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INFORMATION REQUESTS AND CONSEQUENT SEARCHES IN AEROSPACE DESIGN

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1. Introduction

Making requests for information is an essential part of the design process [Court, 1996]. Every day engineering designers need to undertake searches to satisfy their information requests in order to progress their design tasks. However, the process of making requests and the consequent searches is not fully understood and is part of the ongoing research discussed in this paper [Aurisicchio, 2003]. The aim of the research is to explore: (i) the way in which engineering designers make requests; and (ii) how they interact with external knowledge and information repositories, including other designers. In order to achieve these aims, empirical research was conducted in a large industrial aerospace company by observing engineering designers undertaking variant design tasks. The nature of this variant design work usually involves incremental development of an existing component or product. Hence, making information requests takes place in the context of the current project as well as in the context of another project. After an initial ethnographical participation phase, a number of specific research areas were identified and investigated including the context, intention, type and subject of a request, along with the source, media, duration and outcome of a search. The results presented in this paper focus on the following areas: the *context* and *type* of a request, and *source* used to satisfy a request. By *context* we mean the connection or not of a request with a particular project, distinguishing between whether it is the project the designer is currently working on or another project; by *type* the nature of a request; and by *source* the repository from which design information is sought.

2. Review of relevant studies

Current understanding on making requests for information was reviewed using categorisations developed by Kuffner [Kuffner, 1991], Baya [Baya, 1996] and Eris [Eris, 2003]. Information access routes were reviewed using categorisations developed by Court [Court, 1996] and Marsh [Marsh, 1997]. These reviews provided the necessary background for the data collection phases of this research and helped to structure the data analysis.

3. Research approach

3.1 Overall research methodology

The research approach involved using ethnographical methods in an industrial aerospace company, in conjunction with a diary study and observations with shadowing. The research was divided into two main phases. During the first phase four main studies were undertaken: (i) ethnographic participation study; (ii) pilot diary study; (iii) diary study plus post-diary study interviews; (iv) pilot observations

with shadowing study. During the second phase one main study was undertaken that involved observations with shadowing.

3.2 Data collection methods

Ethnographic participation

Ethnographic participation was used as an initial stage to characterise aspects of the social and organisational behaviour of engineering designers, as well as to generate insights into the topic of making requests, understanding searches and using design information. During the ethnographical participation, the researcher worked in the company as a member of a design team with a genuine design task and team role. At a later stage, a diary study and observations with shadowing were used to obtain evidence for the insights obtained and to further characterise information requests.

Diary study

Diary studies were adopted as they provide a means of gaining information from participants in great detail over an extended period of time. A group of fourteen engineers was asked to fill out real-time design diaries for five weeks. To further investigate each request episode, together with its associated search, semi-structured interviews with audio-recording lasting between 15 and 80 minutes were conducted at the end of each week with each of the participants.

Observations with shadowing

Observations with shadowing were used as a means of collecting request episodes by direct observation. In this part of the study the researcher worked in partnership with engineering designers from the collaborating company. The designers were asked to 'speak aloud' any information request that they would form in their minds and observational data detailing the way each search was undertaken was captured by the researcher.

3.3 Data analysis

During the first phase of this research project, 392 search episodes were collected using both the diary study and the pilot observations with shadowing. Of the total 392 search episodes, 243 episodes accessed one source only, 42 two sources, 10 three sources, 4 four sources, 1 five sources, and 2 seven sources. In total 302 independent request episodes were collected and the results presented in this paper are based on this data. For the purpose of this research, a request is defined as a question or a statement expressing the need for information related to the design task at hand and for which a response is required. This paper uses the following coding schemes for the requests made and the sources used.

Three *contexts* were used to code a request episode: *current project*, *another project* and *project independent*. *Current project* was used to classify any request that was connected to the project the designer was working on. *Another project* was used to classify any request connected to any project different from the one the designer was working on. Another project can be in any of the following stages of development with respect to the current one: completed, ahead, parallel, or behind. Finally *project independent* was used to classify any request not associated with a project. Project independent requests were further subdivided into three categories*: engineering*, *tools* and *process*. The requests assigned to the category *engineering* mainly concerned materials data, manufacturing specifications and the geometry of standard parts; those to *tools* concerned tools for design, design management and design analysis; and those to *process* concerned design management processes.

It is noteworthy that on occasions requests generated in a current project context contain the intention to search for the information in another project context. However, sometimes designers intend to answer the requests from the current project but in the end use another project context. Essentially this indicates that for some requests the intention to refer to another project context spontaneously shows from the request, whereas for others it could only be inferred from the source searched through.

Based on the work developed by Eris [Eris, 2003], a distinction was made between two request *types*: reasoning requests and other requests. By *reasoning requests* we include those that Eris described as Deep Reasoning Questions (DRQs) and Generative Design Questions (GDQs). Under *other requests* we include verification, definition and factual questions.

The designers were observed to raise *reasoning requests* for a number of purposes, e.g. to understand about causal relations between design states and linked events; to understand the functioning of engine parts, design tools and specific procedures; to acquire the rationale for designs; to discuss design moves. The results also showed that *other requests*, though apparently less significant than the reasoning requests, were made with different intentions, ranging from the need to confirm design information or to compare it with that from another projects, through to understanding specific design issues. Further research to characterise these differences is currently in progress.
During data collection, it was observed that engineering designers use a wide range of *sources* to satisfy their information requests. The coding scheme used includes seven main classes for the sources: colleague, report, drawing, database, book, hardware and not undertaken. Each of these classes may represent a number of different sources. The class *colleague* includes formal and informal contacts with one person, or more than one person, in the company. The class *report* relates to any written record of a piece of work. The class *drawing* relates to any pictorial representation of a design element. The class *database* refers to any collection of information about the product, as well as material and manufacturing information. The class *book* refers to a standard account of a subject used for study. The class *hardware* is used when designers seek answers to their requests by inspecting physical products. Finally, the class *not undertaken* refers to those requests which were raised by a designer but not investigated due to impediments, e.g. time restrictions.

4. Findings

The results of the various studies showed that designers attempt to satisfy requests from a wide range of sources. Figure 1 shows a breakdown of total number of accesses for each source, by type of a request whereas Figure 2 shows a breakdown by type and context of a request.
From Figs 2A and 2B, it can be seen that, in the context of a current project, the percentage of *reasoning requests,* at 18%, is around half that of *other requests,* at 38%.
Reasoning requests were mainly posed to colleagues (15%) to resolve creative design issues and analysis issues. As for creative design issues, designers were observed approaching their colleagues to discuss design moves and ways of embodying design ideas. Regarding analysis issues, colleagues were asked to explain the rationale behind designs, the causal relations between design states and linked events, and how engine parts functioned. Drawings, databases and hardware were rarely used to answer reasoning requests (approximately 1% each). No access to a report or book was encountered. A notable number of instances of requests not undertaken was found (3%).
Other requests were predominantly answered by colleagues (27%) face to face, or through phone calls and emails. Analysing the nature of these requests helped to characterise the work of individual designers, which consisted not only of generating design solutions but also following their evolution through development, a responsibility which entails frequent communication with several parties. Other requests to colleagues were made not only to access information strictly necessary to generate design solutions, e.g. material specifications, configuration and geometrical data, but also for project management and planning, e.g. material and machining lead times.

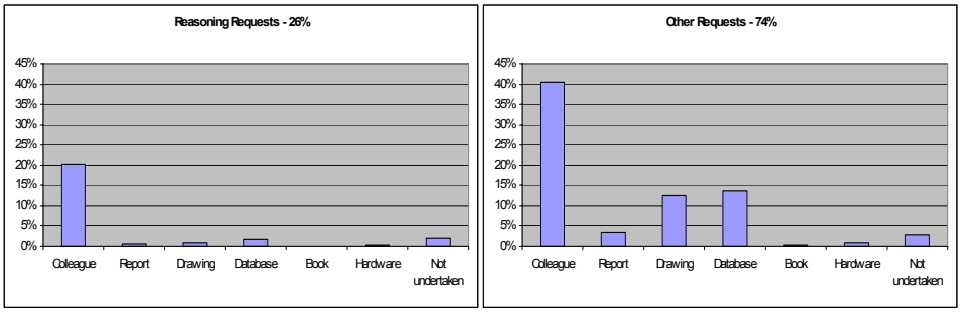

Figure 1. Breakdown of accesses for each source, by type

The work of individual designers was often found to depend on that of other designers working in the same design department and on the project. This suggests that designers make requests to colleagues

in order to keep up to date with project developments, e.g. checking the progress of other designers whose work may affect theirs, as well as a means of rapidly verifying shared data. Drawings were fairly frequently accessed to answer other requests (6%) whereas reports, databases and hardware were rarely accessed (1% each). No access to books was encountered.

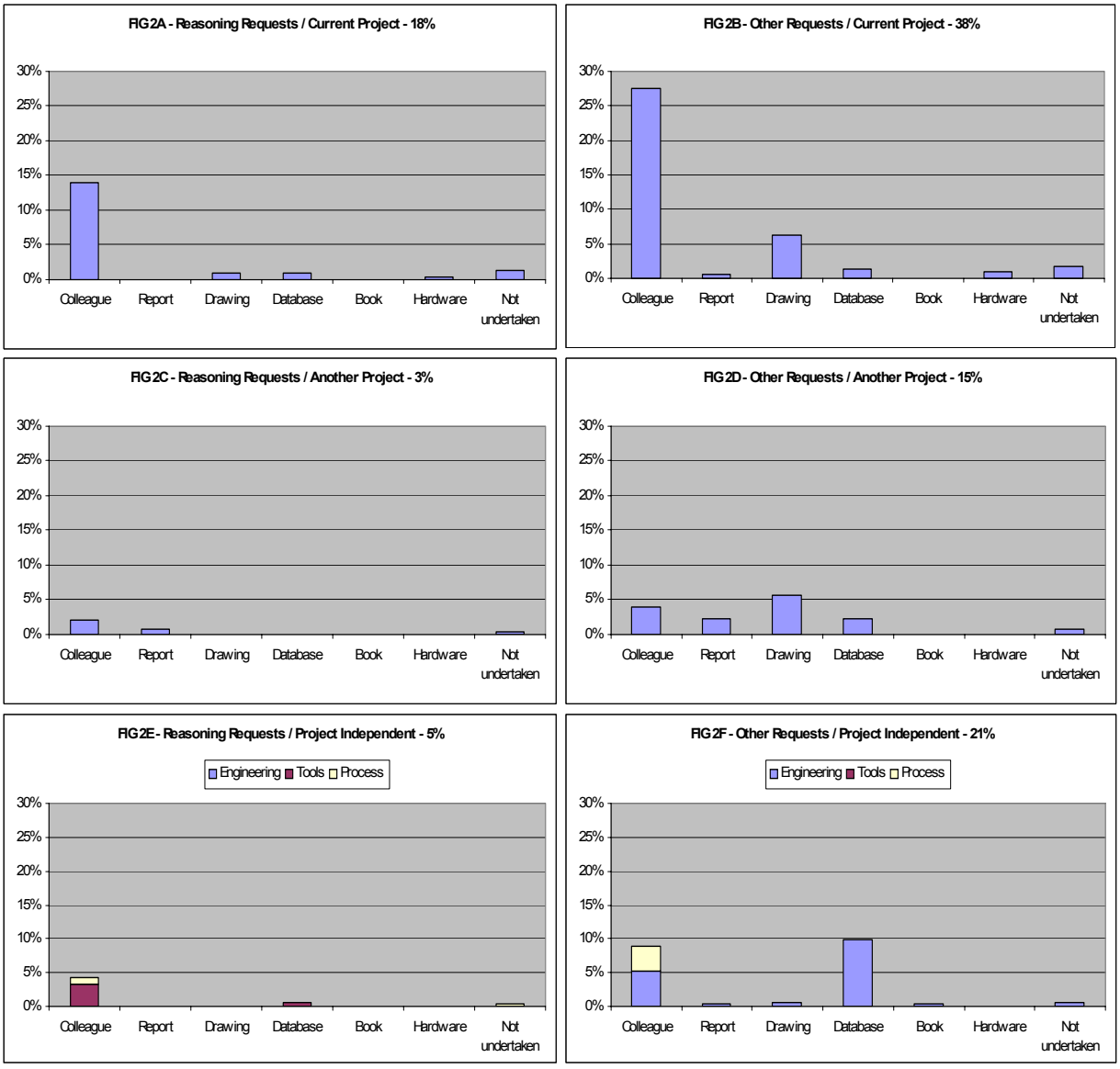

Figure 2. Breakdown of accesses for each source, by type and context

As shown in Figs 2C and 2D, in the context of another project, the percentage of *other requests,* at 15%, is five times that of *reasoning,* at 3%. The overall number of requests at 18% shows how much the design of a new engine is based on other engines.

Reasoning requests were made to revisit procedures used to design and to conduct analysis on similar assemblies, as well as to access the rationale for designs and to interpret designs. To answer reasoning requests, colleagues and reports were the only sources used, with the former preferred to the latter. A few instances of requests not undertaken were observed (1%).

Engineering designers from the collaborating company were observed to *read across* solutions as well as manufacturing methods from other engines. Other requests were made to investigate a wide range of design aspects, e.g. operating conditions, geometry, configuration, behavioural data (stress), manufacturing classifications and materials used on similar parts. The dominant source for answering other requests in another project was drawings (6%). This was followed by colleagues (4%), reports

(2%) and databases (2%). It is noteworthy that one in every five other requests was in the context of another project.
As shown in Figs 2E and 2F, in the project independent context, the percentage of *other requests,* at 21%, is around four times that of *reasoning,* at 5%. To further differentiate the requests, the subjects are subdivided into three categories: *engineering*, *tools* or *process*.
Reasoning requests were answered by colleagues (4%) and databases (1%). The subjects of these requests were only in the categories *tools* and *process.* The former includes mainly requests about how to use design tools as well as tools to run analysis of designs and to manage designs. Occasionally requests about causal aspects of tool usage were found. The latter includes a small number of requests enquiring about company procedures and their feasibility. A few instances of requests not undertaken were found (1%).
Other requests were predominantly investigated through databases (10%) and asking colleagues (9%). Rare instances of accessing drawings (1%) as well as reports and books were also encountered. Databases and drawings were only used to access *engineering* information, e.g. material data, manufacturing specifications and geometry for standard parts, whereas colleagues were also asked for *process* information, e.g. contacts, data storage permission and data format and compression to send out files.

5. Discussion

This paper has characterised the *context* and the *type* of engineering requests, as well as the *sources* accessed to satisfy these requests. Results show that the context of a request significantly influences which access route is used by engineering designers. In the context of a current project, see Figs 2A and 2B, colleagues (42%) dominated, with drawings (7%) being the only other significant route. In the context of another project, see Figs 2C and 2D, a much more even split was found between colleagues (6%), reports (3%), drawings (6%) and databases (2%). Finally, in the project independent context, see Figs 2E and 2F, colleagues (13%) and databases (11%) dominated any other access route. It was also found that the access routes used by designers were influenced by the type of a request. Reasoning requests were answered predominantly by colleagues (21%), with reports, drawings and databases being accessed very rarely (between 1-2% each). The most frequent access route for other requests was a colleague (40%), followed by drawings (13%), databases (13%) and reports (3%).
Overall, when satisfying an information request designers asked a colleague (60%), through formal or informal contacts. This figure was obtained by combining the data collected from the self-reporting data collection method (diary study) and the first hand data collection method (observation with shadowing). The results, from the observational study on its own, indicate tentatively that this figure is around 15% higher. Further observations are to be undertaken to confirm this. Different results depending on the data collection method confirm research undertaken by Marsh in the same industrial setting. According to Marsh's empirical research [Marsh, 1997] designers were found predominantly asking colleagues to answer requests (87%). Assuming that our tentative result from the observational study is confirmed, a reduction of 12% in the requests to colleagues has taken place. This could be explained by the fact that during the seven-year gap between Marsh's study and ours several changes were introduced in the collaborating company as a result of a series of knowledge management initiatives. For example, the company introduced a capability intranet that now allows designers to access a large amount of information online. The contribution of the capability intranet to information accessing can be identified in the accesses to the source databases.

6. Conclusions

The sequential use of ethnographical participation, diary study and observations with shadowing has enabled us to observe and characterise the context and type of information requests raised by engineering designers, along with the sources accessed to satisfy such requests. The results are specific to designers working on variant design tasks within a large aerospace company. The results showed that engineering requests are mainly directed at colleagues (60%). Other preferred routes for

answering requests are databases, drawings and reports. The context and type of a request significantly influence which access route is selected.

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