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A Comparison Between the Provision of Information to Engineering Designers in the UK and the USA

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Understanding the information accessing activities of engineering designers has been a topic of considerable interest both to industrialists and researchers alike in forming the basic requirements and specification for document management systems, engineering database management systems and information delivery systems. As part of this effort studies have been undertaken to establish how the designers themselves access and distribute this information. However, such studies have been specific to the host country in which the research was originated and comparisons with the wider design community across the world have not possible to establish or quantify. This paper will present the salient findings and observations of a global comparison between engineering designers working within the UK and USA. It is based on two questionnaire surveys, one undertaken in each of the two countries, where over 300 designers were questioned. Thus, it is anticipated that this paper would serve to enhance the management of information and the associated information delivery systems on a world-wide basis. © 1998 Elsevier Science Ltd. All rights reserved

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Introduction

In the future, the goal of reducing product design-to-market lead times will become more and more important, especially in the context of the engineering function of a company. This is due to the increasing pressures forced on companies as they seek to introduce their products into a rapidly expanding and continually changing market place and to maintain and ultimately improve their competitive edge.

During the early 1990s the emphasis has been predominantly focused on achieving competitive advantage through the modification of the traditional design process and the adoption of a more concurrent approach to New Product Development (NPD) with the focus on a reduction in the product design-to-market lead-time.[1–3] This change has been reflected in new methods of manufacturing, since it is generally accepted that during the early stages of NPD over 75% of the total project costs may already be built into the product before any manufacturing is commenced and that approximately 80% of the life-cycle costs is driven by the decisions made in the first 20% of development effort.[4,5] This has also been raised in the UK Department of Trade and Industry's 'Manufacturing into the late

1990s' programme where it is shown that the integration of information into the design and manufacture of products is essential to the overall success of the business.[6] A recent survey of the issues influencing the design of products has also raised the viewpoint that information is an essential foundation to NPD.[7]

In the future, the role and importance of information within engineering and in NPD in particular will become a major factor to ensuring that competitive advantage is gained by a company.[8] Within forward looking organisations information transfer and knowledge usage by design and manufacturing engineers will become crucial to the ultimate success of a product's introduction to the market and a fundamental paradigm is that of the relationship between these engineers.[9] Understanding the methods that these engineers adopt for information and knowledge access, distribution and subsequent application within the engineering function is of vital importance to improving the management of the design process and, ultimately, NPD.[10]

Aside from this there are also a number of other factors that influence the transfer of information and make the handling of it of considerable importance, these factors being based on technical developments, manufacturing developments and legislation.[11,12] This has resulted in a continually growing and expanding 'core-base' of information, which is being produced by specialist groups and organisations. It has been seen that manufacturers, suppliers and researchers are creating new materials and devices; standards institutes and legislators are creating constraints and new requirements; and other engineers, designers and scientists are establishing new principles; that the supply of information is a continually growing domain in its own right.[13] This is compounded by the influence that the diverse range of formats and media in which the information is stored and delivered has on the designers. This is particularly true where they need to understand the manufacturing demands of a product and subsequent restrictions imposed on them by the facilities of their own enterprise and of their suppliers.[14] The efficient delivery of information to designers within the NPD is therefore of vital importance to the overall success of a project or a product redesign. One of the ramifications of such a large supply of information is that it may slow down or even prevent the engineering designer from obtaining a critical fact or piece of information.[15] This has implications in both productivity and product quality; for example it is well known that engineering designers spend between 20 and 30% of their time searching for and handling information,[16–18] which ultimately results in decisions being based on incomplete data or assumptions.[19]

Additionally, the importance of legislation and externally imposed standards will also impose an increasing burden. Companies will need to show and even prove that their products have been designed using appropriate and proper techniques, both to obtain business and to avoid litigation.[20] The diversity and explosive pace of these developments, as seen in the research and technical press and at any trade show or exhibition, only serves to make the situation more complex. This information concerning these developments has to be handled in a more structured and organised manner than at present. Recognising how this information is accessed in the first instance will form an essential part of enabling the developers of future information systems to specify how to construct systems that best reflect the practical use of information.[21]

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The importance of this paper

Understanding the activities of engineering designers and in particular how information is transferred and subsequently used has become crucial to the ultimate success of a products' introduction to the market.[22,23] This is because the designer may be considered as one of the central nodal points of all information flows within an organisation; for example, receiving information from colleagues, from other departments, from specialists, from suppliers, from external organisations and so on; then transforming this information and distributing it to other designers, specialists, analysts, manufacturing engineers, subcontractors, etc. In many companies it is the engineering designer who leads a project team and collaborates with all other parties' involved.[24] This topic of research has been of considerable interest in recent years and many studies have been undertaken in order to establish the requirements that engineering designers make upon this information;[25–27] and in the work of the authors has been directed to this accordingly.[28–31] Some of the preliminary findings from this work have been previously published in this journal.[32]

However, these studies have been very specific to the host country in which the survey was originally undertaken and comparisons on a wider scale not possible to quantify. Therefore, the purpose of this paper is to present the salient findings of such a comparison between engineering designers in the UK and USA. The aim of the investigations described herein was to ascertain by questionnaire survey the current methods and sources used for the transfer of engineering information within the industries of both countries. This was achieved by undertaking two identical questionnaire surveys (one within each country), where over 300 respondents were analysed. The importance of this paper is in the capacity of being able to provide a global comparison between the information transfer and subsequent recording methods of engineering designers and the findings serve as a means for enhancing the development of information management/delivery systems on a world-wide basis.

Survey methodology

In order to develop extensive all encompassing and yet succinct questionnaires, the methods and theories used by other design researchers who had undertaken similar surveys were adopted.[33–40] The resulting surveys constituted two main activities: a full-scale questionnaire survey within the UK and an identical survey within the USA.

Design of the UK and USA questionnaires

One of the focus points for the questionnaire was that of ensuring that it fulfilled the purpose of the research work by ascertaining the current methods and sources for the provision of information to engineering designers. Considerable detailed attention was therefore given to the design of the questionnaire. This was based upon the findings of Kuffner and Ullman,[41] Turner,[42] Hoinville and Jowell,[43] Bradburn and Sudman,[44] Sudman and Bradburn,[45] Pugh and Morley[46] and Oppenheim.[47] To this end, Hoinville and Jowell[48] state that "A good questionnaire has to be designed specifically to suit the study's aims and the nature of its respondents. It needs to have some of the same properties as a good law: to be clear, unambiguous and uniformly workable. Its design must minimise

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potential errors from respondents, interviewers and coders. And, since people's participation is voluntary, a questionnaire has to help in engaging their interest, encouraging their cooperation, and eliciting answers as close as possible to the truth".

With this in mind, a specification for the survey questionnaire was developed, which included limitations on the length of the questionnaire, time to complete the questions, ease of use and administration, the type of questions covered and the phraseology used. The latter two limitations are discussed below.

Questions covered. Owing to the fact that there were different information 'requirements' to be established, hard facts needed to be generated, as did differing strengths of opinions about for example; the shortcomings in current delivery techniques of information sources and systems, and particularly differing levels of awareness of what actually exists, it was important that the questionnaire be constructed in a manner to cater for all of these possibilities. To take account of this, Oppenheim[49] suggests that the questionnaire consist of both *open* or *closed* questions; where a closed question is one which provides the respondent with a choice of alternative replies and an open question one that gives the respondent freedom of choice to answer it. The questions, therefore, consisted of both of these types of question (or as the authors term *finite* (coded) and *qualitative* (open-ended) types to ensure that suitable feedback would be achieved from the respondent. Many of these questions were therefore, easily answered by simply using *yes/no* answers, check boxes or by using the *Likert* 5-point scale[50] and sub-divided to include the following topic areas:

- Textual (hardcopy and computer delivery).
- Visual (videos, exhibitions, demonstrations).
- Participatory (conferences, seminars, training courses).
- Oral (representatives, consultants, colleagues).

The purpose for which information was required was also examined, as information may be required for solving a particular conceptual design problem or equally it may be required to improve the performance of a particular product, increasing its life or making manufacture more cost-effective. This may be at any of the concept, embodiment, or detailed stages of the design process.[51,52]

Phraseology. In order to reduce the possibility of confusion or ambiguity arising from a badly designed questionnaire and also to ensure ease of administration, the following three principles proposed by Hoinville and Jowell,[53] defining the layout of questionnaires were observed:

- Promote fluent questioning.
- Facilitate accurate and comprehensive recording of answers.
- Assist the subsequent economical transfer of data into computer readable form.

Within this it was also vitally important to ensure that the questionnaire avoided: multi-question questions, long questions, tongue twisters, unfamiliar words and phrase, generalisations, negatives, hypothetical questions and questions that invited distortion.

USA questionnaire. The methodology behind the development of the USA questionnaire was identical to that undertaken for the UK survey.

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[33] *Op. cit.* Ref. 14.

[34] *Op. cit.* Ref. 15.

[35] *Op. cit.* Ref. 17.

[36] *Op. cit.* Ref. 29.

[37] *Op. cit.* Ref. 30.

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[41] *Op. cit.* Ref. 31.

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[47] Oppenheim, A. N., *Questionnaire Design, Interviewing and Attitude Measurement*. Pinter Publishers, London, UK, 1992.

[48] *Op. cit.* Ref. 43.

[49] *Op. cit.* Ref. 47.

[50] Likert, *A Technique for the Measurement of Attitudes*. Columbia University Press, USA, 1932.

[51] Pahl, G. and Beitz, W., In *Engineering Design*, ed. K. M. Wallace (2nd ed.). The Design Council, London, UK, 1996.

[52] Pugh, S., *Total Design: Integrated Methods for Successful Product Engineering*. Addison–Wesley, UK, 1990.

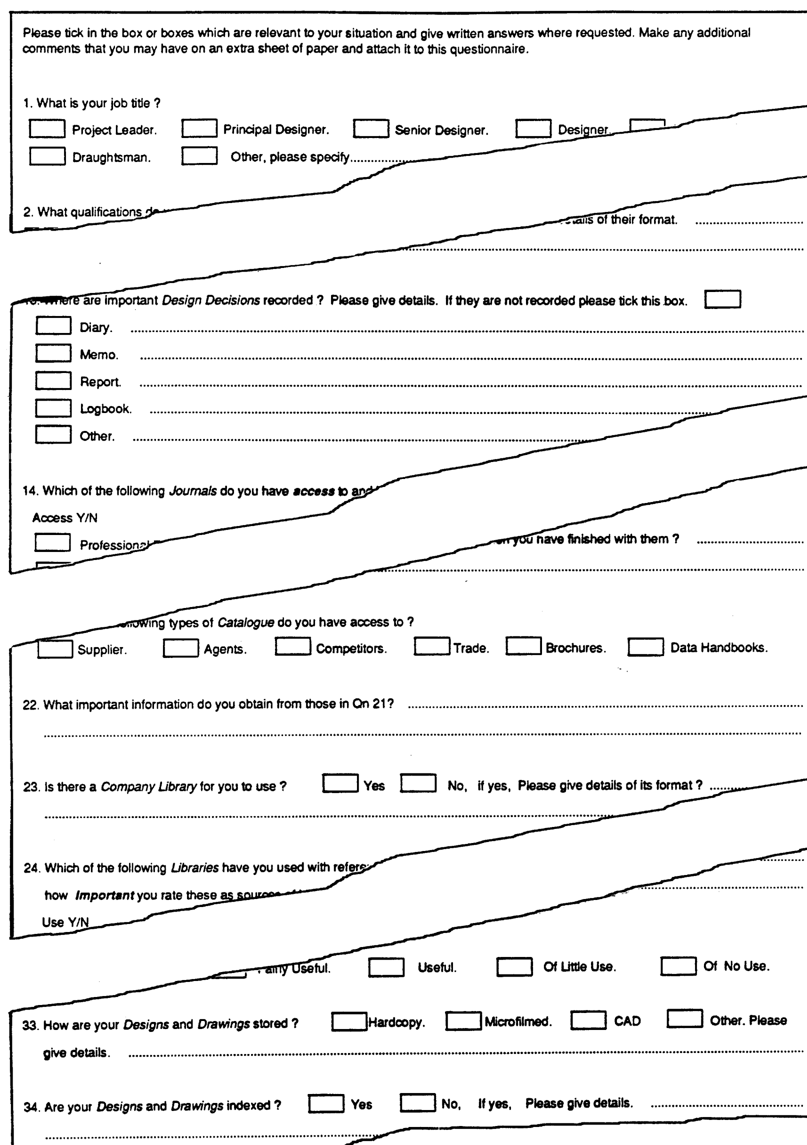
[53] *Op. cit.* Ref. 43.

Again considerable detailed attention was given to the design of the questionnaire. This was based upon the results of the UK survey.[54,55] The main modifications to the USA questionnaire were those related to the differences in language, and those relating to specific sources of information, e.g. journals, magazines, government institutions, bibliographic databases.

An eight-page questionnaire presented in booklet format was produced for each survey, consisting of 53 questions (a sample page is shown in *Figure 1*).

Questionnaire response

Apart from the extensive effort undertaken during the development of the questionnaires, the ultimate success of the study was dependent upon the


Please tick in the box or boxes which are relevant to your situation and give written answers where requested. Make any additional comments that you may have on an extra sheet of paper and attach it to this questionnaire.

1. What is your job title ?
Project Leader. Principal Designer. Senior Designer. Designer.
Draughtsman. Other, please specify.

2. What qualifications ... of their format.

... are important *Design Decisions* recorded ? Please give details. If they are not recorded please tick this box.
Diary.
Memo.
Report.
Logbook.
Other.

14. Which of the following *Journals* do you have **access** to ...
Access Y/N
Profession... you have finished with them ?

... types of *Catalogue* do you have access to ?
Supplier. Agents. Competitors. Trade. Brochures. Data Handbooks.

22. What important information do you obtain from those in Qn 21?

23. Is there a *Company Library* for you to use ? Yes No, if yes, Please give details of its format ?

24. Which of the following *Libraries* have you used with refer...
how ***Important*** you rate these as sources ...
Use Y/N

... Useful. Useful. Of Little Use. Of No Use.

33. How are your *Designs* and *Drawings* stored ? Hardcopy. Microfilmed. CAD Other. Please give details.

34. Are your *Designs* and *Drawings* indexed ? Yes No, If yes, Please give details.

Figure 1 Sample page design of survey questionnaire

[54] *Op. cit.* Ref. 28.
[55] *Op. cit.* Ref. 29.

selection of respondents. The work from the pilot survey ascertained how the most appropriate respondents could be selected for the main UK and USA surveys. The total number of questionnaires distributed was 1050 (950 within the UK and 100 within the USA).

An excellent response to both questionnaire surveys was received, in that 211 completed usable scripts were returned within the UK survey (22.2%) and 24 completed usable scripts were returned within the USA survey (24%). Both of these responses are encouraging in that they are greater than the 'typically' expected response of 5 to 10% and would indicate a genuine interest in the subject.

However, despite this clear difference in magnitude of the questionnaire responses in both surveys, it is important to recognise that this paper will provide a comparison of what is happening in engineering offices in a number of industries within the UK and USA; something that has not been done previously. It is also important and essential to recognise that the data presented here is *greater* than that previously published on the subject, therefore providing a base for making a comparison between the two countries.

Survey results and comparisions

The following section provides a comparison of the main results and findings from the two surveys and the resulting observations. These have been categorised into the following areas:

- Information typically found in the engineering function of an enterprise;
- Type of respondent;
- Industrial and design activity;
- Recording, storing and transfer of design decisions;
- Influence of computing facilities.

Information typically found in the engineering function of an enterprise

From both of the surveys it was possible to categorise the information typically found within an enterprise and that accessed and transferred by engineering designers, into that either accessed *internally* and *externally*.

Information and data obtained *internal* to an organisation is clearly crucial to the efficient execution of design work. Such internal information comprises many specific types, which include the following, in no particular order of priority:

- product specification;
- previous design schemes;
- existing design reports;
- other department reports;
- data handbooks;
- development and test data;
- sales data;
- commercial data;
- marketing data;
- manufacturing data;
- service feedback;
- in-house parts catalogues;
- design guides.

This information was obtained from a variety of sources within the company, these being either individuals or specialist departments.

Information obtained *external* to the designers' own company was found to be accessed from:

- journals and magazines,
- catalogues,
- libraries (public, national, academic and state/county),
- patent information,
- the government,
- non-specialists (press, press releases, magazines),
- suppliers,
- design guides,
- bibliographic databases,
- exhibitions,
- trade fairs,
- shows,
- conferences,
- seminars,
- lectures and courses.

The specific content of the information accessed from the sources referred to above will not be dealt with this paper, rather the focus will be on the accessing methods undertaken by the engineering designers. A detailed discussion of the content may be found in Court *et al.*[56,57]

The type of respondent

Let us first focus on the backgrounds and experience of the respondents, which were found to provide an indication of the wide range of occupations, broad qualifications and experience covered.

Job function, qualifications and experience. The function and role of the respondents showed that those surveyed within the USA were concerned more with design from a project management perspective when compared to those within the UK, although more of those within the UK were concerned with consultancy (described within the 'other' category). More specifically, it was found that each respondent's occupation was directly associated with the design process with almost half being concerned with the design itself and half with its management within both surveys. Within the UK survey it was found that 48% represented principal designers, senior designers, designers and designers or draughtsmen and 52% company directors, chief designers, design managers, project leaders and consultants. Similarly, within the USA, it was found that 41% represented engineers, designers, and drafters, with 59% representing project managers and project engineers.

In a similar manner to the categories of designer role, the qualifications of the two-countries differed. Within the UK it was observed that approximately one-third of these respondents were of graduate qualification level (29%), two-thirds of a Higher/National Diploma level (66%) and very few without qualifications (5%). However, within the USA it was observed that the majority (over 80%) were of graduate level with 32% having a PhD/MS and 56% a BS. The remainder encompassed 4% with associate degrees, 4% with other qualifications and very few without qualifications (4%).

[56] *Op. cit.* Ref. 29.
[57] *Op. cit.* Ref. 32.

These results are interesting, in that they indicate that engineers within the USA are in the main of a graduate level compared to the more vocational background of the UK. It is thought that this is strongly influenced by the traditional educational systems within the two countries, and considering that the majority of the UK respondents had over 25 years experience, it is not surprising that they had this type of background in education. Typically, graduates in the UK have been drawn into the more scientific subjects that support design rather than focusing on design as a subject in its own right. This is an area that needs to be addressed by the educational establishment in the UK to encourage the brighter students to focus on design and has been recognised by a number of recent institutions and national bodies.[58]

In a similar manner, the number of year's experience within engineering provided a very significant result within the UK. It was found that the majority (94%) had at least 10 years' experience and over half more than 25 years' experience. The USA survey provided a more even spread, with 71% having over 10 years experience and 12% over 25 years experience.

The engineering designers working activity. Each respondent also estimated their distribution of working hours specifically concerned with meetings, searching for information, designing and paperwork was estimated by each respondent. The time spent undertaking the four specified working activities, attending meetings, searching for information, designing and dealing with paperwork, were almost equally represented within both surveys. For the UK these were divided into 16, 18, 43 and 23%, and for the USA 20, 20, 34 and 26%, respectively (*Figure 2*). Here it can be seen that in both cases the majority of engineering designers' time is involved in activities other than designing. However, the differences between the UK and USA is that UK designers tend to spend more time designing at the expense of the other three activities. The time spent searching for information is significant in both surveys, where almost one-fifth of an engineering designer's time is spent accessing information. If this time could be reduced or managed better, then more time could be devoted to the activity of designing. These values for information access compare well to those observed in similar design research; where Cave and Noble[59] observed that 20–25% of a designers' time was spent searching for information, Garnett,[60] 27–33%, and Putre,[61] 30%.

Moreover, it can be said that perhaps they need to spend this much time to obtain the information required for a particular task and that it is an inherent part of an engineering designers' job function.

Industrial and design activity

The activities in which the respondents were involved were categorised into industry types, work type and area and operating procedures.

Type of industry. The industrial sectors within which the respondents undertook their design work were divided into ten core areas: aerospace, oil/petrochemical, defence, process, power generation, automotive, construction, manufacturing, agriculture, and electronics. It was found that the industrial background of the respondents represented a good coverage of main stream engineering disciplines within the UK but was mainly confined to the aerospace, manufacturing and electronics industries within the USA.

[58] RAEng, Visiting Professors in Principles of Engineering Design. The Royal Academy of Engineering, Interim Report-May London, 1994.
[59] *Op. cit.* Ref. 15.
[60] *Op. cit.* Ref. 17.
[61] *Op. cit.* Ref. 18.

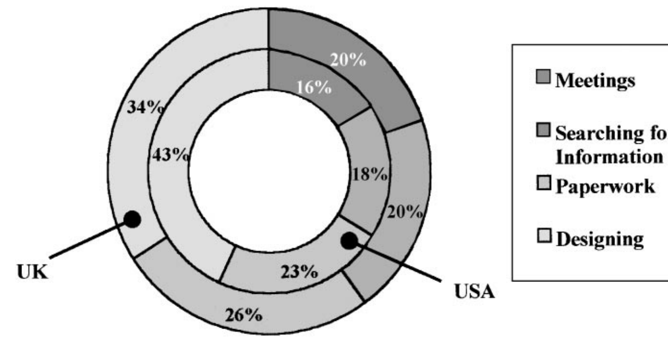


Figure 2 The engineering designers' working activity

Similarly, the specific areas within which the design activities of the respondents were undertaken again provided a broad range and coverage of types. Within both surveys, the majority were concerned with product design and those of OEM, system design, component design, test equipment design, and manufacturing systems design had equal coverage. This shows that engineering designers of both the UK and the USA undertake very similar areas of work.

Type of design work. The definitions of design activity proposed by Pahl and Beitz,[62] namely, original, adaptive and variant design were used in both of the surveys. The UK survey shows that under one-third of respondents are concerned exclusively with original design work. The majority undertake a mixture of these design activities. The type of design activity undertaken by the respondents was found to differ in the area of 'original' design, where those working within the USA were seen to focus on original design more than those of the UK. In fact, 50% of respondents were concerned exclusively with original design work, the remainder undertaking a mixture of design activities. This has clear implications for information systems in that they will have to have a large emphasis on facilities that can handle historical and in-service design data, as well as the more abstract and non-specific information.

Operating procedures. In terms of the adoption of formal methods or processes, the results are rather revealing and alarming. No use is made of any formal operating procedures or methods by nearly 40% of the respondents within the UK and one-third (33%) within the USA. However, the procedures that were adopted are predominantly those that have been developed 'in-house' (43% UK, 46% USA); referred to as codes of practice in the survey and implying procedures for small aspects of the design work rather than a global or all encompassing method. A small proportion (9% UK, 4% USA) use or have use of procedures that are dictated or required by their clients and subcontractors, the remainder using national standards (23% UK, 16% USA).

Recording, storing and transfer of design decisions

The methods adopted for recording, storing and transferring the decisions made during the design process were found to relate to a number of specific areas.

[62] *Op. cit.* Ref. 51.

Recording design decisions. The methods adopted by the respondents for recording the decisions that they make during their design activities were also similar in both surveys, with the only exception of memos and project files, where those in the USA used them more widely than those in the UK. It was interesting to find that the use of design logbooks and notebooks were identical in both countries, where almost half of the respondents used them (45% in UK, 50% in USA). The format of these was predominantly that of hardcopy, although the use of personal organisers, both manual and electronic, was found to be increasing. It is interesting to note that only a very small proportion of use was attributed to computer recording with less than 10% in both cases, although the USA being the greater. Other places where design decisions were recorded were also found. The major sources were diaries, memos, reports, notebooks and others, which included data/calculation sheets, project/contracts, designs/drawings, and computers. *Figure 3* provides a breakdown of the methods for recording design decisions for each country. This enormous variety of locations for this particular set of information gives some cause for concern.

The majority of these locations are personal and others are large contract or project files that are unlikely to lend themselves to easy perusal and access. At later stages in the design process the reasons behind such decisions will have been forgotten and not recallable. Alarmingly, it was found that almost one-fifth of UK respondents (17%) did not record their design decisions compared to only 8% in the USA, which has severe implications on the overall development of the product design as it progresses to completion.

Information storage. The predominantly used methods for storing designs and drawings were found to be those of either hardcopy, microfilm computer-aided design (CAD). Owing to the fact that some respondents were concerned with using a combination of these types of media, the results are broken down into the use of the specific types (*Figure 4*). These were found to differ between both the USA and UK, where it was found that those in the USA use computer-based methods more than those in the UK, who tend to focus more on hardcopy formats. Here, the clear progression and use of CAD is seen in the USA survey.

It was found that 73% of UK respondents and 79% of USA respondents indexed these designs and drawings, although the methods used ranged widely. These methods were divided into categories such as: job number, part number, drawing number, chronological order and product.

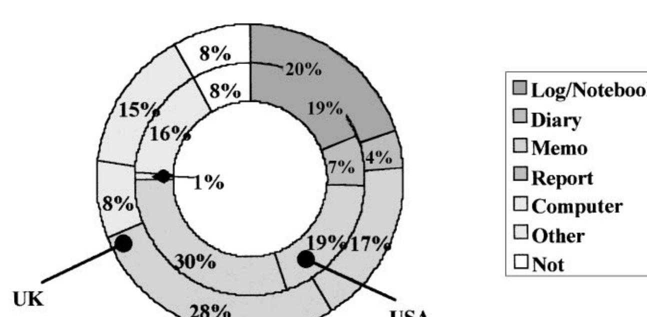


Figure 3 Methods used for recording design decisions

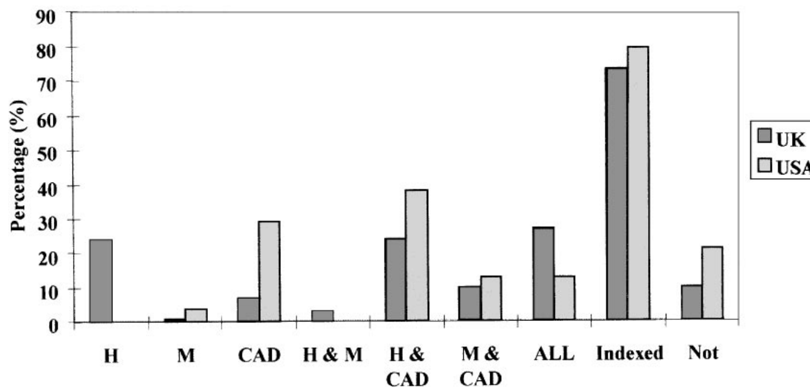


Figure 4 Use of hardcopy (H), computer (CAD) and microfilm (M) storage media

Alarmingly, it was found that 10% of UK respondents and 21% of USA respondents *did not* index their drawings. Once again this presents severe restrictions and problems for subsequent usage; in many cases, the access to these drawings and designs will not be possible.

Personal information sources. Information obtained on a personal basis was found to be a very influential factor from where engineering designers sought solutions to their design problems. The most commonly used personal sources were found to be colleagues, personal contacts, personal experience, representatives and consultancy, both within the UK and USA.

Similarly, the type of personal information system used by the respondents reflected this. Here each respondent was asked to describe the format of his or her own personal information system used during his or her design work. The most common format was the ubiquitous 'filing cabinet and shelf' system that was used by 80% in the UK and 83% of the respondents in the USA. The UK respondents had not even progressed that far and were stuck with only a 'desk and drawer' system, whilst very few of the USA respondents (8%) were still relying on a 'desk and drawer' system. This shows the current importance and reliance on traditional forms of information recording and storage; essentially those that are 'hardcopy' based, of easy local access and of a familiar nature to the respondents. At the centre of this is also the issue that engineers and designers still prefer to store their information locally in their filing cabinets and shelves. Additionally, this enables them to keep control of the information that they have spent a significant amount of time gathering and provide reduced search times for subsequent reference. Within this, there is also a cultural problem that is commonly found amongst engineers; where this method of storage is often considered to increase their 'job' security and they seek credit or recognition for new ideas or designs based on this information. It almost ensures that they maintain their own self-importance, rather than make the information widely available to other colleagues and allow them to take the credit for the work.

Interestingly, within the UK survey, 36% of respondents used a computer-based system compared to over half (58%) of respondents within the USA. Surprisingly, 5% of UK respondents stated that their personal information system was non-existent compared to none in the USA.

Figure 5 provides a breakdown of this, and once again this clearly shows how the up-take of computing technology is influencing the activities of the engineering designer.

Transfer of design information. Despite the inroads made by CAD it is interesting to see that the methods predominantly used for the transfer of design decisions within the UK were paper-based. The preferred methods of conveying the design intent to manufacturing or construction units, adopted by the respondents were found to include: 3D computer models, hand drawings, computer-aided drawings, numerical control tool paths, photographs, schematics, physical models, sketches, and reports. Those primarily reported were hand drawings, sketches and schematics, although it is encouraging to note that computer generated drawings were used by over two-thirds of the respondents (refer to *Table 1*).

However, when comparing this to the USA respondents, it is clearly seen that there has been a progression towards the use of computer-based methods for conveying design intent. *Table 1* shows that a high proportion of engineering designers within the USA made use of CAD, 3D computer models and NC Tool paths, with a corresponding reduction in the use of hand drawings. When comparing the frequency within which these decisions were transferred, it can be seen that once again a high proportion of engineering designers within the USA made an increased 'regular' use

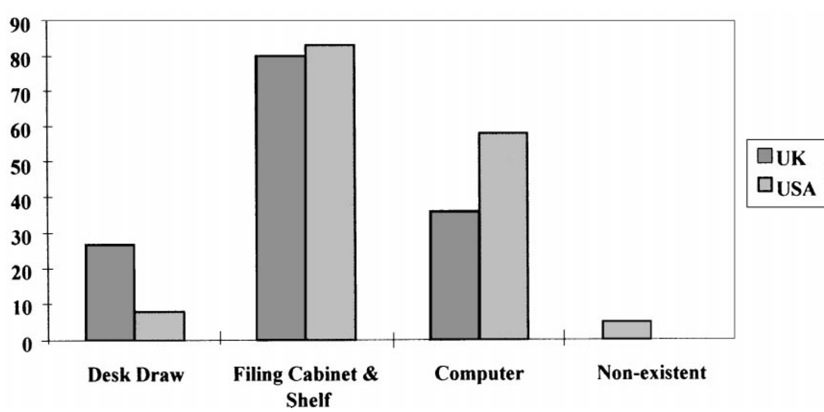


Figure 5 Type of personal information storage systems

Table 1 *Media used to convey the engineering design intent*

	UK	USA
3D Models	23	62
Hand Drawings	87	66
CAD Drawings	72	83
NC Tool Paths	8	25
Photographs	39	33
Schematics	65	66
Physical Models	33	54
Sketches	77	75
Reports	62	50

of CAD, 3D computer models, NC Tool paths, and hand drawings in comparison to those within the UK, with a corresponding reduction on the use of sketches and physical models. The resulting breakdown of the frequency of this usage is shown in *Table 2*.

The influence of computing facilities

General access to personal computers was seen to be widespread both within the UK and USA, although all of the respondents within the USA were found to have access to a computer of one form or another. It was extremely encouraging to note that 86% of UK respondents and all (100%) of the USA respondents had access to a personal computer of one form or another (*Figure 6*). However, the use of the new technologies was more extensive in the USA than the UK. Only 8% had access to CD-ROM's in the UK compared to 46% in the USA. It can be seen that within the USA more engineering designers used personal computer-oriented applications to store their design information compared to those

Table 2 *Detailed breakdown of the media used to convey the engineering design intent*[1]

	UK		USA	
	Regular	Occasional	Regular	Occasional
3D Models	46	54	67	33
Hand Drawings	15	85	75	25
CAD Drawings	65	35	95	5
NC Tool Paths	30	70	67	33
Photographs	45	55	34	66
Schematics	86	14	87	13
Physical Models	82	18	8	92
Sketches	57	43	28	72
Reports	58	42	17	83

[1] The values for both the *regular use* and *occasional use* columns represent a proportion of the overall percentage given in *Table 1*. *Regular use* represents the frequency of at least once per week and *occasional use* represents a frequency of at least once per month.

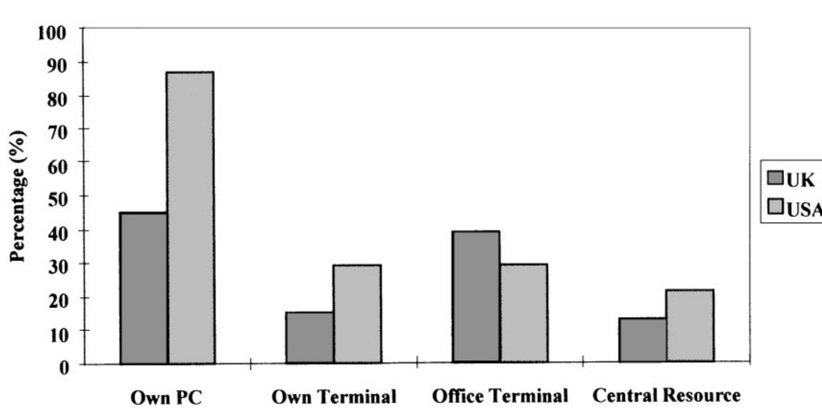


Figure 6 Access to computing facilities

of the UK. This is again reflected in the use and up-take of the newer technologies of CD-ROMs, databases, hypermedia systems and electronic mailing systems (*Figure 7*), where only 2% had access to multimedia systems compared to 17%, 19% to electronic mailing facilities compared to 71% and none access to hypermedia systems compared to 8% to hypermedia systems in the USA, respectively.

Observations

The results from both surveys show that it is still necessary for progress to be made to computerise of information access and transfer in engineering design, in order to move away from the existing predominance of 'paper-based' methods. This is evident from the findings related to the type of personal information system used by the respondents and that there was an increased use of personal computers by engineering designers within the USA. Additionally, the up-take of the 'newer' technologies such as CD-ROMs, databases, hypermedia systems and electronic mailing systems within the USA clearly show how engineering designers are beginning to access, store and transfer their information.

This is an indication of the advancements in new technology that have occurred between the instigation of the UK survey and the US survey; since the two surveys were not undertaken at the same period of time, there was approximately an 18-month gap between them. An indication of this may be seen when comparing the growth in computer purchases and the compounding reduction in unit prices during the last three years. Data from two extensive reviews of the growth in information technology (IT) use within the UK, undertaken by Martin,[63,64] identifies two important results. First, these reviews show that there has been a rapid increase in the purchase of general computing systems during the last four years. Between the two review periods, it was seen that the average budget for IT spent increased by over 9%, with the engineering sectors making the greatest improvements (refer to *Figure 8*). Second, there is clear evidence that the new emerging technologies and rapid application development tools (previously referred to in Section 3.5), are now being widely used, with 58% making use of client/server systems, 48% using rapid application software,

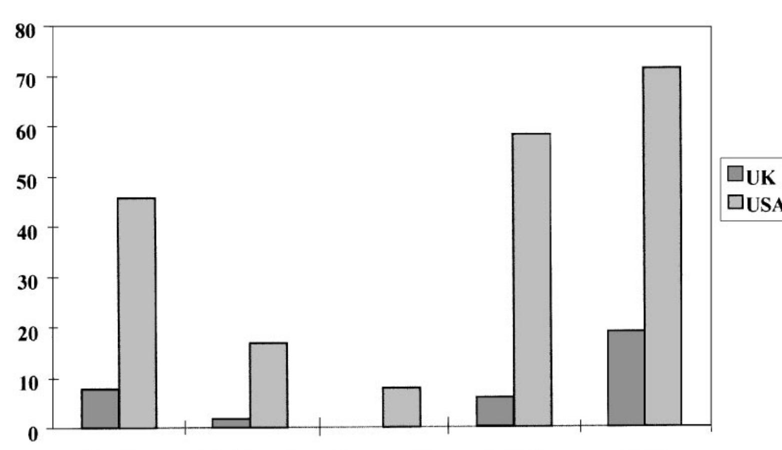


Figure 7 Use of 'new technologies'

[63] Martin, B., *Information Technology Review 1994/95*. Price Waterhouse, London, UK, 1995.
[64] Martin, B., *Information Technology Review 1995/96*. Price Waterhouse, London, UK, 1996.

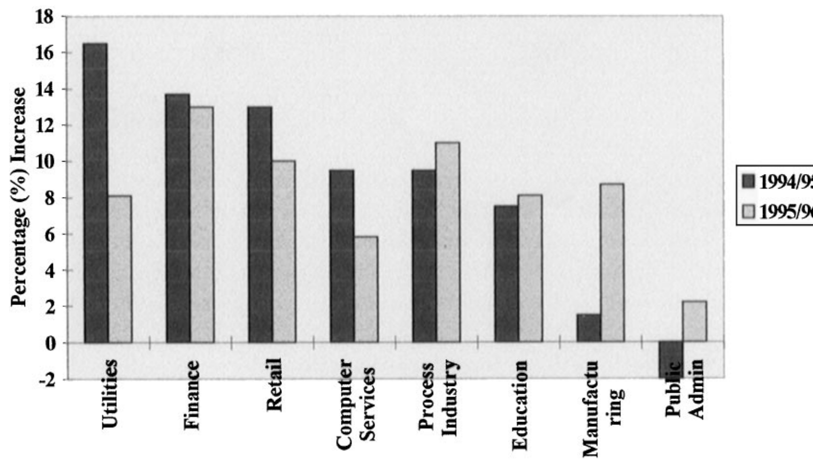


Figure 8 Increase in IT budgets by sector [adapted from Martin[64]]

28% using document imaging systems and 20% using groupware products. The ranking of the importance of each of these is shown in *Figure 9.* These findings concur with the observation for our own survey, in that there has been a significant shift in the way companies work and, moreover, the way in which their engineers and designers undertake their tasks.

Another area of significant growth providing an avenue with which engineering designers are becoming familiar is that of the World Wide Web (WWW). The increasing expansion, access, and use of WWW sites and systems, combined with the ever-improving access and transfers protocols, proposes to make this the most widely used medium of information and knowledge transfer in the next decade. It is undoubtedly already changing the way in which engineering designers work; working from remote locations, engineering designers can now work with their colleagues in virtual proximity; they can communicate using real images and text descriptions as if they sat next to each other.[65] The findings from the two surveys also serve to show that this is the way in which engineering designers are focusing, both as individuals and as enterprises as a whole. The ease with which the WWW can be accessed and subsequently browsed allows almost anyone anywhere in the world to access information anywhere in the world.[66] Nevertheless, the WWW has some limitations at the present time. Often the information and data are unstructured and difficult to locate, resulting in data transfer rates being slow and dependent on the time of day when it is accessed (i.e. it is often difficult to 'download' documents in the afternoon from the UK, as the US is also on-line). Another common problem for the WWW is the size of the resource being downloaded and physical location of the site.[67] However, solutions to these are emerging with the advent of caching techniques, intelligent search engines, data compression and secure WWW sites.[68] What methods and media engineers and designers will be using in the next millennium remains to be seen.

[65] Culley, S. J. and Chawdhry, P. K., Flying around the wide world of the web. *Design Engineering*, 1996, 24–26.
[66] Zdrahal, Z. and Domingue, J., The world wide design lab: an environment for distributed collaborative design. *Proceedings of the* 11*th International Conference on Engineering Design* (*ICED'97*), Tampere, Finland, 1997, pp. 249–254.
[67] Ordieres-Mere, J., Bello-Garcia, A. and Ortega-Fernadez, F., Impact of VRML and WWW technology in a construction project life cycle. *Proceedings of the 11th International Conference on Engineering Design* (*ICED'97*), Tampere, Finland, 1997, pp. 260–264.
[68] Drisis, L., Wide area design teams: tools for collaboration. *Proceedings of the 11th International Conference on Engineering Design* (*ICED'97*), Tampere, Finland, 1997, pp. 255–260.

Conclusions

Despite the clear difference in magnitude of the questionnaire responses of both surveys, this paper has been able to provide a comparison of some

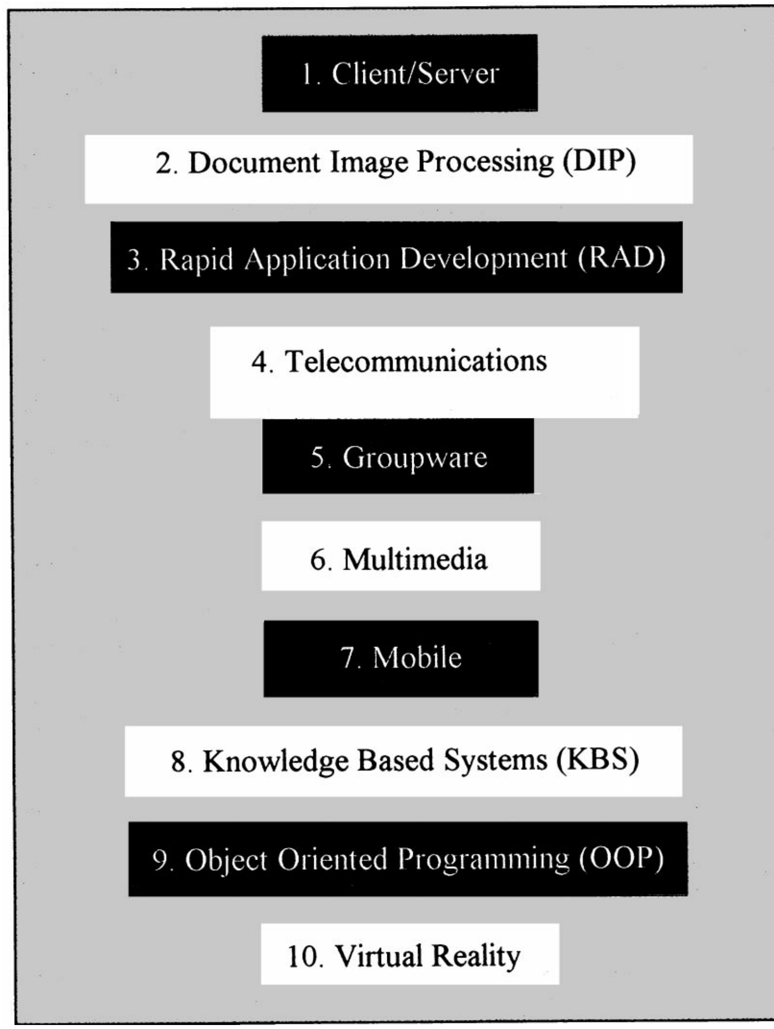


Figure 9 Beneficial technologies ranked by respondents [adapted from Martin[63]]

of the salient findings observed from two questionnaire surveys, to indicate what is happening in engineering offices in a number of industries within the UK and USA. It has presented the key findings relating to information typically found, type of respondent, industrial and design activity, the recording, storing and transfer of design decisions and the influence of computing facilities.

These findings show the current use of information access and transfer media within the engineering design function of an enterprise. It has highlighted the significant use of 'paper-based' methods, although the increasing use of new technology applications is becoming increasingly the norm. However, it is still clearly evident that the handling of design information is a vital part of engineering designers activities and that, although new procedures, methods and systems are available for information use are widespread, there is still considerable scope for improvement.

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