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INFORMATION EVALUATION: EMPIRICAL INVESTIGATIONS IN ENGINEERING ORGANIZATIONS

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INFORMATION EVALUATION: EMPIRICAL INVESTIGATIONS IN ENGINEERING ORGANIZATIONS

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ABSTRACT

The management of information in engineering organizations is facing a particular challenge due to the ever-increasing volume of information needs to be dealt with. It has been recognized that an effective methodology is required to evaluate information in order to avoid information overload and to retain the right information for reuse. By whatever approaches, information evaluation judgments are made in those engineering organizations in order to support businesses decisions. Investigating those practical methodologies would benefit the overall information evaluation research. This paper addresses this practical information evaluation issue firstly by briefly reviewing the idea of information evaluation, the definition of value, and related research work on the value of information in various areas. Then a series of industrial empirical investigation activities, based on interviews in engineering organizations, are introduced. The evaluation approaches in those organizations are analyzed and compared according to the nature of each of the organizations. The current practices are then summarized. Finally, several further issues including the impact of the newly developed information evaluation methodologies and the implementation issues associated with this evaluation assessment method are raised.

Keywords: Value, Information, Information Evaluation, Investigation

1   INTRODUCTION

There are a number of challenges associated with managing information in engineering organizations and in particular associated with the ever-increasing volumes of information, the continuously evolving nature and the wide variety of uses of the same information. It has been recognized that an effective methodology is required to be established to evaluate information in order to avoid information overload and to retain the right information for reuse [4]. Little seems available, however, to help organisations address these challenges. The authors have undertaken a series of industrial investigations on assessment or filter mechanisms for information in existing industrial and business environments to support the research and development of tools and techniques which attempt to evaluate the 'value' of information.

Value is a key to a successful business, yet, like information and knowledge, it can be an elusive concept. Tools and methodologies exist for valuing a variety of intangible assets in engineering, project management, financial, accounting and many other fields, but they do not address fully the issues associated with valuing information. However existing work in a variety of fields, such as supply chain management, network risk analysis, decision making support in management, financial service and accounting, and in the library sector, have attempted to put value on information to some degree. The approaches have a number of limitations when considered in the context of engineering information with its complexities and range of elements [12].

The practical methods of information evaluation exist in industry and the business world and are used everyday. Critical decisions are made on the basis of high value information, which requires information being evaluated beforehand. On the other hand information overload is a problem facing almost every organization and finding and distinguishing the high value information is getting more and more difficult. All of these facts reflect the organizations making evaluation judgement on

information, whether they realize or not, in their everyday work in their own ways. Investigating these practical ways of working would be very beneficial to the overall research on information evaluation.

The paper considers the state of the art in information evaluation which is then supplemented with a series of industrial empirical investigation activities based on interviews in engineering organizations. The evaluation approaches, such as they are, within these organizations are analyzed and compared. The current practices are then summarized and a summary of best practices is presented. Finally, several further issues including the impact of newly developed information evaluation methodologies by the authors, i.e. measuring each information attributes and using Bayesian Network theory to calculate the possibility of information distribution [20], together with the implementation issues associated with this evaluation assessment method are raised.

The paper is organized as follows: in Section 2, a review of information overload, value and information evaluation is introduced; then in Section 3, the industrial empirical investigation process is presented; Section 4 summarizes, analyzes, compares and discusses the results from the investigations; finally Section 5 concludes the practical information evaluation investigated and vision of overall general solution.

2   INFORMATION EVALUATION

Modern engineering organisations and organisations associated with and supporting engineering activity are becoming more dynamic and fluid in nature. This is due to the diverse and complex nature of work tasks, trading relationships, environments, as well as the temporary vital importance to the success of a project or a design. If, as is widely argued, information and knowledge are commodities [8] then it is truism for both the individual and the corporate body that they can only afford to acquire and maintain so much. This is not solely for financial reasons, but because of the limits of storage capacity and restricted processing capabilities. However, until recently, the approach of many organisations has been to gather all information regardless of the cost, which leads to what can be thought of as information waste and a cost burden. A recent survey [9] revealed that 80 percent of information filed has never been used. Furthermore, it has been widely reported that the performance of an individual or an organisation can be detrimentally affected by too much information [1] [4].

2.1   Information overload

The problem of information overload is increasing as new technological developments are fast growing [5]. Information burdens, including personal, organisational and customer loading [2], can have a variety of side effects on people and the organisation such as low productivity and stress leading to "information fatigue syndrome" [11] [14]. Many organisations are aware that these problems generate some fundamental questions such as: how much information does an organisation need? Which pieces of information does an organisation need? And when does the organisation need them? [4] In particular, there can be a failure to learn from previous experience because the information has not been captured or it is not readily retrievable in a meaningful context. The latter problem may well be compounded by the context information or metadata lost amongst the large information systems such as large databases.

Finding answers to these questions is important for any type of organisation operating in any business sector. However, in highly competitive global engineering markets the resolution of these issues is particularly critical. This is because of the information-intensive nature of engineering and construction processes, and in particular the design process, which relies upon and generates large amounts of information during its execution [17]. Answering these questions is made more complicated by the fact that there can be a combination of creative processes, team based activities, activities within and outside of organisations undertaking varying parts of the activity. In the construction and engineering sector contexts, information can be easily captured but relevant information that may be ready for reuse for the next project or next generation is not that easy to identify along the information life cycle [16].

2.2 Value

Value is a widely used, but poorly defined term. In the abstract sense value encapsulates the core beliefs, morals, and ideals of individuals and is reflected in their attitudes and behaviour in society. Kohler said that "At the bottom of all human activities are values, the conviction that some things 'ought to be'" [10]. Although valuation is a common process when people make a judgment or assessment with regard to their beliefs and expectations, the concepts, definitions and methodologies of valuation are very different in various fields.

In the manufacturing sector, Miles suggested that the definition of value varies with the purpose, viewpoint and intent of the person who defines it. He identified four forms of value: use, esteem, cost and exchange value [13]. Fowler [7] too recognized that for a product, value is how it fulfils a user's need so that:

$$Value = \frac{Worth}{Cost}$$

(1)

Thomson et al [17][18] argued that a common terminology is important when dealing with a wide variety of stakeholders and a value adding toolbox was suggested when addressing customer value expectations by means of problem solving [11]. They suggested that value is a trade-off, in terms of:

$$Value = \frac{Benefits\ (what\ you\ get)}{Sacrifices\ (what\ you\ give)}$$

(2)

which is an output/input viewpoint in which each stakeholder has a unique perspective. In the economic, financial, and accounting world, value is a fundamental topic connected with pricing or costing systems. In these systems, the "what you get" part and the "what you sacrifice" part are both always measured with price, cost, investment levels or some other financial measure. There are many approaches, from a simple balance sheet to complicated professional analysis tools for accounting and financial assessment to help value tangible or sometimes intangible objects [20].

2.3 Valuing Information

When information needs to be valued – for example in the calculation of either costs, say of storage or generation or benefits of information, say to the individual or the project, – the commonly used evaluation methods are inadequate because of the combination of tangible and intangible characteristics of information. Past work on the subject predominantly focuses on specific kinds of information from particular backgrounds. The following domains have been chosen for study and reviewed by the authors: supply chain management, Value Of Information (VOI) for risk analysis, project management and business management including financial, banking, IT, and librarianship [19].

Arguably the methods in these domains represent the state of the art in activities associated with the "evaluation" of information and they describe the key issues and some of the factors that are relevant to large engineering projects. However none describe specific techniques that could be directly applicable to engineering information. It is clear that to undertake an information 'valuing' activity will require some means of defining the information entities and an associated overall process. As a part of the research, an investigation to the current practices of information evaluation in industry can be beneficial to the research.

3 THE INVESTIGATION PROCESS

The research on information value and the review on information evaluation above have made it clear that it may be possible to put some form of value tag on information, to help solve the problems, such as information overload, decision making, and information publishing, and so on. However in order to gain an understanding of the more practical and empirical approaches in the industrial and business world, a series of industrial investigations have been designed and executed. Before the design of any of the investigations the nature of information **Value** needs to be clarified, which will influence the way of conducting the industrial investigations.

3.1 Multi context evaluation

The authors have illustrated that information has its own intrinsic value and can be viewed as an asset of a corporate body when its invisible value is leveraged [19]. In this information age, individuals and corporate bodies acquire ever increasing amounts of information, and it is thus necessary to understand the value of information within different contexts. Through-life activities in particular have the propensity to generate large amounts of information and knowledge, and either too much or too little information can be damaging to the performance of individuals, organisations and systems. This can result in low productivity and stress leading to information fatigue syndrome [14].

There are already researches about the multiple nature of information and the **benefit** the information can make to a whole corporate, a department, or an individual, especially in financial and economic world [14] [4] [6]. Therefore the authors propose the idea of a multi-level 'values' of information based on the definition of value, i.e. "benefit" over "cost", This makes the information evaluation process, like any other evaluation process, a context sensitive one. Not only is the process context sensitive but the results of evaluation and post evaluation activity are also likely to be affected by the context.

An individual evaluator who is in an evaluation process can be evaluating the information as a representative of him/her self as a user, for their department, or for the whole organization. Based on the particular situation, individuals must clarify the key elements of context in which they will conduct the evaluation before actually undertaking it. This also does not necessarily require the framework to be the same, in fact the criteria or even the parameters in the calculation could be various, as will be seen in the investigation process.

The authors propose three levels of information evaluation (IE)

• *Personal Level*

In the personal level, the IE process is undertaken upon a piece of information in respect of a current or predictable information need of an individual. The 'Benefit (what you get)' part of 'Value' is reflected in capacity to fulfil specific and particular information needs, solving a problem, or supporting the decision making of the individual. And the 'Sacrifice (what you give)' part of 'Value' is the time or effort that the individual expended to gain, assimilate and improve that information for use.

• *Enterprise Level*

In the enterprise level evaluation, the IE process is undertaken on a piece of information or a set of information objects that fill their capacity to satisfy an enterprise or a department's needs. Effectively this is IE at a collective level, for a collective audience. The 'Benefit (what you get)' part of 'Value' is reflected in the capacity to support a process or an activity within the enterprise (team, department, or a branch of company). The 'Sacrifice (what you give)' part of 'Value' is mainly the historic and ongoing costs, time, or efforts expended to support access, provision, distribution, maintenance, and so on.

• *Corporate Level*

In corporate level evaluation, the IE process is carried out on an information or knowledge 'property' which assigns to it a monetary value or score according to the extent to which it is necessary for the corporate body to act profitably. It is to enable information to be treated as an asset in a similar way to other assets, such as buildings, equipment and so on. The 'Benefit' (what you get) part of 'Value' is reflected in the capacity to maintain, support, or increase corporate or company performance. The 'Sacrifice (what you give)' part of 'Value' is mainly the cost or investment of acquisition, maintenance, storage, and so on.

Identifying the multiplicity of information multi-level 'values' is a starting point not only for the industrial investigations, but also for the overall research on IE. Thus the industrial investigations need to find the right sources to be investigated in each of the levels. Furthermore the research on information evaluation also needs to address the difference of framework and methodology between different levels.

3.2 The industrial investigation process

It has been presented that the information evaluation activity is a multi-level one. This requires that the industrial investigation process finds the corresponding resources to the corresponding value level and uses right approaches in order to gain the right perspectives from the right sources. Therefore the following 'perspectives' are planned to be collected from each organization that is going to be investigated to match the corresponding level of information evaluation:

- Senior management perspective, which reflects the corporate (and personal) levels of IE;

- Project management perspective, which reflects the enterprise (and personal) levels of IE;

- ICT (Information and Communication Technology)/ Document management perspective, which reflects both the enterprise and personal levels of IE.

The investigation processes were conducted through interviews which followed a pre-prepared questionnaire which contained a tailor made set of questions for each of the levels. The questionnaires contained broadly the following types of questions:

- Demographics: including questions about the background and position of the interviewee;

- Information definition and classification: including questions about the types of information the interviewee deals with and information systems the interviewee uses on an everyday basis;

- Information evaluation methods: including questions about the methods, procedures, criteria, and other aspects of information evaluation that the interviewee uses to make judgement on information value;

- Knowledge management approaches: including questions related to knowledge sharing, management, and transferring from the interviewee's perspective;

- Final considerations: contains a question about the biggest challenge in knowledge and information management the interviewee is facing.

A total of 28 structured interviews were conducted with a template questionnaire of 35 questions in 4 construction consultancy organizations and 3 engineering organizations. Although the investigations covers a lot of areas from construction to engineering, this paper only uses the materials collected from the 3 engineering organizations because they are more comparable. In this case the interview total is 13, which are: 3 interviews in Company A, 3 interviews in Company B, and 7 in Company C. All three perspectives are covered in each company.

4 THE ANALYSIS OF EMPIRICAL IE APPROACHES

From the investigations that have been undertaken a set of results about information evaluation can be summarized including common IE solutions and problems that are facing the individuals and organisations interviewed, associated with the methods of working on projects and so on. Interestingly there are also many differences in IE in each of the companies. This section illustrates those common points and the differences, and then presents three typical IE scenarios.

4.1 The over-all analysis

From the organizations investigated, there are some common points for knowledge and information management issues diagnosed from the results of the interviews.

4.1.1. The three level of IE

This idea of multiple levels of IE has been substantiated by the investigations. All the three senior management persons who have been interviewed in the three companies regard information as an asset to the company. They try to make sure that information, or sometimes the whole information system in the company, both support and are beneficial to the improvement of the performance of the organizations. Cost is an issue that they worry about, which most of the time is the negative effort of retrieval, store, maintain, improve, and all other ways of dealing with information and the trade off between the positive efforts and negative efforts makes the sense of value. Most of them have been

aware of the issue to increase the 'value' of the information assets but predominantly from the business or strategic point of view. Both positive effects of having the right information at the right time, and the negative extra efforts spending on seeking it, are in their mind and the best balance is what they are seeking for.

The department leaders or project managers that have been interviewed are concerned more about the positive effects associated with 'Value' and mostly they are worried about finding good information, making it accessible to the whole department to enable the department or teams complete work on schedule and within budget. The negative issues, i.e. the cost, time, or effort of accessing information and improving information are of less concern to them. All of the four project/department managers interviewed claim that they are not too worried about the cost issues of information, sometime maybe the time spent related to information, but the priority is always using right information to finish the job and project on time.

The other people that have been interviewed are mostly from an Information Technology (IT) background or importantly engineers who are doing the actual work. But there are still some differences between the IT personnel and the engineers. The IT personnel are for the most part are thinking as the information provider and their IE perspectives are closer to the enterprise level rather than the personal level, when they judge and push the appropriately valued information to the right audience. The engineers are in a different domain and quite clearly think in IE terms at the personal level. All their IE activity is just to make sure the information they are using is of 'high value' and can support them to finish their jobs. The personal time and efforts expended is a concern as part of their sacrifice for the information, which they may consider as the price paid for the information.

One thing needs to be pointed out is that the senior management people and department and project people also need to undertake personal IE when they are acting in their personal role. In that situation the IE process and concerns of them are no difference from any other personal ones.

4.1.2. The workspaces

IE processes are conducted informally all the time, almost everywhere, everyday in all three engineering organizations investigated. Although the business types and nature of work are different, the systems and procedures are common to some degree. Company A is a manufacturer that makes products with long life time; the branch of Company B that has been interviewed is doing relevant short term design work; and Company C also designs products on a multi-national basis.

There are four main types of information systems in each of the three organizations apart from the email system, these are: the company Intranet, the professional data and document management systems, the shared spaces, and the archive system. The Email system is a common tool in all organizations for everybody to use and email systems are not counted as a part of this IE research at this stage.

> **The Intranet system** is a tool for all organizations mostly to publish information and sometime used as yellow pages or phonebooks for people to contact people. Engineers use the Intranet mostly to obtain information to support their work, and companies also use it to push valuable information within the companies. In most situations the IT departments are in charge of putting right information onto the company intranet but more and more often, as in Company A and B, particularly knowledgeable people, sometime called knowledge managers, are in charge of what to publish onto the Intranet and the IT department only undertakes the technical publishing work.

> **The professional data and document management systems** have different names in different organizations but the nature of them is basically the same. These systems serve the engineering work such as design, calculation, development, modelling, simulation, as well as managing the design and CAD data. Also there are engineering document management systems to manage the documents generated throughout the engineering development process. These systems include: EDMS (Electronic Document Management System), PDM (Product Data Management System) System, EDRMS (Electronic Document and Records Management System), DOORS (Document Object-Oriented Specification System), and many more. Although this class of

system varies in purpose, implementation and usage, the various IE processes need to be applied on the information entering and storing in the systems.

The Shared space is a storage space, some time virtual, used by all organizations to help engineers share information during their work with the team or department. Sometimes it is called names such as: J: Drive, or X: Drive like in Company A and C. This kind of space tends to be used as a 'transit depot' for engineering information, but there are some instances when it is used for long term storage. However in most situations the information within is moved into archive systems when projects finish.

The Archive system, some time is called a library as in Company B is mostly used to store 'old' documents and information when a project finishes, or a product is already out of service, and other similar occasions. Most times the information in archive is "sort of old" as one interviewee said, but it doesn't mean the information is not important. There are many reasons to put this information into archive but the biggest one is obviously the legal one. In Company A, interviewees claim that some information about a product is required to be available 6 years after the product is out of service by law, and some project information is required to be around at least 12 years by the laws that their products must follow. But actually almost all information stays forever. Another main reason to archive information is for reuse. In an extreme situation as in Company A, the information within their archive system is stored almost forever, stated by the archivist who was interviewed. So the three organizations all invested heavily in archive systems and claim that the cost of storage and management keep going up during the interview.

Besides all these information systems, there are always personal computer systems and some information is stored in individual hard drives. This is not advocated by any of the three organizations but it is a fact of the real world. With the increased usage of professional data and document management systems, personal information will eventually be eliminated. Many organizations claim that they won't allow any personal information to exist in the future.

Specifying all those information systems in the three investigated organizations is for the purpose of identifying the IE processes among them. It can be seen in Figure 1 that there are always IE processes involved when an engineer needs to decide where to store information. The detail criteria and IE methods discovered in these companies are introduced in the next section.

4.1.3. The IE criteria

An Information Evaluation process is fundamentally composed of two key parts or processes - establishing and assessing the elements which are measurable, and then the associated methods to aggregate them together. A preliminary method to evaluate information based on information characteristics has been established by the authors which contains these two parts [20]. In the industrial investigation, all the practical IE work can also be regarded as 'information characteristics based'. Within the different levels there are different emphases on the same characteristics. In this section, these information characteristics are analyzed and compared.

From Table 1 it can be seen that, at a corporate level, *Accuracy* (information being precise and close enough to reality [3] is a very important characteristic and most senior managers require the information to be as accurate as possible and this is also the key criteria. While in Enterprise IE, *Trust* (Confidence level of information) is cited by all project managers and information that can be trusted is a qualification to be used in the department to support the work. And at a personal level, *Usefulness* or *Usability* (Information being user-friendly, easy to use) [3] are the most referred to characteristic which reflects the fact that engineers tend to use the information to support personal work and information that is easy to be used is always the biggest criteria in a personal IE approach.

There are a lot of other information characteristics that were mentioned during the interview process and the interviewees gave various opinions on the IE process of based upon their individual situations. These information characteristics established by the empirical investigation support the IE theory that the authors have developed [20]. The key information characteristics the authors identified from literature also appear in the industrial investigation process and were mentioned by interviewees.

In the three organizations investigated, the three levels of IE show a focus on different information characteristics. This is summarized in table 1.
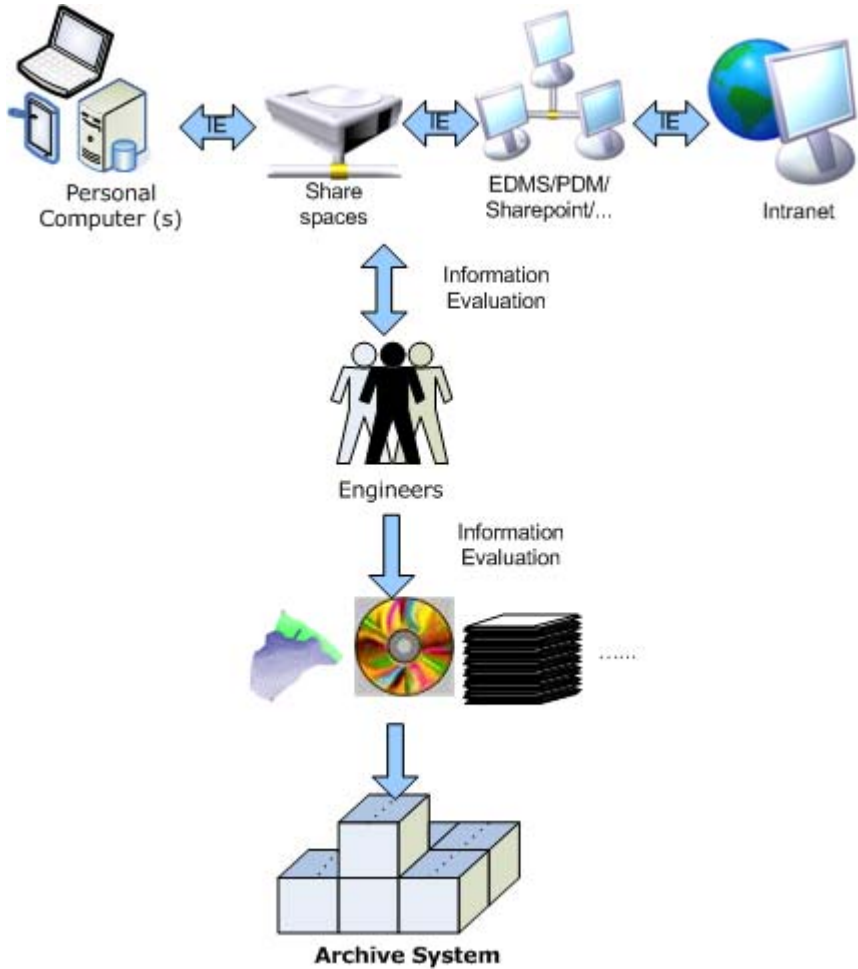

Figure 1 The IE processes among workspaces

Table 1: Information Evaluation characteristics

	Company A	Company B	Company C
ICT/ Document Management System (Personal IE)	Trust, Source, Relevance, Usefulness	Completeness, Usability, Source	Usefulness, Relevance Context, Up-to-date, Accessibility
Project Management (Enterprise IE)	Completeness Trust, Relevant Usability	Source, Trust level, Creditability, Validity, Context	Access control, Trust level
Business/ Strategic (Corporate IE)	Trust, Usefulness, Relevance	Up-to-date, Accuracy	Relevance, Accessibility, up-to-date, Accuracy

4.2 The typical processes in each company

In this section, three typical processes involving Information Evaluation in each organization are presented. All these processes are from real industrial practices and while the performer who undertakes these processes may or may not be fully aware of the idea of information evaluation it still has to be done on a regular basis in real industry.

4.2.1. Company A: Archive

Company A's archiving system has between 7-9 million documents on two of their main sites whilst new documents are flowing in every day. Due to the nature of its business, the documents about its product have to been kept for the product's long lifetime plus 6 years, which means the documents stay in an archiving system for a very long time, sometimes over 40 years.

The company rules say certain kinds of document must be archived after the project is finished or the product is in service. Only signed original copies of documents can be archived. The archive department has a series of attributes, such as: the author(s), date of issue, owner, project, and many more. Different sets of attributes apply to different types of documents and each attribute is supposed to be completed before a document is archived

The catalogue teams within archive departments check the attributes of each document that comes in and make a judgement of whether it is ready to be archived. The catalogue teams only checks those attributes and have no technical expertise on judging the content. The archived documents are still owned by the technical departments who generated them and the archive department just keeps the document for them. The company's archive rule is too general and most of time it is the technical department that decides what to send to archive.

IE issues: from the archive process of Company A, two issues of IE are raised:

1. The IE judgement on documents can be done with attributes or metadata linked to the document, not the document content itself. Many chance the evaluators are just making the IE judgement by explicit attributes and metadata of a document's, such as the catalogue team in Company A's archive department. So the 'meta-data' about document is crucial in an IE process carrying out by non-expert evaluators.

2. To judge what to send to archive and what not to send is clearly an IE process and only high value documents need to be and should be sent to the archive, and put the rest to some less accessible archive, like Company A uses offsite container to keep those kinds of documents. In Company A this is been done by the technical departments who generate and own the documents. Capturing the knowledge of how to make that judgement of what to archive is clearly the basis of an IE solution. This is due to be established in the further investigations of the authors in this on going research.

4.2.2. Company B: Distribute

Company B has an Intranet as described above and there are experts who decide what to publish onto this Intranet. The experts use a coding system to record the maturity of information that is ready to be published. For example, green banana code means information is not ready while yellow banana code means the information is ready to be published. The publishing process also identifies separate audiences and the maturity of the same information at a stage could be different for different background levels of audience. An example is a half finished technical specification document which may be useable to an experienced expert i.e. high value; but may not be useful for a junior engineer who has less experience.

IE issue: User driven information evaluation is considered in the authors' research and the 'relevance' level varies for the same information but to different users. More broadly the context of every user is not same so that the value calculation is not the same [20]. In Company B this is solved by the knowledge of experts who push the information but in a long term view it would be useful to have an IE methodology that can make this judgement automatically or semi-automatically.

4.2.3. Company C: Accessibility

Company C claims its Accessibility problem is big due to the nature of its business and its multi-national background, especially when the engineers in one office in one country are trying to access some certain information in another office in another country. This is unique in the investigations, not only the13 engineering interviews, but the rest of the 28 interviews as the rest are all claiming that they don't have an accessibility problem. Engineers in Company C, who are doing designs, sometimes

need information from other parts in other countries, which they can not get access to. In this case the difficulty of accessing significantly increases the value of the information. At the moment Company C has no solution on this and can only use the best information they can find to support their work.

> **IE** issue: Accessibility is one of the information characteristics that the authors established as being important from the literature and yet only Company C has this problem while all the other interviewees all claim that they can access the information they want. The "virtual" "high" value caused by lack of accessibility should not be taken into account as the research the authors are undertaking regards the information as an object that already been obtained. However this accessibility increased value issue has been studied in some research about information systems. The authors have reviewed and discussed this issue. [21].

5 DISCUSSION AND FURTHER WORK

5.1. Discussion

Several issues worth discussing have been identified after the information evaluation industrial investigation has been carried out..

- The multi-information systems coordination problem: as has been shown above in Section 3.1, every organization has a set of information management systems and engineers using them tend to make their 'value' judgements on information randomly and individually. This applies to a wide range of scenarios for example: what information should be kept in the shared space, what should be sent to archive, what should be kept in PDM system, and so on. One solution, (being investigated by Company A, B, and C), is to use Sharepoint 2007 from Microsoft Corporation to manage, share, and archive all information generated in their work. But another way may be to put a value tag on each piece of information and only archive high value information to reduce the information overload problem, referred to in many of the interviews.

- Storing everything is the approach taken by all the three organizations at the corporate and enterprise level. The storage cost is low especially for the electronic documents but the maintenance cost is increasing rapidly. Also Company A is scanning all old paper documents and scanning work has been scheduled in for the next ten years. It thus can be seen that better organization on storage would be a solution to the information overload problem. However with business search engines improving, like Google business search (Google Corp.), Autonomy (Autonomy Corp.), FAST search (Fast Search & Transfer ASA.), and other search tools, finding information in storage is not as hard as before. But again putting a value tag on searched information would increase the usefulness of the information found.

- The "embedded knowledge" is one of the biggest assets of any organization, including the three that have been investigated. There have been discussions that high value information contains more useful knowledge [15]. Also keeping the knowledge (which is what drives the IE process) is crucial to make the business run well in the future, like the publishing problem in Company B, and the archive issues in Company A. Developing an IE method would also be helpful in knowledge capturing and management for industry in the future.

5.2. Future overall solutions

For the overall knowledge and information solutions in industrial and business organizations, good professional information management systems linked to systems such as PDM, EMDS, Microsoft Sharepoint, and so on are essential. But this is not the only part, a good built-in search engine for all archived information, together with a mechanism or an engine that can give some form of information value tag, during archive or storage, or after search, would be equally important to make the efficient running of business and reduce the information overload problem. This ideas of solution will be improved with the on going information evaluation research.

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