An investigation into the use and content of the engineer's logbook

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The majority of engineers maintain a logbook, or some form of personal notes. Many of these logbooks contain a significant amount of design information and knowledge which is not formally reported. Despite this, logbooks are rarely formally managed, with the content only available to the authoring engineer. It is arguable that such potentially valuable information should be available to the wider organisation, where it could be of considerable benefit. It follows that there is a need to create improved strategies for managing logbooks. However, prior to achieving this, it is first necessary to understand and characterise the use and information content of current engineering logbooks. This paper presents the results of a detailed survey and analysis of a variety of engineering logbooks, focussing on exploring how and why engineers use logbooks and revealing the various classes of information they contain.

Keywords: design knowledge, design activity, information processing, use of logbooks

In modern organisations, the effective use of information and knowledge is a prerequisite for sustaining competitive advantage and efficient operation (Moran, 1999; Dietel, 2000; Chaffey and Wood, 2004). To support this, considerable work has been undertaken by both academia and industry to improve the representation, organisation and access of information across and between organisations (Laudon and Laudon, 1996; Curtis and Cobham, 2000). This improved information and communication management has had a very positive impact on business processes, improved decision making and importantly, increased levels of innovation (Baird et al., 2000).

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The reliance of organisations on information is particularly apparent in the engineering sector (Ward, 2001). Large amounts of information are necessary, not only to support core business processes, but also for

www.elsevier.com/locate/destud
0142-694X $ - see front matter *Design Studies* **27** (2006) 481–504
doi:10.1016/j.destud.2005.12.001

design, manufacture and product life-cycle activities (Pugh, 1990; Ullman, 1992; Christian and Seering, 1995; Lowe et al., 2004). Furthermore, it has been demonstrated that improved information and knowledge management can lead to improved product quality, improved performance and significantly reduced time to market (Tichkiewitch and Brissaud, 2004). The importance of information for engineering organisations was also highlighted in a survey by Court et al. (1998), involving over 300 organisations. This survey revealed that engineers typically spend 20–30% of their time involved in information-based activities, particularly searching and retrieving.

As a consequence of this reliance on information, significant research dealing with information management in the context of engineering design has been undertaken. This work has dealt with the management of product data for design and manufacture (Peltonen et al., 1996; Crnkovic et al., 2003), the management of design data and documents (Pye, 1996; Heidorn, 2002), and the effective utilisation of trade journals and suppliers' literature (Culley et al., 1999; Lee et al., 2000; Iskander et al., 2001).

Much of this work focuses on formal, structured information and associated information systems. In contrast, relatively little work has been undertaken that deals with what can be thought of as informal information and, in particular, the information stored in the engineer's logbook.

These logbooks are typically paper-based notebooks used by individuals to record personal, informal notes and information relating to a particular task or activity. Until recently, managing such information has been all but prevented by technological barriers. This is primarily due to the lack of tools to allow the recording of such informal and frequently unstructured information. However, with the advent of new electronic notebooks (Microsoft corp., 2005) there is a real potential to incorporate this valuable information into enterprise-wide information management systems and engineering information systems. Although certain technological barriers have been overcome, strategies for representing, organising and managing the informal and unstructured information content of the logbooks need also to be created. Central to achieving this is the requirement to understand and investigate the current use and information content of the engineer's logbook.

To address this important issue, this paper presents a detailed investigation of engineering logbooks based on a survey of practicing engineers and an analysis of over 2000 pages of design related information. The first section summarises related work in the area of information and knowledge management in the context of engineering design and discusses the engineer's logbook. Following this, the research method is discussed and the results presented. From these results, a framework for characterising the information content of logbooks is proposed and its implications for engineering information management are discussed.

1 Background

Engineering processes and in particular design processes are heavily dependent upon information and can be viewed as information processes or an information transformation process (Hubka, 1988; Ognjanovic, 1999). The importance of information is underlined by the fact that design activities both consume and create large amounts of information as they proceed. During the early stages of the process the designer will acquire information from many sources, such as handbooks and design guides, catalogues, journals, books, conferences and training courses, to name but a few (MacLeod and Corlett, 2005).

As the design proceeds, this information will be used to inform decisions, undertake modelling and analysis and identify what further information is needed. Throughout this process, the information will be evaluated and recorded by members of the design team in a variety of formats, such as sketches, notes and meeting minutes. Furthermore, at each stage of the process, a proportion of this information will be formally recorded in technical reports and other design documentation such as CAD models to support the project as it progresses. As almost 80% of design is adaptive or variant (Pahl and Beitz, 1984) rather than original, access to this information and knowledge is particularly important for future projects. This design information may describe past designs, document the decisions taken and describe potential limitations of existing designs, or their suitability for adaptation. It can therefore be argued that the efficacy of the design process is highly dependent on the effective utilisation of this existing design information.

In order to support this, considerable work has been undertaken to develop strategies and tools for the improved management of design information. However, whilst many techniques have been researched for managing formal information, informal information has received considerably less attention. Existing research in these two areas is summarised briefly below, and the research issues highlighted.

1.1 Managing formal information

There is a large body of research concerning the management of engineering information and in particular formal information. For example, there have been considerable advances in the management of design documents with Electronic Document Management (EDM) systems (Hendley, 2005), the management of product definition data with Product Data Management (PDM) systems (Gain, 1996) and electronic catalogues to assist in part selection (Allen et al., 2002). Their success can be attributed to combination of significant technological improvements made over the last few decades, such as more sophisticated ways of organising and accessing information (Baeza-Yates and Ribeiro-Neto, 1999) and the adoption of standard information representation and exchange formats, such as XML.

1.2 Managing informal information

There are a variety of sources for what can be thought of as informal information in the engineering design process. These may include handwritten memos, emails, annotations on drawings, 'back of the envelope' calculations and comments in the margins of reports. One of the most important sources of such information is the engineer's logbook, which is widely used by most organisations in many design domains. Interestingly, the logbook has received little attention by researchers. This lack of research can be attributed to two factors: technological barriers and the lack of standards and strategies to support effective recording, searching and retrieval of this informal information.

Work has been undertaken in the area of handling informal design information and in particular, design rationale capture (DRC) systems (see, for example, Bracewell and Wallace, 2003). According to Lee (1997), design rationale includes 'not only the reasons behind a design decision but also the justification for it, the alternatives considered, the trade-offs evaluated and the argumentation that led to the decision'. These systems have gone some way to increasing the richness of information recorded during design activities. However, logbooks may contain considerably more than design rationale (for example, contact information, calculations, notes of meetings and notes not related to design activities, etc.). As a consequence, a more general strategy is required for dealing with logbooks. One major challenge is to determine what information to capture, its underlying form of representation, its level of detail and any supplementary information necessary for it to be reused effectively (Hicks et al., 2002).

2 *The engineer's logbook*

It has long been common practice for engineers and designers to keep logbooks. This process is sometimes a part of a formal training programme, but is also widespread custom and practice. These often detailed written records are a necessary outcome of a variety of design processes. This is illustrated by the fact that much of what is known about engineers and inventors of the past has been extracted from their historic working papers and notes. Perhaps, the most famous example of this are Leonardo da Vinci's (1452−1519) notebooks. From these notes, it has been possible to understand some of his designs and even reproduce them, demonstrating the amount and potential value of the information contained within these personal notes. Similarly, the National Cataloguing Unit for the Archives of Contemporary Scientists (NCUACS, 2004) continues to archive logbooks and other personal material from more contemporary engineers of note such as Sir Frank Whittle, for historical research.

The potential value of such information is also highlighted in a study by Court (1995). This study revealed that following the individual's memory, logbooks, diaries and memorandums is the most widely used and one of the most important sources of design information and knowledge.

In general, logbooks take the form of a hardback book held by either an individual or project team (Horenstein, 2002). These logbooks are used to record information which describes the results of activities and tasks, is required for future activities or may be of value in the future. An entry may contain, for example:

- fundamental design knowledge;
- a rich source of design information and rationale that supports decision making, such as the outcome of calculations, or a consideration of trade-offs;
- the results of analysis and modelling, including failures as well as successes;
- informal information regarding suppliers and customers;
- the outcome of discussions or meetings with experts and colleagues; and
- information for design audit purposes and a legal record for accountability and Intellectual Property issues.

As previously stated, a proportion of this information will eventually be incorporated into formal reports and design documentation. However, a large amount of potentially valuable information will remain largely unreported by any formal means.

Many of these issues could be overcome by the creation of an electronic logbook, combining ease of input with the well documented advantages of computer systems for search and retrieval.

2.1 Managing paper-based logbooks

At the end of a project or a period of employment, it is common for the logbook to be either consigned to a storage facility with little or no indexing or cross-referencing, or to be kept by the engineer as a record of work done. In both cases there is a significant loss of potentially valuable information. Wider access to such material could provide current and future project teams with

- a more complete understanding of previous design issues and how they were resolved;
- information and knowledge for others to continue or validate previous analysis and modelling;
- a single accessible location for ideas, sketches and notes relating to a given project or design, improving the 'collective memory' of an organisation; and
- better support for concurrent and distributed design activities.

2.2 Towards an electronic logbook

As mentioned in Section 1.2, the inability of organisations to manage informal information sources such as logbooks can be attributed to a combination of technological barriers and a lack of standards and strategies for logbook use. In the case of technology, Tablet PCs and other related software are overcoming some of these technological barriers (such as the need for natural pen input and improved search methods for unstructured information). However, no complete electronic engineering logbook is yet widely used. This may be because a common feature of existing electronic logbook projects is the general lack of research into why existing paper logbooks are used and what they actually contain, despite widespread assumptions of what is required of their electronic replacement. For example, Gwizdka et al. (1996) list 10 requirements for the Electronic Engineers Notebook (EEN) project, although it is not clear on what these are based. The Oak Ridge National Laboratory (Geist, 2004) have created an electronic 'notebook' as part of a wider US

Department of Energy project and point out many advantages over paper logbooks, but again give no justification for the stated requirements. Although limited in scope, some specific requirements concerning the structuring of design notes for more effective reuse have been formulated (Gwizdka et al., 1998). The study emphasised the need for structure to be unobtrusive and customisable to individual preferences and level of expertise. However, others (Erickson, 1996; Skidmore et al., 1998) appear to base requirements on personal knowledge or experience.

Wilcox et al. (1997) do undertake a logbook usage study, consisting of interviews with 11 employees. The results showed logbooks were used for personal notes, ideas and a reminder of important items/to do lists and were generally arranged chronologically. The study also revealed widespread dissatisfaction with current methods, including: notes taking too long to write, difficulties in locating past entries, and a lack of integration with their computer. However, the sample interviewed did not consist of engineers and the study focused solely on use and did not consider content in detail.

The creation of strategies for logbook use is frustrated by a number of factors. These include information use being affected by a wide range of personal, social and cultural issues such as personality, qualifications, education, experience, culture, language, communication, time, learning and information literacy (Ward, 2001). Other factors such as the individual's position in the organisation or stage in the design process may also have an impact on how individuals use information and thus how logbooks are used.

In order to overcome the lack of strategies for managing logbook information, it is firstly necessary to develop an understanding of the use and content of existing logbooks. Such an understanding is a prerequisite for the creation of electronic technologies that match or surpass the levels of functionality and performance of current paper-based logbooks.

3 Research method

The objective of this research was to investigate how engineers currently use their logbooks and to establish the information content. From this, a strategy for more effective recording, access and reuse of the information may be developed.

This paper reports on the results of a survey and analysis of logbooks and was driven by two complementary sources: a questionnaire to understand the background issues and reasons for using a logbook

(Section 4) and a sample of 16 paper-based logbooks to analyse the information content in detail (Section 5).

The questionnaire sample consisted of 50 respondents holding various positions within large companies, SMEs and academic institutions, although a majority (60%) of respondents can be classed as working in research or as design engineers. In addition to this, over 30% of the respondents were engineers trained and working outside of the UK, adding an international dimension to the findings. The backgrounds of the sample are shown in Figure 1.

The questionnaire focussed on three areas: (i) reasons for maintaining a logbook; (ii) format of logbook; and (iii) information location and reuse. It was felt that covering these three areas would give a broad picture of the reasons for logbook use, as well as more specific data on how the information they contain is used.

The logbooks were obtained from the participants of the survey and comprise a total of over 2000 pages of engineering notes. A range of logbooks were sought from individuals involved at various levels of responsibility within design teams. These included senior mangers, project managers, CAD operators, engineers and research engineers and within various organisations, including large multinationals and medium-sized

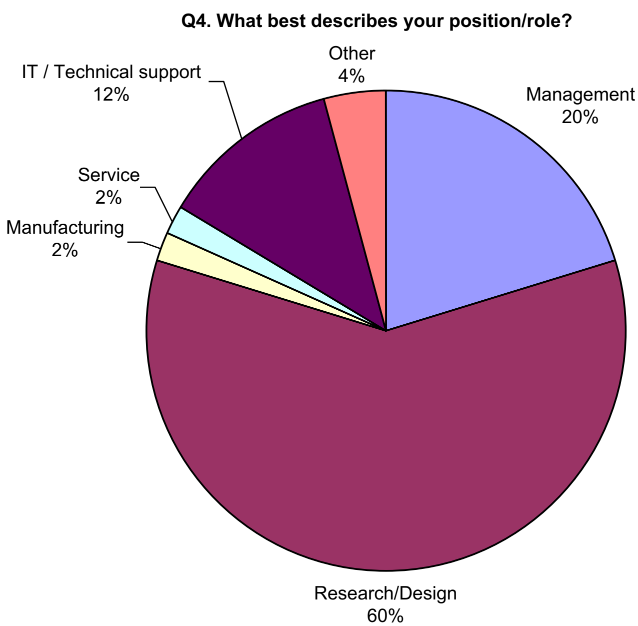

Figure 1 Professional background of respondents

enterprises operating in the packaging, pharmaceutical, aerospace and defence industries. The background of the authors and a description of each logbook are presented in Figure 2.

The analysis consisted of several parts. Firstly, a preliminary analysis of the logbooks established the types of information they contained. These types were then grouped into 13 information classes and a sample of the logbooks were then analysed against the 13 classes by both occurrences (how many) and amount (how much space they occupied). From this, it was decided that recording occurrences was the most appropriate metric and the complete sample was then analysed. This is illustrated in detail in Figure 3. It should be noted that this assessment of information content considers the generic types of information the logbooks contain, not detailed information on context, nor intended use.

4 A survey of the use of engineering logbooks

In order to investigate the use of logbooks, a study of the practices of 50 engineers was undertaken. Results are presented in the following sections.

4.1 Reasons for maintaining a logbook

The first part of the questionnaire sought to establish the reasons why engineers maintain a logbook. Respondents were asked to select the top three reasons from a predetermined list. This list was elaborated through initial discussions with engineers and included: ‘organisational requirements’, ‘training’, ‘personal record’, ‘project record’, ‘reminder of work in progress’, ‘evidence for professional qualification’ and ‘other’. The results are shown in Figure 4 and highlight the two most frequently

Logbook ID	Description			
	Role	Organisation Type	Format	Pages
1	Design	SME	Ring binder	137
2	Design	SME		158
3	Management	Academic	Hardback	96
4	Management	Academic		96
5	Management	SME		62
6	Management	SME		87
7	Service	SME		48
8	Design	Large Company		85
9	Design	Large Company		85
10	Management	Academic		83
11	Research	Academic		86
12	Design	Academic		91
13	Research	Academic		83
14	Research	Academic		43
15	Design	Academic		47
16	Design	Academic		24

Figure 2 Logbook sample details

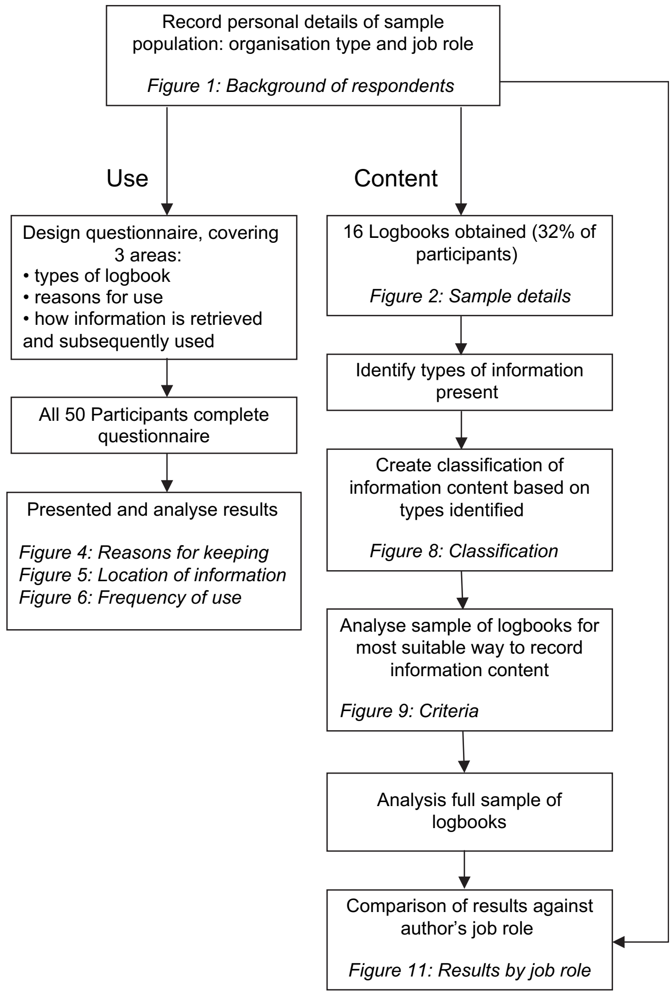

Figure 3 Research method

occurring reasons: 'a reminder of work in progress' and 'a personal work record' (>70%). In contrast, only 20% indicated that the logbook was linked to organisational policy or accepted practice. Alternative reasons given included habit or training (38%), record for the organisation (24%) and evidence for qualification purposes (20%). Within the 'other' category responses included reasons such as recording actions and other people's input or for the formalisation of creative working sessions.

4.2 Logbook format

Preliminary discussions with a variety of practicing engineers revealed that the format of logbooks may vary significantly. To investigate this further, participants were asked to identify the type of logbook they kept: hardback, bound sheets, diary, electronic or other. In addition,

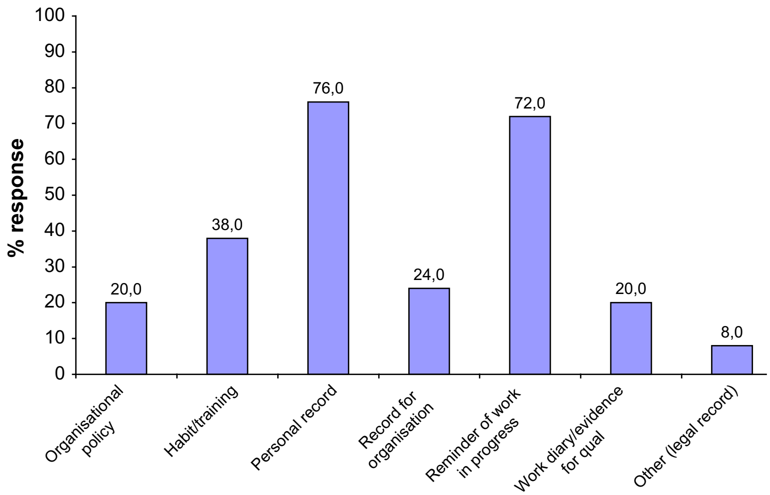

Figure 4 Reasons for keeping a logbook

respondents were also asked to specify the number of concurrent logbooks maintained and whether they were project based, personal or general.

The results reveal that the majority of engineers keep a single logbook (50%), although a significant number kept separate logbooks for different projects (35%). Logbooks were mostly hardbacked books (61%) and loose sheets kept in ring binders (27%). Of the 50 participants, two respondents used a laptop computer as a logbook, although they were not Tablet PCs.

4.3 Information location and reuse

To allow us to investigate how information was located and to what extent it was reused, respondents were asked to select the method they used to locate relevant information: 'browsing', 'indexing', 'cross-referencing', 'page numbering', 'memory', and 'other'. Respondents were also asked to specify the frequency with which they referred to their current and past logbooks.

Most participants indicated that they generally located information by browsing through pages (61%), or by recalling the approximate date of entry from memory (22%). Only 14% used a more formal approach such as an index or contents page (7%), or a cross-referencing system (7%). These results are illustrated in Figure 5.

The frequency of access by the author was also investigated for both current and past logbooks. The results are shown in Figure 6. Sixty-two

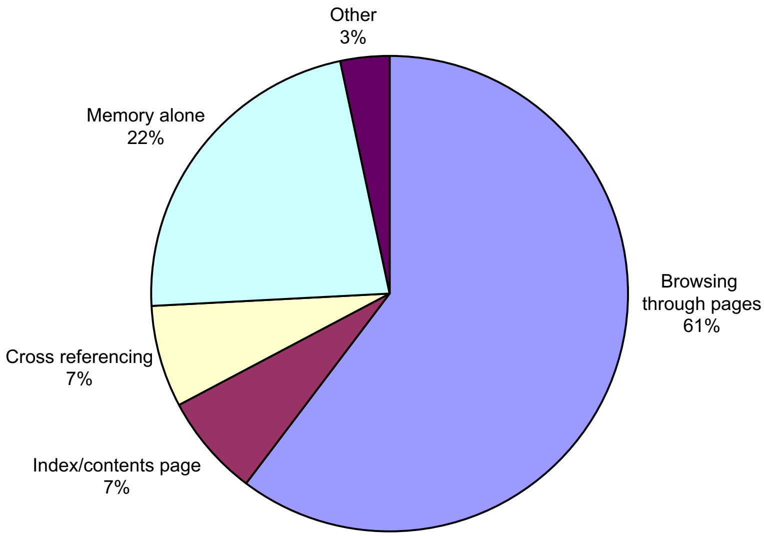

Figure 5 Ways of locating information

percent referred to existing information in their current logbooks on a daily basis, with a further 28% referring to the information on a weekly basis. Just 10% referred to them only for specific events.

Interestingly, 18% of those questioned did not retain past logbooks, which implies that any useful information they contain will be permanently lost to both the author and the organisation. Of those who did retain their logbooks, 42% referred to them for specific events only, and 26% referred to past logbooks on a weekly basis. This supports the idea that older information generally refers to issues or events that

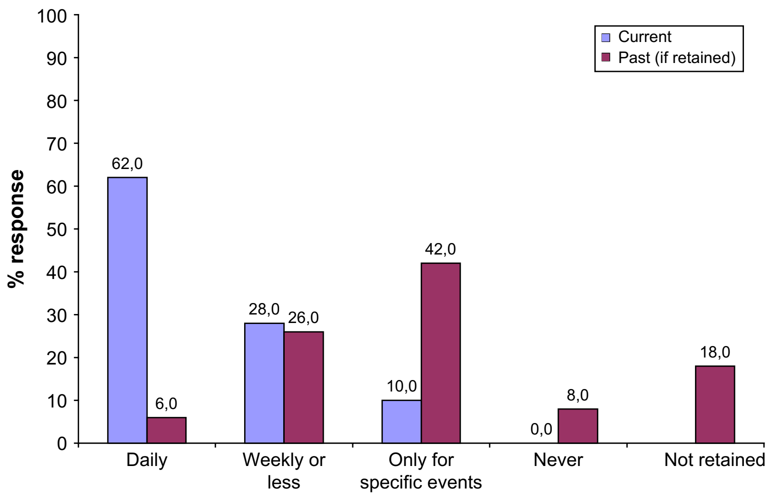

Figure 6 Frequency of use of past and current logbooks

have been resolved. It may also be that the apparently imprecise and inefficient way in which engineers locate the information contained in their logbooks makes this activity so difficult or time consuming that many do not attempt it.

5 Logbook information content

This section discusses the detailed analysis of the information composition of the logbooks. As stated in Section 3, the first phase of the analysis sought to establish and classify the various types of information contained within the sample logbooks. This classification of information is then used to evaluate the overall information composition.

5.1 Definitions

For clarity, various terms used in this work are defined below. For the purpose of this study an 'entry' in a logbook is defined by two dates or a date and a terminator. A terminator could be a ruled line or an empty portion of a page. In practice, entries were clearly defined with little room for misinterpretation. Full definitions of the other terms used are given in Figure 7.

5.2 Information classes

The analysis of information content revealed 28 information types. From these information types, 13 classes emerge. The 28 types and resulting 13 classes are defined in Figure 8. The 13 classes have also been grouped according to the two fundamental information formats – textual (6), graphical (3) or a combination of both (4).

CAD drawings have been identified separately from other external documents due to their relatively large number and special importance in

Term	Definition
Logbook Entry	An entry in a logbook, which may consist of a number of information types, started by a date or title etc. and terminated by a ruled line, empty space or start of a new entry.
Information Type	Specific forms of information: examples include note, 2D sketch, calculation, pie chart etc.
Class	A group of particular information types. For example, photographs, CAD drawings, brochures etc. have been grouped into the class 'External documents'
Occurrence	The number of times a particular class is present in a logbook, expressed as a percentage of total information content
Amount	The proportion of a logbook represented by a class of information, expressed as a percentage of the total number of pages.

Figure 7 Definitions of terms used

	Class	Description	Types
Textual	Written Notes	Personal notes made by the engineer in an individual or collaborative work session.	*Writing* *Computer Code*
Textual	Meeting Notes	Notes taken as a result of a meeting	*Meeting Notes*
Textual	Contact Details	Names, phone numbers and email addressees etc	*Contact Details*
Textual	Calculations	Hand calculations, from simple to complex	*Simple Numerical* *Matrices*
Textual	Tables of Figures	Hand drawn	*Tables of Figures*
Textual	Completed Forms	Usually completed by service engineer on-site	*Completed Forms*
Graphical	Sketches	Hand drawn, from pencil scribbles to 3D representations with colour	*Simple line (2D)* *3 Dimensional* *(above) + Colour*
Graphical	Graphs/Charts	Hand drawn	*Line Graphs* *Scatter Graphs* *Pie Chart* *Gantt Chart*
Graphical	CAD Drawings	Printed and pasted into the logbook	*CAD Drawings*
Text & Graphical	External Documents	Sections from reports, product info, photos etc, pasted into the logbook	*Product Brochure* *Printed Tables of Figures* *Graphs/Charts* *Data Sheets* *Photographs* *Drawings* *Sections of Formal Reports*
Text & Graphical	Annotated External Documents	As above, but altered or marked up by hand	*As External Documents*
Text & Graphical	Annotated CAD Drawings	As CAD Drawings, but altered or marked up by hand	*Annotated CAD Drawings*
Text & Graphical	Memorandums	Added information in the form of 'post-its', 'sticky notes' or symbols in order to highlight important information or elements to keep in memory.	*Memorandums*

Figure 8 Types and resulting classes of information

the context of engineering design. Annotated documents were also defined separately as these annotations are an important part of the information selection process for designers.

5.3 Information content

Prior to analysing the information content of the 16 logbooks, a sample was analysed for both the occurrence (how many) and amount (how much space they occupy) of information classes in order to determine the most suitable measure. This preliminary analysis revealed that a significant proportion of the most frequently occurring information classes also represented the greatest proportion of the total amount of information.

Although for some classes of information there was not such a direct correlation, the relationship was not worse than 2:1 (for example, 32% of occurrences and only 17% of amount). During this analysis it was observed that some logbooks contain a large number of blank pages. These blank pages can constitute a significant proportion of the logbook (up to nearly 50% in some logbooks, with an average of 23.2%).

While both metrics provide a useful description of information content, it was felt that occurrence was the most suitable measure as it is independent of the length of entries and amount of blank pages and thus the results are less likely to be skewed by an individual's information recording style. Consequently, the number of occurrences of an information class was selected as the metric for comparing and characterising information composition of the logbooks. A summary of the result is shown in Figure 9.

The information content of all 16 logbooks was then analysed against the classification of information previously developed. In order to reduce subjectivity it was important to apply a consistent and unambiguous strategy for identifying an occurrence of a particular information class. At the highest level, an occurrence may represent an individual entry, i.e. between two dates or a date and a terminator, such as a line or a blank portion of a page. However, many individual entries are

	% by occurrence	% by amount
Most common class	47.0	45.2
Two most common classes	74.2	72.4
Two least common classes	5.6	3.8

Figure 9 Comparison of criteria used to present results

composed of a number of information classes. For example, a single entry composed of a 'written note' followed by a 'graph' then another 'written note' on an unrelated topic would constitute two separate occurrences of 'written note', even though they may be contained in the same entry. Therefore, each entry had to be analysed in some considerable detail. The results are shown in Figure 10.

Although there appears to be a large variation in the information content, there are a number of similarities. None of the logbooks contained

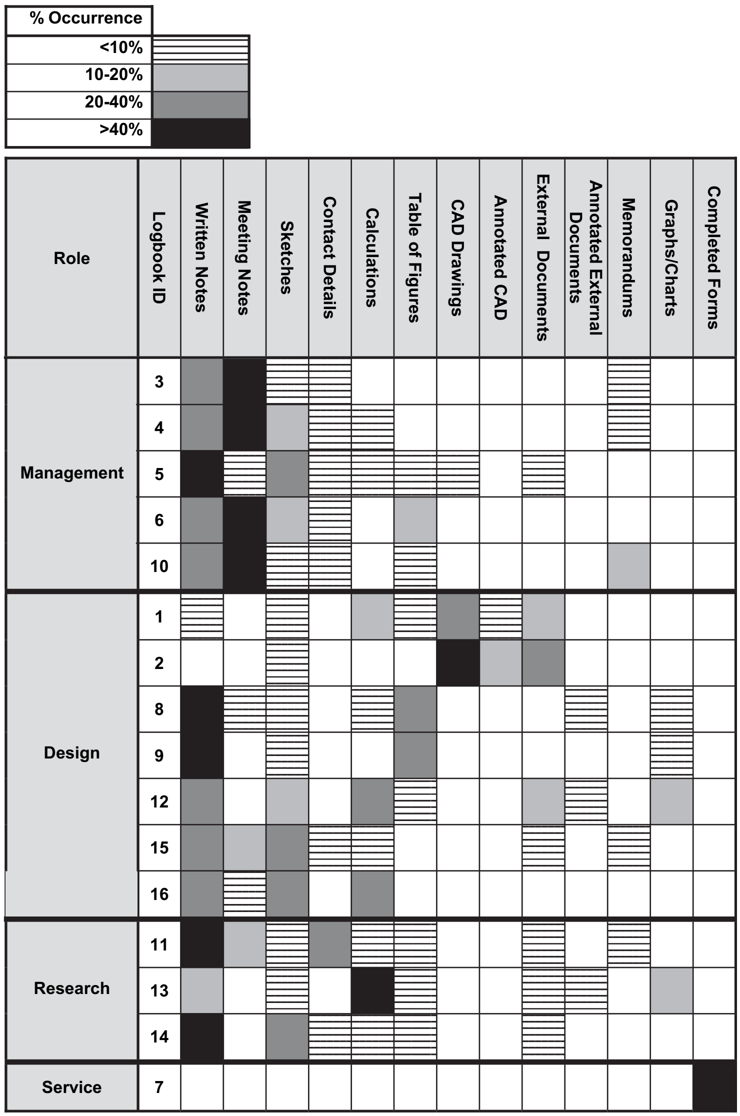

Figure 10 Contents (by % occurrence) of each logbook

more than eight information classes (from the 13 defined earlier), with the average being six. Overall, the most common classes of information were written notes, meeting notes and sketches. The results in Figure 10 are also grouped by the author's main job role. This is discussed further in Section 5.4.

Note also that the class 'completed forms' occurs only in the service engineer's logbook. Although a 'special case', it was felt that it should be included as it represents a common type of logbook and as such is important to consider in the creation of any new logbook strategy.

5.4 Impact of author's role on information content

In order to provide further insight into the information composition of the 16 logbooks, each was evaluated against the author's job role. For the purposes of this work, four organisational roles were used as the basis for analysis: Management, Design, Research and Service engineer. Figure 11 shows the average percentage occurrences of each class grouped by the author's role.

It can be seen that 72.3% of the occurrences in the logbooks of those in a management role are written notes or notes taken in meetings. In contrast, designer's logbooks contain a similar proportion of written notes (33.3%), but they record a broader set of other activities. Sketches, calculations and tables of figures are much more prevalent (36.5% total), as are external documents such as CAD drawings and component specification sheets, making up a further 22.8% of the logbook on average. This diversity reflects the range of activities that design encompasses, and the importance of external information sources for design work. Like designers, the research engineers also favoured written notes (37.2%) and sketches, calculations and tables of figures (38.1% total) and recorded very few meetings (5.1%).

These 'profiles' show that while the contents of a logbook are somewhat dependent on the engineer's role and the work they do, there are also

Figure 11 Average (by % occurrence) of each class, grouped by job role

Author's Role (number of logbooks)	Average % (by occurrence) of information class												
	Written Notes	Meeting Notes	Sketches	Contact Details	Calculations	Tables of Figures	CAD Drawings	Annotated CAD	External Documents	Annotated External	Memos	Graphs & Charts	Completed Forms
Management (5)	32.5	39.8	13.9	2		4.2			1.7		5.1		
Design (7)	33.3	3.4	16.5		12.5	7.5	11.0	2.9	8.9			2.3	
Research (3)	37.2	5.1	16.2	9.5	17.1	4.8			4.8			4.8	

some strong similarities between different roles. Written notes are the main method of recording work in all roles and account for just over one-third of occurrences across all job roles. Similarly, with the exception of the service engineer, sketches consistently make up around 16% of all logbooks.

These profiles also demonstrate the diverse way that logbooks are used and reinforce the need for this research, which may support the establishment of strategies and eventually standards to enable better use of this potentially valuable information.

6 Discussion

This section discusses the key findings and design implications that the usage survey and analysis have revealed.

6.1 Logbook use

The survey revealed that engineering logbooks are typically used as a personal work record and to provide an active reminder of work in progress. They also serve as a reference source for future work in most cases. The most common forms of logbook are a hardback, lined, A4 book followed by a collection of loose sheets gathered in a binder. Two-thirds of engineers use a single logbook, the remainder keeping a separate logbook for each project in which they are involved. In general, information content is structured chronologically, with information being located by recalling an approximate date and browsing through pages.

Engineers refer to current logbooks on an almost daily basis, whilst past logbooks (if retained at all) are generally only referred to by the author on a weekly basis or less, or for specific events only. This is supported by Sellen and Harper (2002) who suggest that a paper document acts as a reminder through its physical presence, which would be lacking if, for example, a completed book was filed in a central store. The difficulty of locating entries through recalling an approximate date and then browsing pages may also mean that it is simply too difficult or time consuming for all but the most important entries.

An argument could be made that rather than being too hard to locate, the past information is not accessed frequently because it is not needed. This is not borne out by either the comments of the engineers surveyed, or by Wilcox et al.'s 1997 logbook usage study which found authors generally had difficulty locating information and expressed a desire for better methods to support this activity.

As an example, one respondent in this survey remarked that easy access to past logbooks would be a 'distinct advantage' for their work, while the following comment was made by a senior engineer working in a large organisation in the United Kingdom:

'I used to keep a "design log", this was used on a number of occasions to directly save the company money. For example, I had details of a job I had done to make an amendment to a drawing. included as part of this was a set of retrospective actions to bring existing components up to the new standard. Months later I was approached by the manufacturing concessions department about the job as a number of components were made to the wrong standard, the information in the logbook provided enough information to point to the retrospective action that saved them producing concession drawings. Another example was during concept work involving patent work, from it I was able to provide all the alternative solutions envisaged to tighten up the patent as much as possible and the exact dates also required for the patent application.'

The survey also broadly supports the other findings of Wilcox et al. (1997), which also reveal logbooks have a commonly chronological structure, with entries being separated with lines or by starting a new page and locating entries by memory and browsing.

The largely personal nature of logbooks has implications for the wider reuse of information by the organisation or even a small project team. For example, most participants indicated that they would be happy to share logbook information with colleagues. However, as browsing and memory are the predominant ways of locating information, it would be much harder for someone with little prior knowledge of what the logbook may contain to locate information without assistance from the author. The issues of information quality and trust also become important as the informal nature of logbooks means that the meaning and intention of the information is often harder to gauge than in a formal report, which will usually follow a certain style or accepted guidelines. For example, although not analysed in detail in this work, most of the external documents also lacked any kind of written reference to their source, or even a date. There is clearly a balance to be struck between ease of recording and ease of reuse and any strategy must provide visible benefit to the author as well as the organisation.

6.2 Information content

The detailed analysis of information content has provided an understanding of what types of information are contained within engineering logbooks and a classification based on these types of information (i.e. the form in which it is represented, such as written notes or a bar graph) has been developed. In total, 13 classes of information were found to exist in the logbooks. The sample represented logbooks from various types and sizes of organisation and the information content was analysed by number of occurrences and also against the engineer's job role. Although just over half of the logbooks were from academic institutions, there was no significant difference in the logbook use or content patterns of engineers undertaking the same main job role in academia or industry.

The most commonly occurring elements were written notes, meeting notes and sketches. When considering different job roles, the study revealed that for managers written notes and meeting notes were the two most common entries. In contrast, for design and research engineers, the range of information types found was more evenly distributed over the 13 classes, although written notes, sketches, calculations and tables of figures were generally the most frequently occurring. Written notes and sketches consistently made up nearly half of logbook content across all job roles, except in the case of the service engineer.

The lack of more distinct categories of logbooks for various roles was not expected and may be a consequence of the sample size (although the findings of the analysis and the usage survey are self-consistent). It is also possible that the contents are dependent on a more detailed classification of roles than those adopted in this research. For example, design and research activities are diverse in nature, with much overlap. Many organisations also make extensive use of inter-disciplinary project teams. In this case, engineers may be involved in several projects at once, undertaking different roles in each, but recording everything in a single logbook.

It is important to note that any logbook must be able to support the full range of information classes identified in the analysis, even information that makes up a very small percentage of the logbook (such as contact details or graphs and charts), as its scarcity does not necessarily reflect its importance. However, understanding how different job roles affects logbook use may have other benefits, such as being able to optimise logbooks to do frequent tasks faster, or to aid storage or retrieval strategies.

The classification of logbook content into 13 classes, together with the fact that logbooks contain between 6 and 8 classes of information also suggests that while logbooks are used in very diverse ways, their content is ultimately manageable. Especially when combined with more effective ways of searching and sharing, greater access to the information logbooks contain could lead to considerable benefits, particularly in large and dispersed project teams.

7 Conclusion

Engineering companies, like most other commercial organisations, are highly dependent upon information in order to carry out day-to-day operations and achieve commercial advantage. In particular, the availability and accessibility of information are critical for the design process and the commercial success of the final artefact.

In design research, considerable work has been undertaken that deals with the improved management of formal information sources. However, comparatively little effort has been directed at improving the management of informal information sources such as logbooks. In an attempt to address this, a study of the use and information content of engineering logbooks has been undertaken. It is argued that such an understanding is essential for the development of improved techniques and methods for the effective management of such unstructured information. The study was based on an international survey of 50 practicing engineers and a detailed analysis of 16 logbooks, comprising over 2000 pages in total.

The survey illustrated how important the logbook is as a personal record or reminder of work in progress and also as a record of past work, to be consulted as required. However, the way logbooks are constructed limits significantly the efficiency of this activity, especially for archived logbooks. The broader issue of using them in their current format as an organisational resource is an even more significant challenge.

Twenty-six types of information were recorded. These 26 types were grouped into 13 classes and analysed by number of occurrences. Despite the analysis revealing some classes of information were much more common in specific job roles (such as the predominance of meeting notes in managers logbooks), it was noted that seldom-occurring classes such as contact details are also important and need to be considered when creating strategies for more effective reuse. The analysis also highlighted the difficulties of identifying and organising information content due to its highly unstructured nature. However, it is arguable that by classifying the information into classes, the content can be made manageable.

The overall results of the work provide a unique insight into the engineer's logbook. Establishing the reasons for use and information content of current logbooks is the first step towards developing the requirements for the next generation of logbooks. This may include the creation of an electronic engineering logbook and the development of improved information management systems designed to facilitate more effective reuse of this important source of engineering information.

Acknowledgments

The authors would like to thank all the engineers who responded to the survey and provided logbooks. This work has been supported by the EPSRC Innovative Manufacturing Research Centre in the Department of Mechanical Engineering at the University of Bath (Grant reference GR/R67507/01).

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