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Codification vs Personalisation: A Study of the Information Evaluation Practice between Aerospace and Construction Industries

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In the emerging digital economy, the management of information in aerospace and construction organisations is facing a particular challenge due to the ever-increasing volume of information and the extensive use of Information and Communication Technologies (ICTs). This paper addresses the problems of information overload and the value of information in both industries by providing some cross-disciplinary insights. In particular it identifies major issues and challenges in the current information evaluation practice in these two industries. Interviews were conducted to get a spectrum of industrial perspectives (director/strategic, project management and ICT/document management) on these issues in particular to information storage and retrieval strategies and the contrasting approaches to knowledge and information management of personalisation and codification. Industry feedback was collected by a follow-up workshop to strengthen the findings of the research. An information-handling agenda is outlined for the development of a future Information Evaluation Methodology (IEM) which could facilitate the practice of the codification of high-value information in order to support through-life knowledge and information management (K&IM) practice.

Keywords: aerospace, construction, information value, through-life

Introduction

The construction and the aerospace industries are major parts of the UK economy and also the economies of a large number of advanced industrial nations. The UK construction industry has more than 250,000 firms employing 2.1 million people. Its output is the second largest in the EU and contributes about 8.2 per cent of the nation's GVA (Gross Value Added) (BERR, 2008). The UK aerospace industry has more than 3000 companies employing around 150,000 people directly and 350,000 indirectly through some of their contractors and consultants in the UK and adding about £8 billion annually to the value of the economy in the UK (DTI, 2003). These two sectors differ in number of firms, number of employees and economic output. They make major contributions in terms of jobs and economic output (see Table 1).

"Take in Table 1"

At the bottom of the table it is interesting to notice the differences in terms of the natures of the organisation, the project teams, the working practices and the inter-organisational relationships. However despite these differences both the construction and aerospace industries are commonly involved in products which are complex and have, what can be thought of as, extended operational lives. One of the things that these two 'knowledge-intensive industries' have in common is that the complex and long-life products they build (e.g. buildings and aircraft) tend to encourage the generation of very large amounts of information and knowledge within the overall 'design-use-upgrade' life cycle (see Figure 1). This tendency is exacerbated as in-service life is getting longer as a result of:

- *The product-to-service shift*, as exemplified by the emergence of fleet service agreements from Rolls-Royce (e.g. the Model 250 engine) that reduces the risk and cost of long-term service and maintenance events to the customer, by

providing a fixed cost per flight hour. This provides the basis for continuity in service records and feedback; promoting an increase in documentation.

- *The influence of different contracting systems* for example the private finance initiative (PFI) (HM Treasury, 2006). The levels of PFI experience between construction and their client organisations are frequently different and the difference can be a costly commitment, that is very reliant upon operational knowledge and feedback. However many PFI projects inevitably repositions and consolidates the supply chain and produces an invisible pressure to deliver better solutions to the clients and the customers.

- *Changes in technology*, these tend to lead to a change in the way information is represented, often resulting in more complicated project information or knowledge management tools and information being fed more easily and distributed more quickly to individual recipients (e.g. Web 2.0, email on Blackberry, RSS feeds, instant messaging, collaboration tools, content management portals, e-library). The diversity of understanding required for of the use, capture and re-use of information, information system and knowledge management creates a culture that inhibits employees' capability and full functioning of the adopted systems in an organisation.

The dominant elements of the 'life cycle' – design, use and upgrade – are highly interrelated as shown in Fig.1 and all contribute to the increasing size of the information handling problem.

"Take in Figure 1"

This paper focuses in the extended information and knowledge space by investigating what can thought of as information value and the impact of information overload and it then considers processes for information evaluation. These topics set

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the context for the interviews undertaken within aerospace and construction organisations, which are the main thrust of the paper. The interviews and the question sets are designed particularly to provide insight in to the following questions:

a) How do aerospace and construction organisations currently organise information storage and retrieval?

b) Is the most pertinent information identified and preserved?

c) Does the speedy acquisition of knowledge parallel its hasty disappearance?

d) Is there an evaluation strategy capable of relieving the situation and, if so, what might it resemble?

2 Information Handling Issues in the Literature

The purpose of this section is to link the three basic elements of value, overload and evaluation to set the context for the interviews based on the current views in the literature. Overload is much talked about and discussed but value and evaluation are much less understood, hence this work.

2.1 *Information and its value*

Information possesses intrinsic value and upon realisation of this value can be viewed as an asset of its associated corporate body. The information age seems to have impelled organisations to gather all types of information leading to information wastage, excessive transfer and unnecessary cost burdens, thus beckoning the necessity for individuals and corporate bodies to understand the value of their ever-increasing amount of acquired information. Apart from the obvious financial reasons (e.g. excessive investment in information and communication technology, and high maintenance and storage costs) we must also consider actual limitations in storage capacity, restricted processing capabilities and reduced accessibility.

All this invites the inevitable question of what is meant by value. Thomson *et al.* (2003) argues for clarity, especially when a number of stakeholders are involved. They developed the VALiD approach to help deliver stakeholder value, especially in the design stages, in which the ***trade-off between benefits, sacrifices and resources*** is considered. There is a need to be able to evaluate information, including its contribution to, and consumption of, an organisation's resources, such as its potential benefits and the cost of acquiring and maintaining it. One global aerospace company uses dollar value to conduct the valuation of a document, in which the formula of value is a number of hours per page times burdened rate defined by the information users for engineering. Aggregate values can then be calculated as a total asset value for the knowledge asset. For example, ***the value of a document or its asset value can equal to the number of hours individual spent creating the document X assumed burdened rate per hour*** (DeGard, 2008).

There is also the related issue of information quality. There has been research into data and information quality (DQ and IQ) issues. For example, the academic views of IQ have been studied and categorised into different dimensions including intrinsic, contextual, representational and accessibility (Lee *et al*., 2002). The well-known IQ program, organised by MIT studied the dimensions of DQ and IQ over many years. It will be seen in Section 2.3 how information quality and value interrelate.

2.2 Information overload

The information overload problem has been discussed for a long time and various solutions have been proposed such as concurrency management, new push technology, intelligent agents, and so on (Edmund and Morris, 2000). Choo et al. (2000) said "Information is meaningful data." Nonaka and Takeuchi (1995) state that

"Information is a flow of a meaningful message". Due to the challenge of the ever expanding information, would "meaningful" be enough to deal with all this information that is being accumulated and is circulating around an organisation? Putting value on information (i.e. making it a meaningful message in the words of Nonaka and Takeuchi (1995) is therefore becoming more crucial to judge what to retain and what to discard. Clearly, either too much or too little information can be damaging to the performance of individuals, organisations and systems.

Although current technologies allow easy access to all information they lack the ability to gradate the *value* of the information and rarely allow for the facilitation of document valuation upon production, retrieval and re-use. In addition, there is a wealth of tacit personal knowledge that, if codified into documentary information, could prove valuable to operators of the finished asset or to future designers. Thus from a business point of view, there is a real lack of evaluation tools capable of both quantifying the cost/benefit of performing information evaluation activities and streamlining information storage thus saving time and money (Tang *et al*., 2006). In addition as projects draw to a close, numerous organisations have little help in answering the overwhelming questions of: What information is worth retaining and how might it be reused?

Surveys reveal that 80 per cent of information filed is never used (Inc, 2003) and that knowledge workers dedicate up to 60 per cent of their time to searching for information (McCampbell *et al.*, 1999). In 2007, a study reported that 73 per cent of construction projects are over budget and that poor information is responsible for 50 per cent of errors related to design and construction (CIO, 2007). Additionally, an online survey encompassing 1,009 managers in US- and UK-based companies created insight regarding collection, use and evaluation of information reporting. It was found

that managers spend up to two hours a day searching for information, and more than 50 per cent of the information they obtained had no direct value to them (Accenture, 2007). More importantly, Basex (2008) found, "Information overload has become a significant problem for companies of all sizes…task interruptions alone cost companies in the U.S. $650 billion per year." Figure 2 exemplifies this relationship between the value of information and overload (modified from Eppler and Mengis in 2004) where overload results in a net decrease in the quantity of *valuable* information a single person or system can manage.

"Take in Figure 2"

2.3 Information evaluation

The successful collection of information and knowledge is broadly achievable, however it can be difficult to usefully store and then retrieve the *relevant elements* as has been highlighted above. In addition it has been recognised by Al-Hakim (2007) and the authors (Darlington *et al.*, 2008; Tang *et al.,* 2006, 2008) that effective methods are needed to value information characteristics (e.g. accuracy, completeness, timeliness, currency and trust level) at appropriate stages in the information cycle. The authors, through the review of more than 170 journal papers and interviews with practitioners in both construction and aerospace industries, have derived a set of information characteristics that includes *relevance, impact, costs, currency, usability, accuracy* and *trust*. A variety of metrics based on these information characteristics and empirical methods may therefore be required to prevent information overload, to retain the correct information for re-use, and to identify its history and context to give it subsequent meaning.

 It has been possible to develop a theoretical framework on information evaluation and a number of approaches to automatic information evaluation. In particular a

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Bayesian decision-making network model (called Information Evaluation Modelling, IEM) has been developed by the authors based on the identified seven key information characteristics as mentioned (Tang *et al*., 2008; Zhao *et al.,* 2008).

There are two main hypotheses in the IEM. The first is that information quality does not equal value: value is a ***trade-off between 'benefits of having information' and 'resources spent on storing and retrieving'***, where 'Relevance to a problem', 'Impact of having the information', and 'Information Quality' inform benefits. Information quality is in turn informed by three context-independent attributes including the usability of format, the accuracy of content and the trust of source. The second hyphothesis is that cost is the key factor in the 'resources spent on storing and retrieving'.

Before implementing this information evaluation tool in both the aerospace and construction industries, a thorough understanding of the existing information evaluation practice in both industries was needed to develop the model and the rationales and processes for establishing the evaluation metrics. The next section will give some cross- disciplinary insights which, in particular, identify major challenges in the current information evaluation practice in these two industries.

3. Situations in UK Aerospace and Construction Organisations

This research identified current approaches to information evaluation based on the authors' study of five construction organisations (annotated as C1, C2, C3, C4) and three aerospace organisations (annotated as A1, A2 and A3), involving 28 structured interviews. Table 2 shows the company backgrounds. Interviews can be highly

structured, semi-structured or unstructured (Easter-Smith, 2008). The highly

structured interviews adopted in this study explored three perspectives: business

acitivities, project management and IT/document management. For each interview a

template of 35 questions was used covering the following areas of investigation:

a) *Demographics:* questions about the background and position of the interviewee;

b) Information definition and classification: questions about the types of information

the interviewee deals with and information systems the interviewee uses on an

everyday basis;

c) *Information evaluation methods:* questions about the methods, procedures,

criteria, and other aspects of information evaluation the interviewee uses to make

judgment on information value;

d) *Knowledge management approaches:* questions related to knowledge sharing,

management, and transferring from the interviewee's perspective; and

e) *Final considerations:* identifying the greatest challenge in knowledge and

information management the interviewee faces.

The following sections present the research findings. These were established

by analysing the interviews and then validating them with the participant companies.

The results were also further validated by a follow-up workshop. The research

findings identify the overall knowledge and information management (K&IM)

practices of the organisations. These are linked to the major challenges and

approaches associated with information evaluation practice based on the case studies

of the seven companies.

<p align="center">***"Take in Table 2"***</p>

3.1 Current K&IM practice

The overall K&IM practice is depicted and summarised graphically in Figure 3. IT-related tools form two parts of the time, effort, and money required developing and using the K&IM infrastructure. A common framework is derived from the participant companies' current ICT infrastructure, systems and culture and the way that their staff work on a day-to-day basis.

"Take in Figure 3"

Generally, the K&IM practices in both industries are seen to include three distinct classifications: hardware, software, and what can be thought of as 'criticalware'. Hardware incorporates tangible objects such as databases, networks, servers, communication systems, phone and PDA, personal PCs, shared drives and physical archives , whilst typical software support consists of data and document management systems, process management systems, intranets, extranets, protocols, shared repositories, wikis, blogs, email, yellow pages, Web 2.0, XML tools and intelligent decision support systems.

The most interesting aspect of the classification within, the overall K&IM system is *criticalware.* This is a term that the authors have heard being used to describe information and knowledge that reside in people rather than artefacts and systems. Within this category people and oral information (non-ICT systems) can be categorised into the following subdivisions:

- *Specialists*: auditors, project leaders (usually charged with document valuation upon project completion), knowledge / IT managers, collaboration tool champions, document controllers, librarians, archivists, individuals fulfilling

required functions (enforced by official guideline such an archiving policy or one's self-motivation); and

- *General operational responsibilities.* These are the activities that people undertake to make the systems work, such as face-to-face interaction, brainstorming, post-project review, learned lessons, and communities of practice which engage in discussion, meetings and team collaborations.

The results of the analysis of the case studies can be summarised in three areas, namely the strategies that emerged for dealing with storage and retrieval, the approaches that the companies adopted associated with long-term retention and archiving and the issues associated with 'corporate memory'. These are discussed the subsequent sections.

3.2 Information storage and retrieval (ISR) - Strategy

For reasons of commercial confidentiality it is not possible to name the companies involved. As mentioned above they are listed as C1-4 for the construction companies and A1-3 for the aerospace companies. More importantly it is necessary for the research to characterise them. This is shown in table 2 and is based on 4 elements (1) history, (2) number of employees, (3) annual turnover and (4) office distribution

The interviews and analysis revealed that the information sources within each company were multi-dimensional. The methods adopted by individual companies have evolved in an ad hoc fashion, and are usually dependent on individual employees' time and motivation. Thus each company has their own blend of storage and retrieval approaches as dictated by a variety of factors: the nature of their business and products, scale, culture and history of their organisation, office distribution, and

their level of resources invested in ICT and knowledge management. However there seemed to be three high-level approaches or strategies for storage, disposal and retrieval. These can be characterised as accessibility orientated, people networking and archiving orientated. Their relationships to the elements in Table 2 are shown in Figure 4. These are discussed in the next section.

3.2.1 Information storage and retrieval (ISR - *Discussion*

Figure 4 does seem to reveal some correlation with office distribution and the preferred information storage and retrieval strategy in each company. In particular, the number of employees in a company is directly proportional to its annual turnover. It in turn affects the size of the company and hence its office distribution. It is noted that the office distribution largely affects the preferred strategy in each company. If the offices are widely distributed, the company will take the accessibility orientated or the archiving orientated approaches. Say for company C3, the open-plan layout in most of their offices demonstrates a lack of hierarchy. This supports more people in networking opportunities. However, this does not directly apply to companies A3 and A1. A3 is a sub-company of A2. Even their company offices are not widely spread; it takes the accessibility approach as company A2 does. The aerospace company's (A1) takes the archiving orientated approach because the company is heavily loaded by the number of documents; even their offices are widely distributed in seven countries. Their archiving system has between 7 and 9 million documents on two of their main sites whilst new documents are flowing in every day. Due to the nature of its business and regulatory requirements, the documents about its product have to been kept for the product's long lifetime plus 6 years, which means the documents must stay in an archiving system for a very long time, sometimes over 40 years.

Others, like company C4 which has 22 sub-companies and 100 offices, are globally distributed. Its turnover is around 87 times (refer to Table 2, £7500M/£86M) higher than that of C3 which is the lowest having the least distributed offices. Therefore, company C3 takes the archiving orientated approach as reflected by its own archiving policy. Obviously in C4, face-to-face and email are not efficient enough for the project teams – especially when in different companies inside the group – to push the project forward. The information is put on the intranet-based collaboration tools, creating an electronic archive that is subsequently more accessible within the overall construction company. The collaboration tool 'Champion' is used. The whole infrastructure is undertaken with the support from trained document controllers and administrators who are in charge of the intranet and database *and* who make decisions and checks on what to keep and what is most likely to be useful. Metadata (e.g. description, name, document naming, document type, submission, section, discipline and element) are used to tag documents before they are put on to the collaboration tool. Therefore, a more complicated collaboration tool is actually a joined up infrastructure that facilitates project collaboration and solves the accessibility problem.

"Take in Figure 4"

3.3 Long-term retention and archiving

The analysis of both the physical and electronic storage approaches was most revealing (see Table 3). It can be seen that legal obligation, of necessity, drives company archiving policies. Fortunately, policies mandating physical storage have been streamlined to demand the inclusion only of signed documentation for specified periods (between 12 and 20 years) following which the legal responsibility is handed

over to another party such as the purchasing organisation. This limits the necessity of a lifetime of physical storage.

The challenges and benefits associated with storing information are presented in this section for both construction and aerospace companies. Given the uniqueness of each construction project the opportunities for reusing information such as building design are limited. Some interviewees claimed that they do reuse information for cost forecast and tendering. However, in aerospace organisations, the duration of physical storage is indefinite because of the nature and lifetime of the products (e.g. aeroplane failure may cause a fatal accident at which point the manufacturer must possess documentary evidence to avoid liability). A case in point is Company A1 who has scheduled time over the next ten years to scan *all* out-dated paper documents in order to cope with their high annual turnover and large number of employees. The storage costs are low for both industries due to electronic documentation capabilities; however; the maintenance costs appear to be rapidly increasing.

In light of this, most of the case-study companies are questioning how much data and/or information they should store, capture and transfer, and how much investment they should make in creating and storing new information through the use of IT. Based on these observations, the simple approach of 'store everything' exists in all companies. This is in the absence of methods to establish and then keep what is the most 'valuable' material. This in turn revealed a number of other issues and potential problems:

a) Most of the companies reveal that context and history are not being captured either by word of mouth, community of practice or an ICT system (e.g. Intranet, Extranet or a database). This is seen to be an issue.

b) When evaluation activity depends on personal responsibilities, a self-motivated work-place culture must exist, yet most companies have not inspired this culture; consequently each employee in their own manner and schedule carries out what are really ad hoc valuation and storage strategies. It is questionable whether the storage of electronic documents on personal hard drives should be continued since relying on individuals to identify the information worth storing appears unreliable.

c) There may – for legal reasons – be information of little value captured, conversely there may be high-value information discarded due to weak or unknown contractual or archival expectations and policies.

<p style="text-align:center">***"Take in Table 3"***</p>

3.4 Losing valuable information and corporate memory

One of the greatest assets of each case-study company is their 'Embedded knowledge'. Quintus (2000) illustrated an iceberg model which divides this so-called 'Embedded knowledge' into explicit, implicit and tacit. Explicit knowledge (above the surface) is visible while both implicit and tacit knowledge (under the surface) are hidden. The iceberg may be 'raised' exposing some of the 'implicit' knowledge, but not the tacit. Tang and Nicholson (2007) discussed how high-value information captured based on this 'embedded knowledge' creates more useful knowledge. The theory of knowledge creation according to Nonaka and Takeuchi (1995) and Rao (2004) develops the argument that there are four ways of transferring implicit (originally referred to as tacit) and explicit knowledge, namely: socialisation, externalisation, internalisation and combination. Furthermore, the relationships between personalisation, codification, knowledge and information have been defined by Tang *et al.* (2007) and McMahon *et al.* (2004). In their paper, Tang *et al.*'s 2007 model is related to the value of information in the case-study companies (see Figure 5),

because the authors and some industrialists believe a balance between these four activities may be crucial to facilitate knowledge and information exchange. The four mechanisms are summarised below, they are then analysed in the context of the case studies (Figures 5 and 6).

a) *Socialisation* occurs when implicit knowledge of an individual is transferred as implicit knowledge to another individual using for example webcams, videoconferencing or virtual reality tools. Information is not recorded during socialisation as all knowledge becomes the mental property of others, otherwise known as personalisation;

b) *Externalisation* occurs when implicit knowledge of an individual is transferred to explicit knowledge such as PSP networks, expert systems or online Communities of Practice (CoPs). This activity, called codification, exemplifies the amount of valuable information captured within individual companies.

c) *Internalisation* occurs when explicit knowledge is transferred and stored as implicit knowledge usually through knowledge databases, E-learning and visualization tools. Once this activity dominates the model, it means that information overloading is occurring.

d) *Combination* occurs when explicit knowledge is transferred in various amalgamations such as abstracting, classification and clustering. Information is recorded demonstrating the companies' efficiency in transforming knowledge into information.

<p align="center">*"Take in Figure 5"*</p>

3.4.1 Corporate memory – The data

The interviewees all claimed that IT managers, knowledge managers or collaboration-tool champions did visit company sites in an attempt to capture and publish new and

different types of information as well as finding and publishing instances of information displaying best practices as found by employees. Unfortunately, it became apparent that several reasons mean that loss of knowledge and value are still a considerable problem caused by:

- *Poor knowledge recognition:* Snapshots of projects are often difficult and time consuming to capture, thus information is lost due to forgetfulness and/or lack of value realisation.

- *Knowledge hoarding:* Some companies and teams and individuals, view knowledge as power, maintaining barriers that are complicated to break down.

- *Knowledge walk-out:* Current strategies are insufficient in tackling the problem of knowledge-loss through the disbanding of project teams, senior management retirement, minimal resignation notice and inadequate succession planning.

Interviewees in both sectors confirmed that knowledge-loss is a major problem conceding that knowledge may be lost as fast as it is acquired resulting in a low corporate memory that delays its response to the evolving issues and reduces its competitiveness.

Figures 6A and 6B illustrate a comparison between the overall perspectives in these two sectors based on data from three goups: document managers, project managers and directors. For each group the four knowledge retention mechanisms and there effectiveness are shown. They are performed generally by different software, hardware and criticalware as summarised below (K means knowledge while I means information):

a) Socialisation (refer to K-K personalisation) is achieved by the case-study companies in multiple ways such as: instant messenger, conversations and discussions, workshops, or start up and project review meetings.

b) Externalisation (K-to-I: codification as high-value information) is carried out in the case-study companies by meetings, memos, project reviews, PSP networks, CoPs, forums, best practice and report sharing.

c) Internationalisation (I-to-K: information overload) more specifically, in regard to the case-study companies is conducted through training, learning and lesson learnt databases

d) Combination (K-to-I-to-K / I-to-K-to-I: transfer efficiency) is facilitated via case-study company e.g. by intranets, extranets, collaboration tools, SharePoint, data and document management systems, archive, software and personal PCs.

"Take in Figures 6A and 6B"

3.4.1 Corporate memory - Discussion

Based on this comparison in Figures 6A and 6B a few highlights can be revealed:

- From ICT and document management perspectives, both aerospace and construction sectors seldom capture and codify knowledge as high-value information (0 and 2 per cent respectively). This is possibly due to the nature of their work, which is focused on storing, publishing and retrieving both electronic and non-electronic information. Both sectors present relatively serious information overload problems (that is a larger amount of internalisation activity) and these group of people rely heavily on self-motivation and the knowledge capture from experts (e.g. the technical knowledge that they are lack of mostly). An information re-use comparison finds the aerospace sector has a higher possibility of re-use from past projects (e.g. less learnt database produced by engineers) in contrast to the construction sector where re-use continues to be moderately low.

- Compared to aerospace companies, 50 per cent of ICT / document managers and 28 per cent of project managers in the construction sector greatly benefit from their

use of ICT in the transference of high-value information. This is nearly double (28 per cent of ICT / documents) and triple (8 per cent of project managers) that of the aerospace sector respectively largely due to the fact that interviewees in construction companies come from various backgrounds, including ICT and technical, opposed to the single focused backgrounds commonly found in employees in aerospace sector. This indicates that multiple background ICT / document managers acts as major knowledge brokers in construction to maximise the knowledge transfer based on the K&IM infrastructure mentioned in section 3.1 (hardware-software and criticalware) but not the codification process as reflected in all three perspectives from the results of the study. This externalisation process is still people-centric that is carried out for example by meetings, project reviews, PSP networks, CoPs.

- Directors in the construction sector focus more on personalisation (63 per cent) with what seem to be inadequate ICT skills (only 3 per cent on the activity of combination) thus, capturing only 10per cent of knowledge as high-value information. Usually, the more senior the person, the less ICT skills they posses leading to a lower capture rate of high-level information. The performance of the project managers in the aerospace sector is similar with 57 on personalisation, 8 per cent on transfer efficiency and 14 per cent on codification as high-level information. This leads to the question whether more IT training should be put on directors who normally hold significant amount of valuable personal knowledge that needs to be codified as high-value information.

As discussed, information evaluation appears solely based on individual judgment due to the absence of tools or guidance working to establish what can be thought of as high-value information for future re-use particularly on through-life

products. This important activity is also driven by the ISR strategy as discussed in section 3.2. How much information and knowledge can an employee capture and transfer? How much can a newcomer receive (assuming that the archiving works well on data/information storage)? What is lost at the same time? The question of whether there should be a balance between these four knowledge retention modes is one that needs to be addressed in these very different knowledge-intensive sectors. Finding answers to these questions is complex. The benefits of retrieving valuable information in the future are high yet evaluating information at the point of creation and storage appears currently to be over-problematic and ambitious in nature.

4. Validation

To validate the results of the interviews and case studies a validation workshop was conducted with the industrial participants. The detailed results of this workshop are not included for reasons of space (the workshop report is available upon request from the corresponding author, subject to certain confidentiality restrictions), but, nevertheless, there was a strong corroboration of the findings presented above. In addition, the participants were asked to identify one aspect of 'good practice' from their own company. These are summarised in Table 4 and give useful industry insights into future development of K&IM practice in both sectors.

"Take in Table 4"

4.1 An information-handling checklist for good practice

Generally, the solution proposed by numerous companies (e.g. IBM, Xerox) from the literature (e.g. Galzer, 1993; Lee, 2001; Umemeoto *et al.*, 2004) and the companies in the interviews is to allow technology to drive the company. The technology-based approach, referred to as the codification approach (McMahon *et al.*, 2004) is used to

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capture all necessary knowledge in analogous formats supportive of re-use when dealing with transition from product to service or vice versa. However, accessibility to relevant information and explicit knowledge is not solved by ICT systems alone. In addition to the technology, staff retention improvements and knowledge sharing (e.g. by reward, by knowledge sharing facilities such as a knowledge café) have had to be proposed to solve the weaknesses of the personalisation approach.

Nevertheless, this codification or storage approach will not necessarily instruct organisations how to evaluate data, information and knowledge so that it can be transferred from generation to generation. Furthermore, new technology would not necessarily clarify what information should be kept in a shared space (opposed to personal drives), what should be archived, and what should be maintained in a document management system and so on.

It was clear from the case studies that whether organisations took an 'accessibility inclined, 'people networking' or 'archiving orientated' approach (Figure 4). The issue of retention (Table 3) and thus evaluation was critical. It thus possible to generate a number of questions that would affect the design of an information evaluation method such as the IEM or VAliD discussed above and would also be critical when setting up an information handling and IT infrastructure. The key questions – which constitute a best-practice checklist – are listed below.

(1) Documents are stored for legal reasons, for up to 12 years normally in construction organisations or much longer in aerospace organizations. *What are the specific legal requirements in your sector?*

(2) The storage cost of information is decreasing but the management cost is significant. *Can/Should a person or a firm dispose of some project information except where there is a legal obligation?*

(3) The introduction of 'tags' may make it easier to retrieve valuable information from project information sets. *Should a person or a firm tag what is perceived now to be high, and structure it to be easily accessible in the future?*

(4) The automated addition of some value criteria (e.g. length of use, viewing of a document, etc.) by a search engine or database may assist evaluation. *Should a firm establish the basis for intelligent search in order to distinguish these criteria and search for their electronic information?*

(5) The product and information life cycle are extending due to a number of reasons as mentioned earlier and at the same time the amount of codified knowledge / information is increasing. *Should a person or a firm increase the amount of recorded and/or shared contextual or rationale information by recording details of events across all phases of a project from development, construction/manufacturing, operations and maintenance?*

(6) Generation is changing from time to time and they way that they learn is different from one generation to another. *What is currently perceived as having a high value in the future taken into consideration variations in the learning styles of different generations?*

5. Conclusions

Clearly, if the companies chosen as case studies are representative of the construction and aerospace sector, a common situation facing practitioners is having either too much or too little information available throughout the day (Figure 4 and Table 3). This paper presents and highlights some of the main findings of the case studies from seven organisations in both the construction and aerospace sectors. The work shows that a common K&IM practice (including hardware, software and criticalware) is

being dually adopted in these industries. Of particular note is the concept of 'criticalware' that the authors have identified and is similar to that has been identified in blogs and some user-generated feedback on websites such as Trip Advisor or Amazon.

Three main information storage and retrieval strategies are identified in this work, with a variety of uptakes. Two companies are archiving orientated, four are high-accessibility inclined and the remaining one is people networking inclined. Information overload exists in all companies due to the current ICT infrastructures, 'storing everything' culture, and the nature of their business and products. Too much information leads to a lack of high-value information that makes decision-making difficult and future re-use highly unlikely. It was also seen that – in line with other studies – the valuable knowledge of experienced departing staff is not readily captured .

Even if storage costs are decreasing, the costs of acquiring relevant/high-value information and maintaining it within a sophisticated ICT system are increasing. One possible solution, (being investigated by these companies) is to use SharePoint from Microsoft Corporation to manage, share, and archive all information generated in their work. Regrettably, this software has not yet been implemented fully, not only because of its functionality but also the cost (many companies, especially SMEs, cannot afford to purchase it). An information-handling agenda is proposed here highlighting the need to putting a value tag on searched information which would increase the usefulness of the information found. Having an evaluation strategy as identified in both sectors is therefore useful for identifying high-value, knowledge-packed information while also making the search and retrieval of information more efficient than hitherto.

6. Acknowledgements

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Codification VS Personalisation: A Study of Information Evaluation Practice between Aerospace and Construction Industries
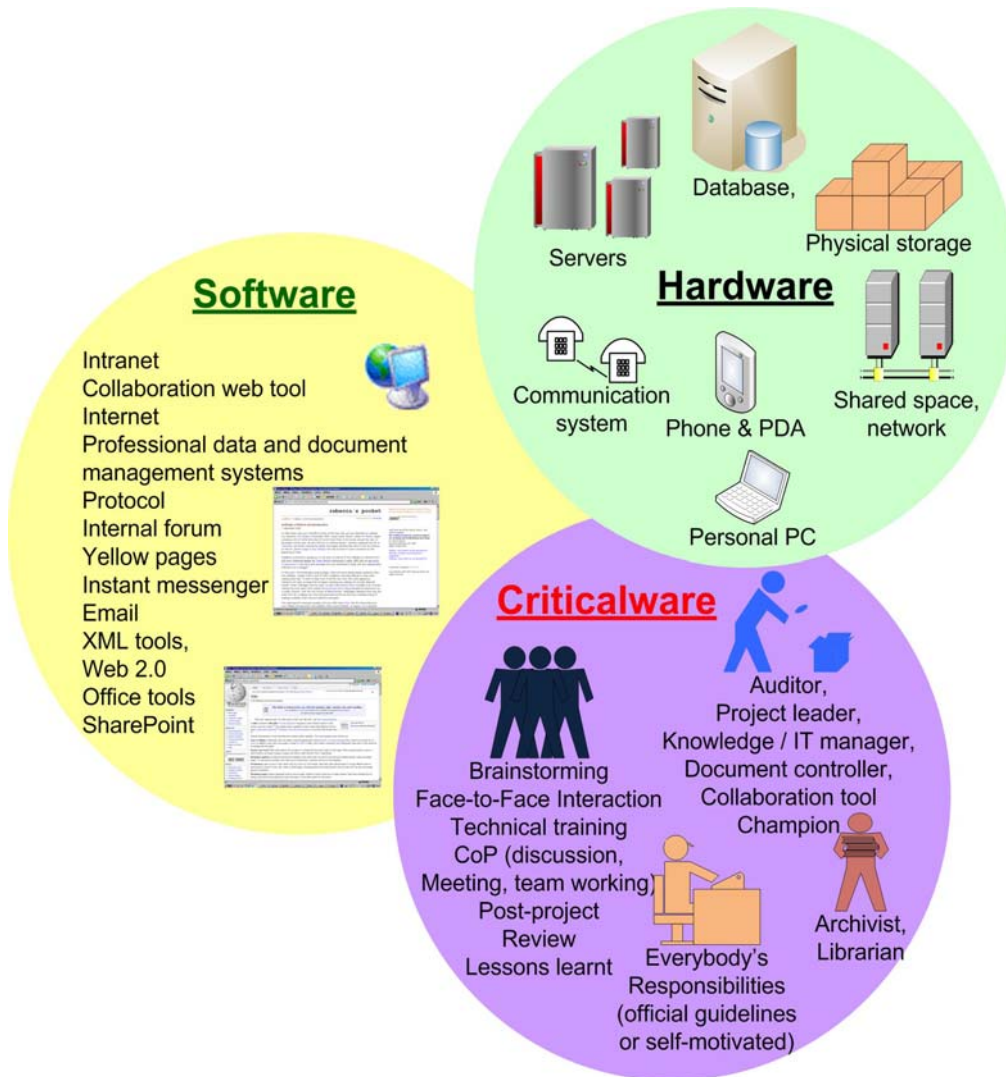
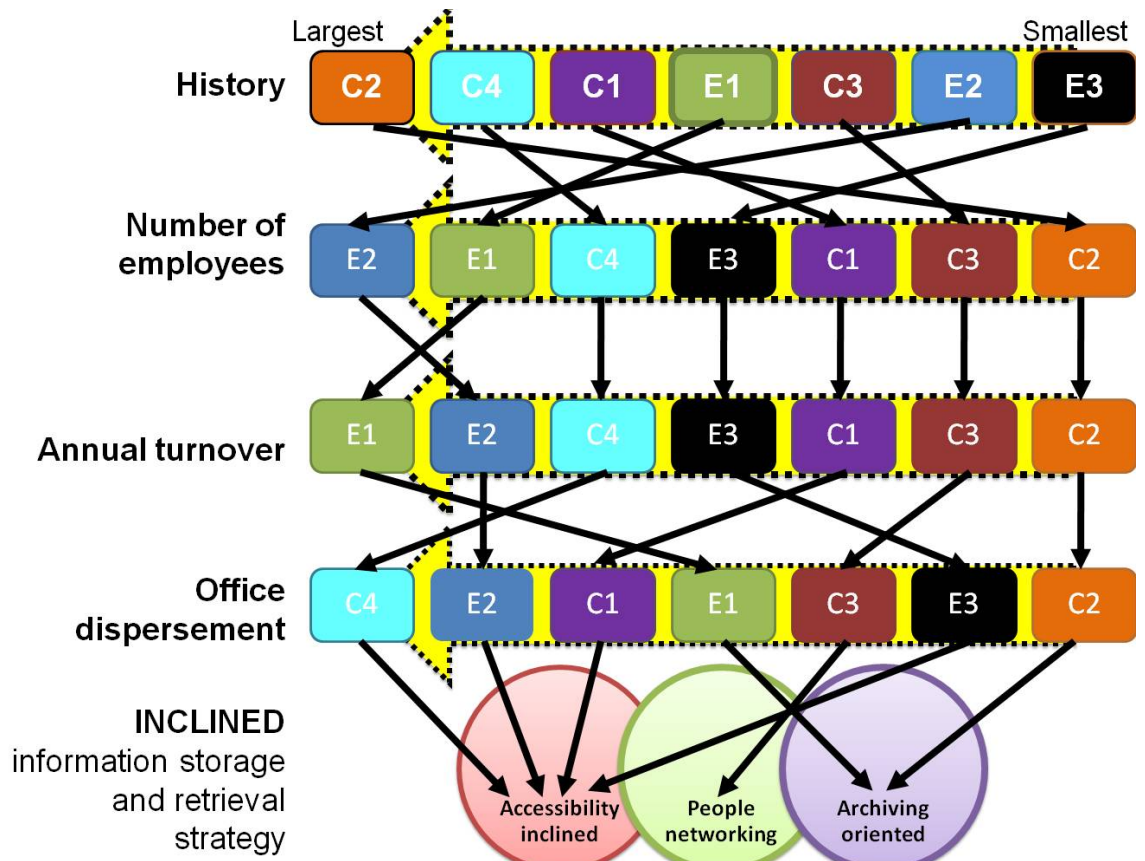**Figure 1.** Possible drivers to extend the product life cycle.
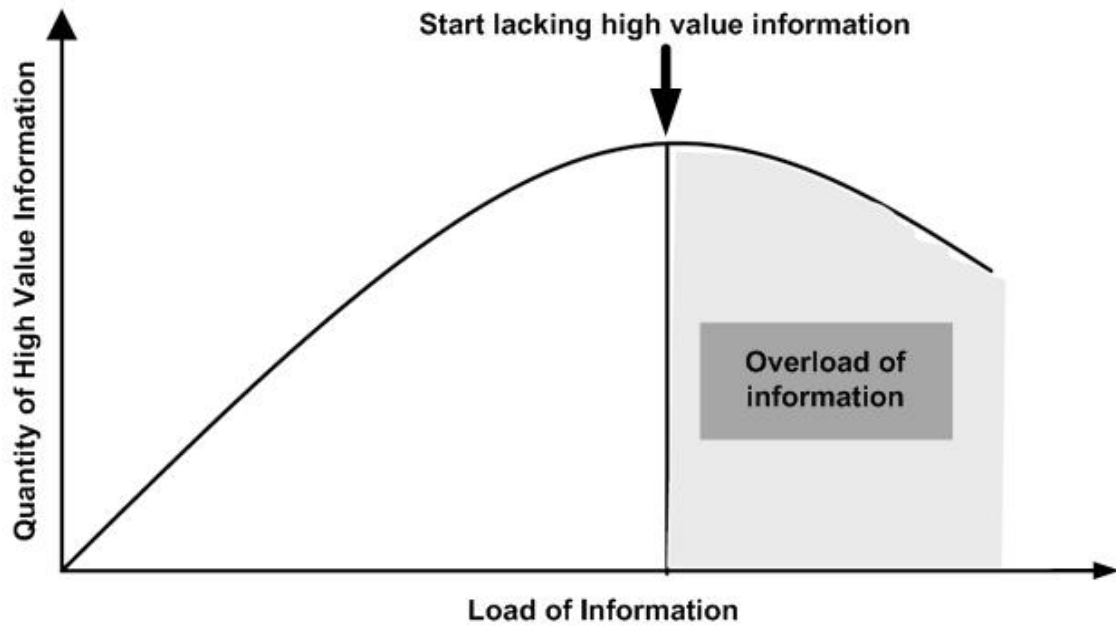
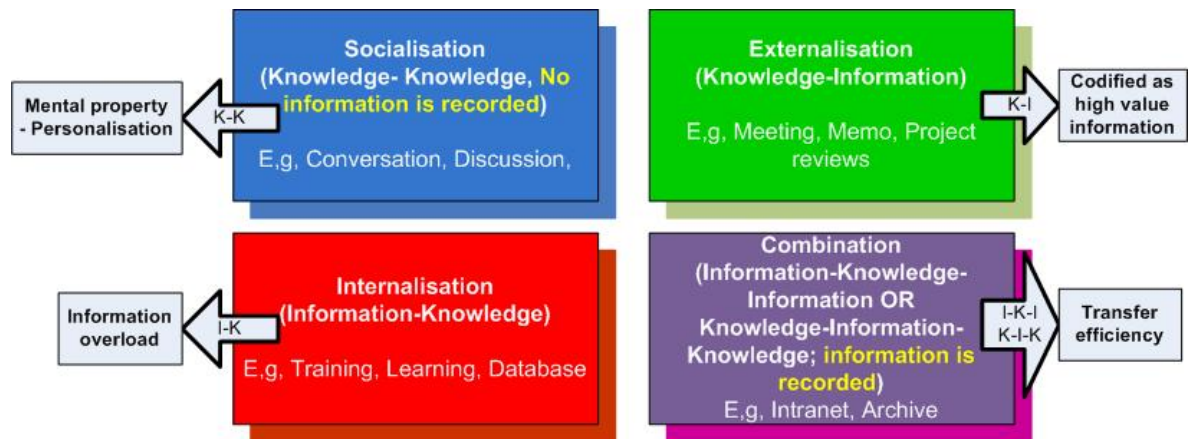**Figure 2.** Information overload phenomenon.

**Figure 3.** Overall K&IM practice in both industries.

Figure 4. Information storage and retrieval orientated strategy in the companies and their background comparison.

Figure 5. Relationship between knowledge creation theory and information value (K=knowledge; I=information).

Aerospace Perspectives

— ICT / Document Mgt. — Project Mgt. — Business / Strategic
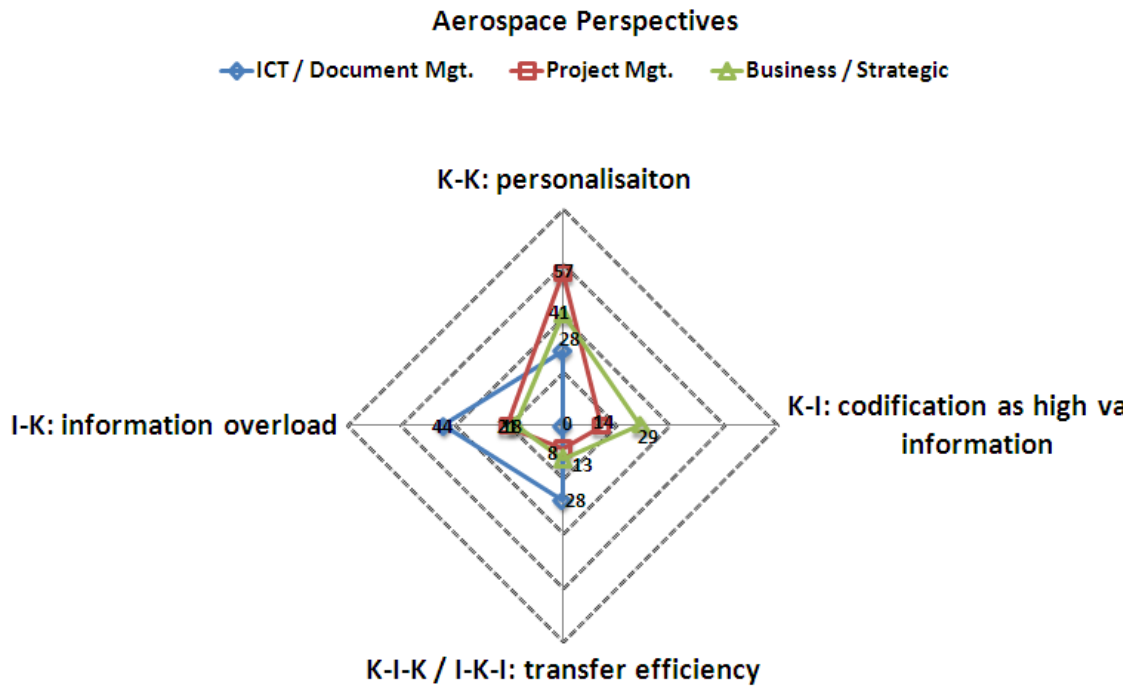
Figure 6A. Overall perspectives on K&I transform in *aerospace companies* (K=knowledge; I=information).

Construction Perspectives

— ICT / Document Mgt. — Project Mgt. — Business / Strategic
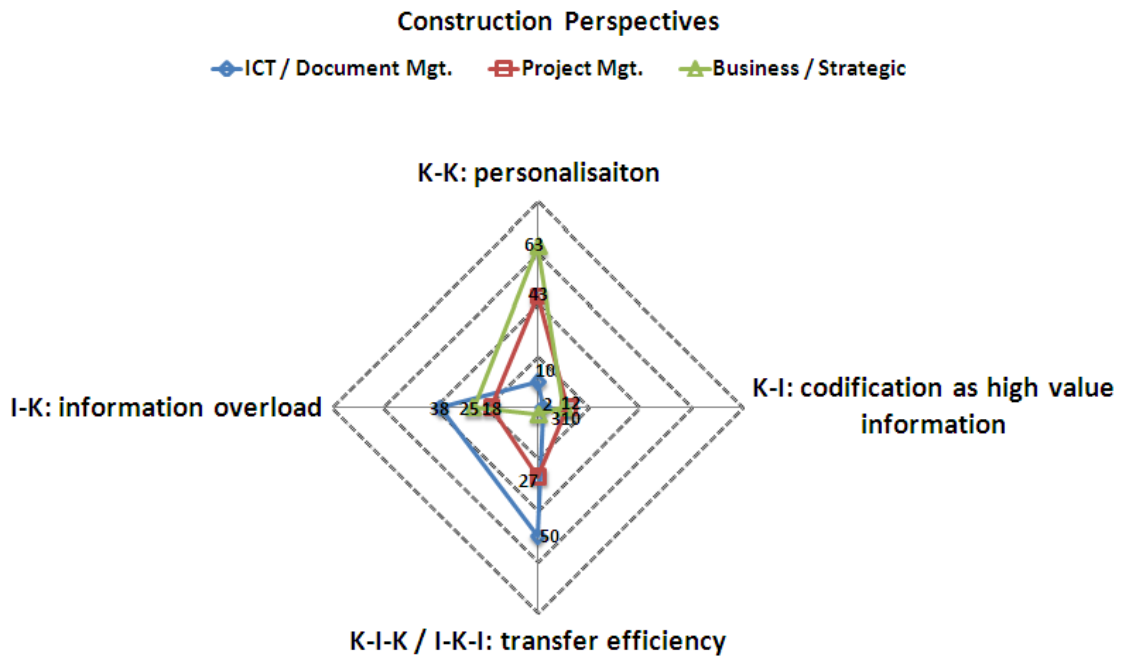
Figure 6B. Overall perspectives on K&I transform in *construction companies* (K=knowledge; I=information).

Table 1. Comparing aerospace and construction in the UK.

	Construction	Aerospace
Number of firm	More than 250,000 firms	More than 3,000 companies
Number of employee	More than 2.1 million people	Around 150,000 people directly and 350,000 indirectly
Output	8.2% of the nations GVA (Gross Value Added)	adding about £8 billion annually to the value of economy
Nature of organization	Highly fragmented	Highly consolidated
Project team	More scattered, non co-located and temporary	More fixed and co-located
Working practice	More multi-disciplinary, mobile and dynamic	Less multi-disciplinary, mobile and dynamic
Inter-organization relationship	Short-term	Long-term

Table 2. Company background of the case studies.

Background / Construction	History	Nature of Products and Services	Scale of Offices and Employees Number	Annual Group Turnover
Company C1	> 90 years ago	A global company providing professional services in Quantity Surveying, Building Surveying, Project Management etc.	40 offices in > 20 countries employing over 3,000 people	> £200 million
Company C2	> 100 years ago	An international company providing professional services and consultancy on Cost Management, Project Management and Building Surveying.	Employing over 750 people	> £50 million
Company C3	>30 years	An international company produces engineering design, project management and consulting services.	19 international offices in 7 countries employing over 1,700 people	£86 million
Company C4	> 95 years ago	A world-class construction, services and investment group.	> 100 offices worldwide employing about 35,000 people	About £7,500 million
Aerospace				
Company A1	> 35 years ago	A culturally diverse company that produces the world's jet airliners.	> 16 sites in 7 countries employing about 57,000 people	About £78 billion
Company A2	> 20 years ago	A global defence and aerospace company.	> 40 offices in 7 countries employing about 97,500 people	About £15,000 million
Company A3	< 10 years ago	A world leading guided missiles and missiles systems company in defence.	13 sites employing around 10,600 people	About £3,500 million

Table 3. Physical and electronic storage situations in the case-study companies.

Company	Life time of paper storage	Life time of electronic storage	Reason(s)	OVERALL storage & maintenance cost
C1	Keep signed copies for 12 years	Keep everything for 6-12 years	Trust, contract and legal obligations	Increasing
C2	Keep signed contracts for 12 years	Keep everything, no formal procedure	Archiving policy & Law	Increasing
C3	Keep everything for 12-20 years	Keep everything for 12-20 years	Legal requirements	Increasing
C4	Keep contractual information for 5-10 years	Keep everything for 5-10 years	Contractual agreements, company practice	Increasing
A1	Keep everything (mostly signed documents) for 'product life time+6 years' to as long as possible (e.g. 99 years)	Keep everything for 'product life time+6 years' to as long as possible (e.g. 99 years)	Law & life time of the products	Increasing
A2	Keep everything (mostly signed documents and final reports) for 5 years to forever	Keep everything for 5 years to forever	Law & life time of the products	Increasing
A3	Keep versions for legal, product and financial information for more than 30 years	Keep versions for legal, product and financial information for more than 30 years	Law & life time of the products	Increasing

Table 4. Aspects of good practices from the aerospace and construction companies.

Company	Aspects of 'good practice' from each case-study company
C1	• N.A.
C2	• Well populated intranet combined with encouragement of use of shared servers rather than personal drives.
C3	• Uses simple but effective system, backed up by good training.
C4	• Effectively encouraging knowledge re-use is difficult but worthwhile. • Younger employees more open to this than older ones. Graduates embrace new technology which facilitates their everyday on-the-hoof knowledge re-use.
A1	• Effective development of lessons-learned database together with increasing culture of its use. This promoted by appointing 'knowledge-brokers' who then have some ownership of the process. • Effective development and use of continuous product development process map, culminating with end-of-project lessons-learned elicitation event.
A2	• Promotion of coffee-drinking spaces, and encouragement to use them. • Trend noted to properly define and more usually adopted data storage procedures/processes.
A3	• Keep K&IM solutions simple and varied (to suit different needs and styles). • Simple solutions like regular poster sessions given by colleagues for colleagues are very productive.