profit margin enhanced	Cost reduced	
	Prevention of poor decision		New opportunity exploited	Market/competitor intelligence increased	
			Process, procedure improved	Personal/corporate knowledge increased	
			Avoidance of Negative Consequences		
			Failure		
			Time loss		
			Money, resource loss		
			Client loss		
			External conflict		
			Internal conflict		
			Legal/regulatory, governance problem		

Table 1. The impact of information use represented as a progression suggesting a chain of events

7.1.5 Scope of Influence

In a companion paper to this (Darlington et al., 2008) which discusses a framework for information evaluation, the authors introduce the idea of different perspectives within a enterprise from which information evaluation takes place. As shown there, evaluation takes place in recognizably different contexts depending at which level of operation within the company the information is being evaluated. For example, in the analysis presented there, three main perspectives are identified, these being, *personal, enterprise* and *corporate*. These perspective do not in themselves delineate boundaries of impact but they do suggest that the potential for impact will be different as a result of the intended users and that a complete idea of the impact of information for the *purposes of value assessment* must take into account the size of the population influenced by the information and the reach of the influence. In other words, not only where the change occurs as a result of information use, but where that change is *felt.* The notion of scope of impact provides an additional dimension to the concept of location. For example, potential impact will vary in consideration of a body of knowledge as a result of the number of potential users of that body of knowledge (or, alternatively, the number of individuals who embody that knowledge). Similarly, if change occurs as a result of information use in a particular domain, then the size of that domain within an organization may have a bearing on the value of the information. As discussed in the previous section, the impact may well be experienced outside the boundaries of the original site of use, thus whilst the location of cognitive or behaviour change may be local to the information user, the effects may be felt externally.

Representations of graduations of scope are fairly arbitrary. However, for the purposes of the locus of impact the authors suggest the graduations *individual, group* and e*nterprise* representing ever-increasing potential extents of influence (as implied also in Table 1). In addition to this, it is suggested that consideration should be given to impact extending outside the enterprise itself, for which the term *societal* is adopted here. This accords with the Yuan & Meadows' description of Impact[4].

7.1.6 A Model of Information Impact

The outcome of the considerations made above is a model of information impact, which has been visualized in Figure 4. As will have been observed, because the possibilities for impact are so diverse and context sensitive, it would be foolish to present such a model as definitive. However, the authors believe that it is facilitating in the process of elucidating the evaluation of information. The model follows from the thesis that information impact can be usefully represented using two principal dimensions: the *locus* of impact and the *outcome* of use. The locus itself can be characterized usefully using the three location dimensions discussed above: knowledge base, domain and operational level. In addition the authors propose an important additional notion, this being concerned with *scope* of influence resulting from information use, and which is related to the notion of an extended chain of events as illustrated above in Table 1.

The discussion in Section 8 has provided a model of information impact which takes into account both locus of impact (8.1.2), outcome (8.1.3 & 8.1.4) and scope (8.1.5). On pragmatic grounds, the potential for negative outcomes of information use has been disregarded. Nevertheless, the analysis provides the basis for the authors' definition of *Information Use Impact* as follows:

'The effect of information use measured in terms of location, outcome and scope'

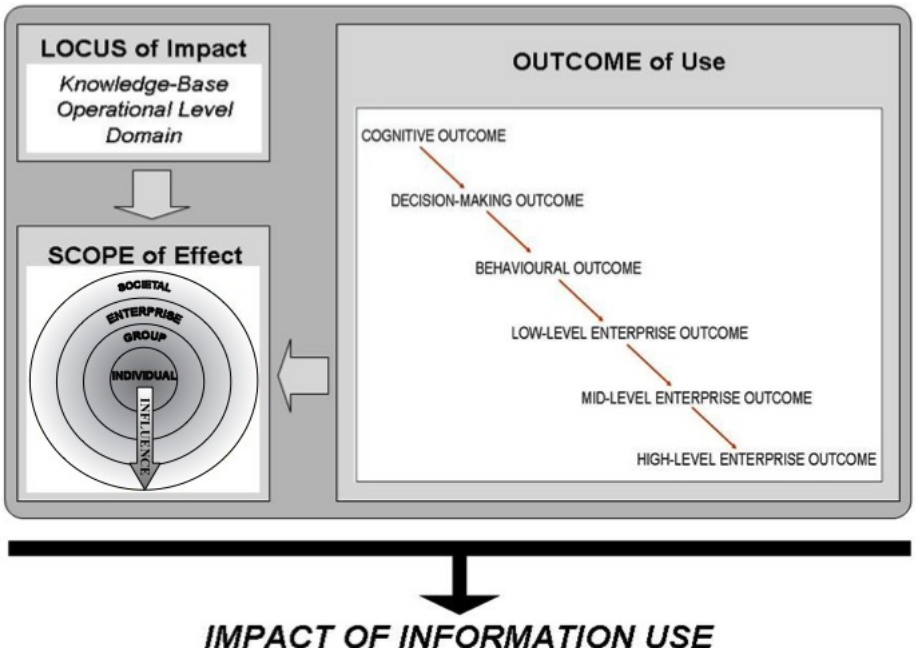

Figure 4. A model of the impact of information use

7.2 Information Use Benefit Definition

It is clearly the case that the impact of information use and the benefit or disadvantage that is derived are closely related. At the same time it can be seen that interpretation of the effect of impact as being beneficial or a disadvantage will be dependent on context and that the magnitude of the effect will be linked in some way to the three parameters expressed in the definition of impact. The above discussion provides the basis for the definition of *information use benefit* coined by the authors.

The improvement in circumstance, advantage or profit derived from the impact of information use

Or by combining the impact definition, benefit then becomes:

The improvement in circumstance, advantage or profit derived from the effect of information use measured in terms of location, outcome and extent.

Finally, it must be noted that any one instance of information use can (indeed, almost certainly will) result in a number of different *impacts*. That is to say, resultant changes will occur in knowledge, behaviour, at different organisational and operational levels, and so on, the result being felt in a number of different locations and amongst a number of different subjects of the effect. At the same time there will be a number of benefits that can be derived from these different impacts. Which impact and which benefits are considered important, and thus which become the object of measurement, is a matter of choice.

8. INFORMATION COST

As noted in Section 2.2 information value can be conceptualized as a trade-off between benefits (explored in the previous section) and sacrifices and resources. These two latter concepts are constituted as cost, either as an input (that is the expenditure or diminishment of resources) or as an output (being the 'cost' resulting from some activity). The authors use the term resources to embrace all such things as monetary expenditure, time, space, and so on. Resources can be thought of as quantitative cost, whereas sacrifices can be thought of as both quantitative and qualitative cost, depending on the circumstance.

The notion of cost is familiar in business activities, where the monetary cost of things and activities is of paramount consideration. Nevertheless, (Tichacek, 2006) in his treatment of project cost identifies that cost may be measured in terms of money, physical resources and time. Indeed, it can be argued that cost may be constituted of all three, not least in respect of the cost of information. These three costs, when related to information, fall into the same two classes identified in relation to that of information benefit; those which are associated with information as a thing; and those which are associated with information use. The dimensions of cost identified by the authors as being important in the assessment of information value is presented in Figure 5.

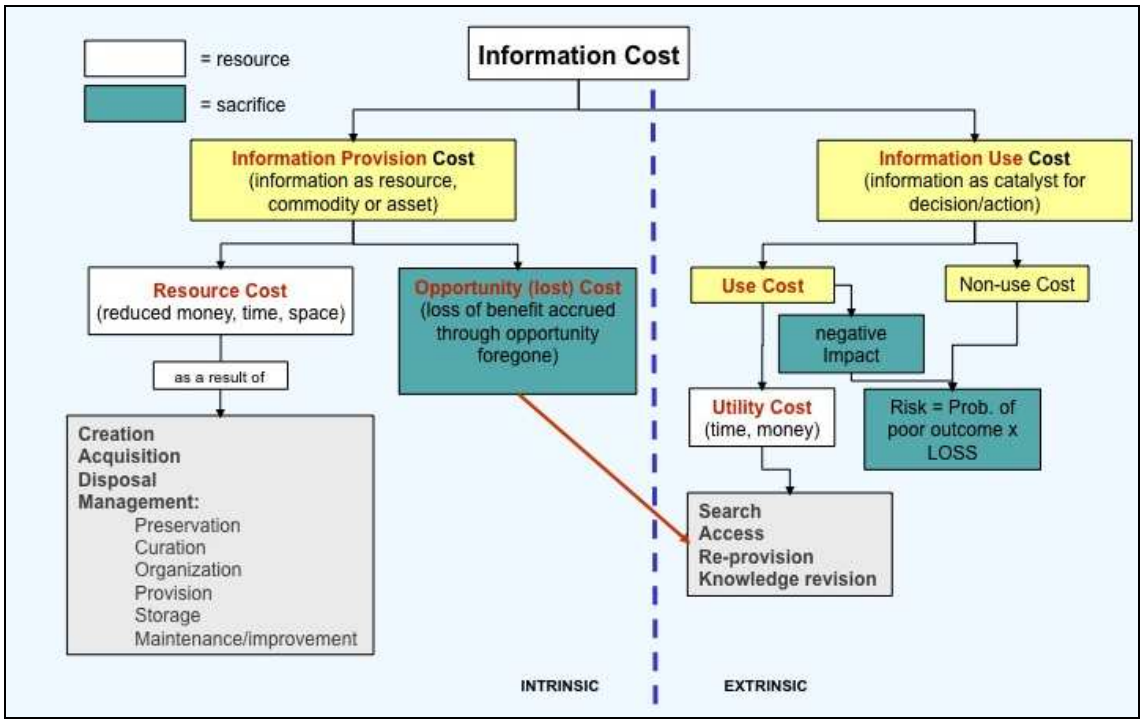

Figure 5. An informal taxonomy of costs associated with information as both asset and catalyst

In (Buckland, 1991; Darlington et al., 2008) the idea was introduced of information being a thing, manifested commonly as such things as a document, a book and so on. At the same time the notion of motivations and post-evaluative actions associated with information evaluation was introduced. These constitute management activities of information as thing. On inspection it can be seen that management of information as thing, in any form, will attract a *cost*, in monetary, time or other resource terms. It does

not do so only directly, but as a result of the management decision. These monetary costs are attracted in respect of the information as facility, commodity or asset. In addition to this is that cost usually referred to as Opportunity Cost, this being defined as the loss of benefit accrued through opportunity foregone. It is evaluated as being the cost of passing up the single next highest-valued choice of opportunity when making a decision about information as a facility, commodity or asset. This 'loss of potential benefit' can be monetary or some other resource, but can be measured in terms of anything that is of value. Thus it can be seen in terms of a *sacrifice* made in order to follow some other action.

In contrast with cost associated with facility, commodity or asset value (i.e. information as thing) is that of information use. Information per se attracts no cost – other than that mentioned – until such time as it is used when, once again, resources are expended in terms of time or money. These *utility* costs may be affected by management decisions. In addition to this, costs associated with the negative impact of information use can be envisaged. These, like opportunity costs, can be seen as sacrifices associated with information use.

It is possible to place all these information costs in the context of the model of value = benefits/cost or in the conceptualization preferred by the authors, Information Value = gain/resources.

Having identified the costs (resources and sacrifices) and benefits they can be integrated in the information value model as shown in Figure 6. The resources, benefits and sacrifices identified constitute the variables in a trade-off which results in the assessment of information value by a stakeholder.

Because of the complex character of cost it is not possible to derive a single definition for cost which provides the utility sought in Felix Cohen's maxim. Instead separate definitions are required for the principal cost dimensions of information *provision* and information *use.* The authors suggest the following:

Information Provision Cost:

'The reduction in such things as time, money and space, and the loss of opportunity arising from the provision of information.'

Information Use Cost:

'The reduction in time and money, and the negative impact arising from the use of information.'

9. RELEVANCE

In general, relevance is a context-dictated property and as such it is not possible to assess the relevance one thing has to another without knowing the context, where context can be said to be the set of facts or circumstances that surround or define a situation or event. This is true of information relevance.

Greisdorf (2000) demonstrates that the concept of relevance is multi-disciplinary, having a variety of, sometimes, inter-disciplinary interpretations and that a search for

appropriate and unifying definitions has taxed thinkers for at least forty years. Amongst the many considerations, he observes that 'the fuzziness surrounding the nature of relevance has led to confusion in identifying appropriate criteria, measures, measuring instruments and methodology'.

There has been a great deal of work over many years – and a resulting large body of literature (see for its development: van Rijsbergen, 1975: Salton & McGill 1983; Baeza-Yates & Ribiero Neto, 1999; Goker & Davies 2009) – related to the assessment of the relevance of information returned as a result of an information search; much of it concerned with defining relevance and arriving at relevance assessments through numerical and computational means. The authors of this paper believe, however, that in respect of relevance for the assessment of *information value* it is the judgement of the user that is important and which should be captured in any high-level definition of relevance. This distinction is clarified in Bade (2007) where he contrasts the means of arriving at relevance through computational methods with 'real relevance as determined by the searcher'.

(Song et al., 2000) in their search for a 'commonsense aboutness theory' identify two key dimensions to relevance in terms of search, these being: (i) '*logical relevance*, often referred to as 'aboutness' (Maron, 1977) and (ii) '*utility*'.

Logical relevance concerns topic-appropriateness, and is a measure of the logical satisfaction of a search query in as much as it measures the relation between the terms in the query with those found in a returned document. As such it lends itself to relatively easy adoption as a metric in *machine* search. Utility, on the other hand, is concerned with the usefulness of information for a user performing a certain task. It is a measure of how useful a document is in satisfying an *information need* (as opposed to an information query).

In terms of information evaluation, it seems then that it is this aspect of 'utility' – associated both with fulfilling current and also predicted need as judged by the user – which is the truly useful one and thus should be implicit in any definition of relevance in respect of information value. The idea of utility as applying to information per se may be extended logically to the information entities defined by the authors (Darlington et al., 2008) these being the information fragment, information object and information system. (Rees, 1966) provides a general definition which – perhaps not so neatly, but certainly completely – captures the utility aspect, defining relevance as:

> *The criterion used to quantify the phenomenon involved when individuals (users) judge the relationship, utility, importance, degree of match, fit, proximity, appropriateness, closeness, pertinence, value or bearing of documents or document representations to an information requirement, need, question, statement, description of research, treatment, etc. (Rees, 1966)*

Since the focus of evaluation here is *information* the authors propose to a adopt a more generalized and simpler form, which preserves the essentials of the above:

'A measure of how pertinent, connected or applicable information is to fulfilling an information need.'

It should be noted here that, whilst relevance as an attribute constitutes one of a number of properties in the authors' conceptualization of information evaluation, it is not a necessary consideration in all evaluation contexts. For example, information as an entity has been identified as being evaluated as a company asset. In this context it is irrelevant to ask 'how relevant is the information?'.

10. AN INITIAL OVERALL MODEL OF INFORMATION VALUE

Explicitly represented and identifiable in the model shown in Figure 6 are the Information Cost attribute, and the Information Impact attribute of information use. Implicit in this model, however, must be the other properties defined in this paper which include Accuracy, Trustworthiness and Usability (which constitute Quality) and Currency. All of these properties increase or decrease the benefits which contribute to gain and thus information value, and therefore they can be considered 'weightings' of a nature that can reduce to zero or make negative the magnitude of *information value* itself. The visualization of this is shown in Figure 6, which constitutes the authors' model of information value.

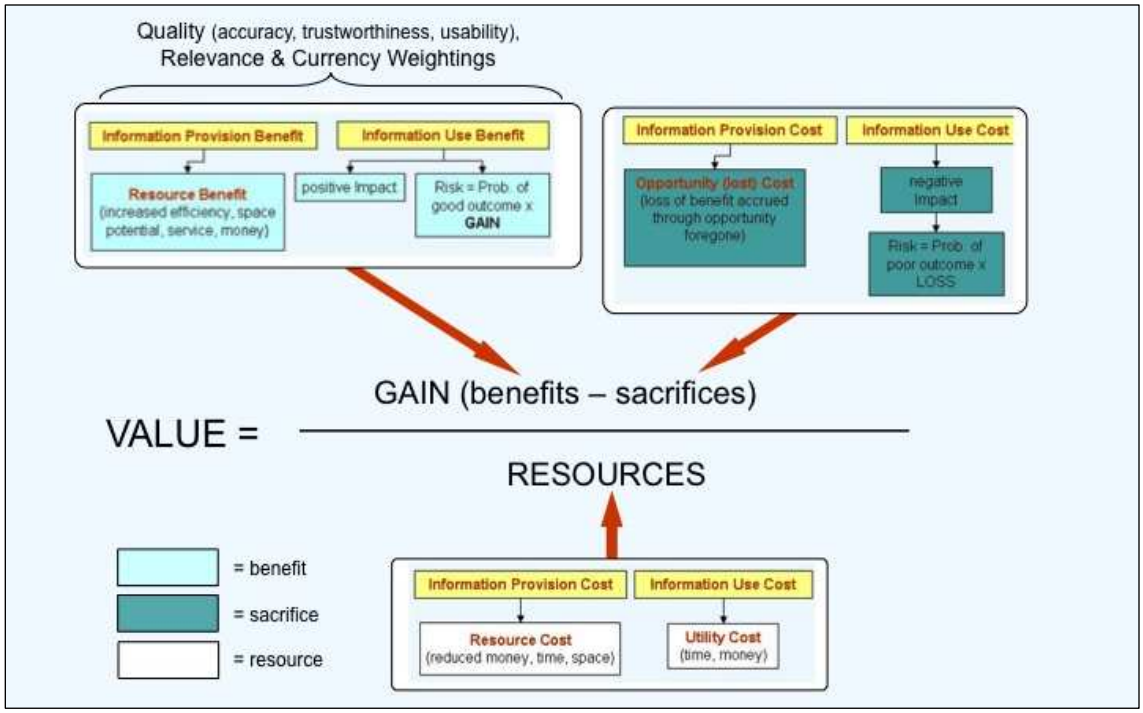

Figure 6. A model of Information Value, showing the contributory properties of *quality* (aggregated from *accuracy, trustworthiness* and *usability*), *relevance* and *currency* appended as weightings to benefits

Given the above analysis it is now possible to derive the definition for information value that has been coined and adopted by the authors, as follows:

'The outcome of an assessment of the trade-off between what is given to have information and the benefit to be gained from having it.'

Finally, the analysis of information value reported in this paper not only reveals the elements that make up information value, but also reveal that there are a number of

different approaches that can be taken to the practical activity which is information evaluation. These approaches are introduced in the following section.

11. APPROACHES TO ASSESSMENT

The above discussion has limited itself to understanding and delineating the dimensions which characterise a number of information properties and properties connected with information use. In the discussion little attention has been given either to which aspects of these properties might be evaluated or how this evaluation might take place. These matters are dealt with in greater detail by the authors in (Zhao et al., 2007). There are, however, a number of different general approaches to making judgements about things – including information – which the authors have conceptualized and which are elaborated below.

For the purposes of information evaluation the authors have created a three-part classification of information assessment methods, these being *direct* assessment, *indirect* assessment and assessment by *association*. These are referred to also as First-, Second- and Third-order assessment respectively to emphasise the relative weight of evidence each brings. The distinction drawn between these three methods is important when practical information evaluation is attempted, since where one approach may be impracticable another, perhaps less ideal but nonetheless useful and doable approach, might be adopted. It should be said here that although the definitions given below apply specifically to information in the form of information objects, assessment by these methods is equally appropriate for information per se although the means of arriving at a judgement may well be different.

11.1 First-order or Direct Assessment

In direct assessment of information, the assessment is made by directly evaluating an attribute of the container (e.g. size, extent) or the content itself. This might be done by counting or by making a judgement. However, in both cases it is the thing itself which is scrutinized such that the value of a property may be established. So for example, the *extent* of a piece of information is made directly by counting the number of words, pages, the space it takes up, etc. In contrast, the *quality*, say, or *accuracy* of a work might be established by sitting down and reading the content. In both cases the assessment is directly on the intrinsic properties of the information itself.

For the purposes of automatic evaluation (that is reliant on computational methods) there are a number of algorithms which might be applied for 'direct' measurement, for example, such things as applying a reading or understanding measure (DuBay, 2004; Smith & Taffler, 1992) or content analysis which provides indications of the concepts and relationships contained within a text (Krippendorf, 2004). Other algorithms can be envisaged such as one for structure characterization, which might, for example, compute a ratio of content size to explicit structural elements, such as contents list, index, and physical decomposition.

The advantage of direct assessment is that it provides high confidence precisely by virtue of its close relationship with the thing that is being evaluated.

Given the above, the following definition is suggested for Direct Assessment:

'Assessment by direct measurement of an intrinsic property of the assessed object.'

11.2 Second-order or Indirect Assessment

The value of some aspects of a thing are arrived at not by direct measurement but by the observation of facts and inferences based on them. In the example given above, the *accuracy* of the information was arrived at directly. An alternative approach, might be to ask questions of the sort 'has this document been written according to some standard?' or 'has the content been subjected to an approval process?' If the answer is yes, then appropriate inferences can be drawn, especially when the evidence is cumulative and not dependent on one value alone. Thus the thing itself is not being measured, the assessment is being made indirectly through the evaluation of a property extrinsic to the document itself. It could be said that indirect assessment is based upon 'information about the information' or meta data associated with the object of interest. Whilst meta data is often embedded in, for example, the document itself, it is often carried elsewhere, thus it is not always necessary to have access to the thing itself at all. This leads to a definition for Indirect Assessment, being:

'Assessment by cumulative evidence of extrinsic attributes of the assessed object.'

11.3 Third-order or Associative Assessment

In associative assessment, the assessment is made quite independently of the object being assessed, indeed it is by virtue of a property of something else. So for example, it can said that a document is of 'high' authority, because it was written by someone who has expertise or standing in a related domain also that a document is trustworthy because it has been published in a learned journal. Therefore assessment through association is established, by assessment of the property of a property not directly on the property of the object of interest. Once again it is not necessary to have access to the object being assessed, indeed it is not necessary to know anything at all about that object except its association. Thus associative assessment may be defined as:

'Assessment by association with the believed properties of some thing other than the thing being assessed.'

The advantage of this approach is that it is efficient since it acts as a sort of short hand The disadvantage is that it allows assumptions to be made that make the inference logically invalid, that is they are believed rather than, necessarily being true. For example, a document may have appeared in a learned journal and because so doing be ascribed with characteristics without, in fact, fulfilling all the assumed attribute requirements (e.g. it might not be clear, or accurate, etc). The inference is false, because the assumption is. Oddly, whilst this assessment method relies least on fact or direct evidence it has a high intuitive confidence.

Provided the information or knowledge is available, making an associative assessment requires little or no computation. If the information is not available then new information has to be inferred; associative assessment provides the basis for automatic evaluation through inference using rules. An example of this reasoning might be: 'if document published in Journal A or Journal B or Journal C then document is a) good quality, b) validated'. However, as noted, the reliability of the conclusions depend on the validity of the rule (the logic) and the truth of the antecedents.

12. CONCLUSIONS

Work on information evaluation has been carried out in a number of disciplines, but this work is not integrated in any way. There is little agreement on what constitutes the fundamental properties of information that contribute to its value, no distinction is drawn between important aspects of these properties, nor is there agreement as to terminology and definitions used to discuss this topic. Furthermore the foundations for making practical evaluations of information have yet to be consolidated. It can be said then that the evaluation of information at both a theoretical and practical level is in its infancy.

The literature and the empirical work by the authors provides a basis for identifying a number of key terms which are central to information evaluation The work demonstrates that it is possible to provide a formulation for *information value* based on a specialization of a general formulation for value which is cited in the literature reporting the authors' earlier work. The concepts associated with these terms have been revealed and subjected to analysis in such a way that the details of a model of information value has emerged, based upon the trade-of between gain (benefit minus sacrifices) and resource expenditure. The understanding of the concepts involved, clarification of their rôle in information value and the model itself provide the basis for developing methods which can be used to arrive at the value of information in its dual manifestations as information which is the subject of provision and management and information as the subject of use and consequent action.

This paper covers three foundational aspects of information evaluation, namely the definition of key associated concepts, then – the heart of the paper – the elaboration and definition of the key properties upon which information assessment is based, and then the identification and definition of three alternative approaches to assessment.

The concepts associated with terms have been explored. These are the terms that – through the literature and empirical research – have been found to describe important properties of information for the purposes of information evaluation. A distinction has been drawn between two property classes, these being *characteristics* and *attributes.* The terms in question include *Accuracy, Trustworthiness, Usability* (contributing to *Quality*)*, Currency, Benefit, Cost* and *Relevance*. The terms refer to properties the values of which can be aggregated to provide a measure of Information Value. It has also been necessary to explore in some detail the issue of impact which has a direct and complex bearing on benefit. Following elaboration of these concepts in order to understand what they might mean, normative definitions have been suggested to aid understanding of the domain, to assist in communication, to provide a basis for modelling information evaluation, and to provide a better foundation for the process of evaluation itself – where the properties are represented as evaluable attributes – whether that be using manual, semi-automatic or fully automatic means.

In addition, three general approaches to information assessment have been identified which illuminate possible methods which might be adopted in arriving at values for the information properties identified. Analysis shows that practical evaluation can be made at three different levels, identified by the authors as Direct (or first-order) assessment; Indirect (or second-order) assessment; and Associative (or third-order) assessment.

13. ACKNOWLEDGEMENTS

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15.

APPENDIX: DEFINITIONS OF CONCEPTS

The following is a digest of the terms and their definitions coined and adopted by the authors and introduced in this paper.

Accuracy	True or correct to a level of precision appropriate to the purpose
First-order or **Direct Assessment**	Assessment by direct measurement of an intrinsic property of the assessed object
Second-order or **Indirect Assessment**	Assessment by cumulative evidence of extrinsic attributes of the assessed object
Third-order Assessment or **Assessment by Association**	Assessment by association with the believed properties of some thing other than the thing being assessed
Information **Attribute**	An aspect of a characteristic, the strength of which affects the strength of the characteristic, or provides a datum about the information. *Intrinsic attribute:* an essential or inherent part or property of a thing, e.g. length, language, typeface, style, but also more abstractly, readability index score, usability index score, etc. *Extrinsic attribute:* arising or originating from the outside, e.g. frequency of use, currency, author, etc.
Benefit	The improvement in circumstance, advantage or profit derived from the impact of information use
Benefit (combining the definition of Impact)	The improvement in circumstance, advantage or profit derived from the effect of information use measured in terms of location, outcome and extent
Information **Characteristic**	A feature or quality of information, the strength of which affects its value
Information **Provision Cost**	The reduction in such things as time, money and space, and the loss of opportunity arising from the provision of information
Information **Use Cost**	The reduction in time and money, and the negative impact arising from the use of information
Information **Currency**	Applicability at the time of interest
Information **Property Magnitude**	The quantity or a scale (rating) or rank position which describes the value of the property according to the metric defined for that property
Information **Property Metric**	The unit and scale used for indicating the quantity or quality strength of the property
Relevance	A measure of how pertinent, connected or applicable information is to fulfilling an information need
Trustworthiness of Information	The reliability of the information based on

	knowledge of its properties
Trustworthiness of Source	The reliability of the information inferred from information about the source
Information **Usability**	The extent to which the information can be used to achieve a person's intended goal(s) with effectiveness, efficiency or satisfaction
Information **Use Impact**	The effect of information use measured in terms of location, outcome and scope
Information **Value**	The outcome of an assessment of the trade-off between what is given to have information and the benefit to be gained from having it

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