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WHAT DESIGNERS THINK WE NEED TO KNOW ABOUT THEIR PROCESSES: EARLY RESULTS FROM A COMPARATIVE STUDY

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1. Introduction

Design processes have been studied in detail for many years, either descriptively, telling us how design is done – or prescriptively, proposing a way in which design should be done. But almost always the goal has been making general statements about design, either for a particular industry such as mechanical engineering, or for all design. So far the aim of design research has been to identify the common features in the processes that were studied and to derive models of these design processes. Two questions have been relatively neglected:

- How general are the observations across individuals, companies, industry sectors and domains; and what are the significant differences?
- How do the participants of the processes see the process themselves?

As part of the Across Design project at Cambridge University and the Massachusetts Institute of Technology (see section 2), designers and design managers from a variety of industries have given presentations and been interviewed about their processes, focusing on detailed descriptions of single design projects. Presentations concentrated largely on the large-scale structure of the process, as well as the drivers for both process structure and the nature of the product. They said little about the detail of how designs actually get created and seldom gave us informative answers to questions about their cognitive processes. We describe an analysis of the style of presentation that designers have chosen (section 3) and then discuss the drivers that designers have selected to tell us about (section 4).

The project members and participants recognized familiar design tasks in the presentations of all the participants. A strong theme across presentations is a strong focus on satisfying the customer. Our case studies indicate that how design processes achieve this and other goals depends on whether:

- The product is designed for production to be sold to unknown customers, or is custom-made (bespoke) for a known customer who negotiates a contract;
- A custom-made product is one of a kind or made in quantity;
- The product is mainly engineered with highly technical content, or is mainly artistic with emotional content;
- The product is actually a service whose result is the design of something;
- The designer is a sole practitioner or member of a small firm, or is a highly placed manager in a large firm.

2. The Across Design project: presentations and interviews

The Across Design project is a multidisciplinary project with researchers from engineering, computing and architecture. The researchers on the project have conducted detailed observational studies of design practice, conducted experiments, and interviewed hundreds of designers in the course of their own past research. The aim of the project is to investigate similarities and differences between designing across industries, and seek ways in which best practice can be transferred. One possible theoretical perspective on how to do this is described by Stacey *et al.* (2002).

2.1 The Across Design workshops

The project includes a sequence of workshops where designers with more than 10 years' experience talk about their design processes to an audience of three to five expert designers from other fields and a small number of interested observers as well as members of the project team. By design, these workshops are intended to collect narratives and subjective views, while enabling an in-depth analysis of the experiences, opinions and presentations of one or two representatives of each field The analysis is qualitative and grounded in the experience brought to the project by the team members. We have conducted five of these workshops, involving 20 expert witnesses from a very broad range of design disciplines, as shown in table 1. All presentations are videotaped and recorded, exhibit material is photographed (or copied from presentation files), and recordings are fully transcribed.
Before the workshops, the designers were provided with a framework of design issues, as a briefing documents, see section 2.3. The designers were asked to give presentations of around 30 minutes, and spoke for between 25 and 70 minutes, taking questions from the academic and industrial participants alike. After each presentation the academic participants asked clarifying questions and encouraged a discussion amongst the participating designers. These discussions were generally free and enthusiastic. The academics asked questions related to specific areas of the framework, in cases where the speaker did not appear to have addressed that area. Several presentations were either preceded or followed by individual interviews with the designers, conducted by a smaller group of researchers.

2.2 The presenters at Across Design workshops

At each workshop we aim to have presenters from a wide variety of industries so that they can observe and comment on the similarities and differences between them. The designers were selected mostly through personal contacts of the research team or through recommendations by other workshop participants. The participants were paid only travel expenses and joined the workshops out of genuine interest in design practice in other fields. The group of participants is self-selecting for people sympathetic to academic research and interested in reflecting about design processes.

Table 1. Participant Design Disciplines in Five Workshops

Oct 2002 (UK)	Diesel engine designer, Software designer, Product designer[1], Urban Planner
April 2003 (UK)	Civil engineer, Web designer, Product designer, Drug designer
July 2003 (UK)	Graphic designer, Jet engine designer and senior manager, Film maker
Nov 2003 (UK)	Artistic fashion designer, Medical device designer, Food designer, Packaging designer, Architect
Jan 2004 (USA)	Architect, Technical fashion designer, Automotive designer and senior manager

For the purpose of later analysis the designers are grouped into the following categories
The participants can also be classified by their present roles in their companies. Most are direct participants in the processes they describe, and either work alone or with a small number of collaborators and assistants. The film maker and the graphic designer are examples. Others are senior managers responsible for large complex projects involving hundreds or thousands of direct

[1] Product designer means a person or firm providing product design services for a variety of firms and product types

participants. Such managers are very process-aware because the complexity of what they design demands process discipline in order to meet strict requirements for performance, cost, schedule, regulations, and other pressures. Thus the direct practitioners described what they did themselves and the details of the items they produced, whereas the senior managers described the process by which their items are created as well as their companies' quest for ever better design methods.

Table 2. Classification of participants

Engineering	Diesel engine designer, Jet engine designer, Medical device designer, Automotive designer
Architecture	Urban Planner, Civil engineer, Architect (2)
Product Design	Product designer (2), Packaging designer
Software	Software designer, Web designer
Science	Drug designer , Food designer,
Artistic Design	Graphic designer, Artistic fashion designer, Technical fashion designer
Film	Film maker

2.3 How the presentations were briefed

Prior to the workshops the academic team developed a framework of questions covering major issues of design in a fairly comprehensive way, based on their combined long term experience in different fields of design research. Participants were given a copy of this framework before each workshop in order to inform them of the issues that we were interested in, and provide some guidance regarding the scope of the discussion. Figure 1 shows an extract from this briefing material. The framework was partitioned into sections dedicated to *markets*, *organisation*, *requirements*, *process*, *data*, *complexity*, *representation*, and *evaluation*. Each of these sections was broken down into sub-issues. For example, *markets* was broken into *customers*, *intermediaries*, *market trends*, *diversity*, *consultation*, *inclusion*, *product ranges* and *innovation*. These summary terms were illustrated by specific questions. For example under customers, illustrative questions included "Who is your customer?", "Is this the same person as the end user of your product?", "Do you design for an individual, a market sector or a group of clients?".

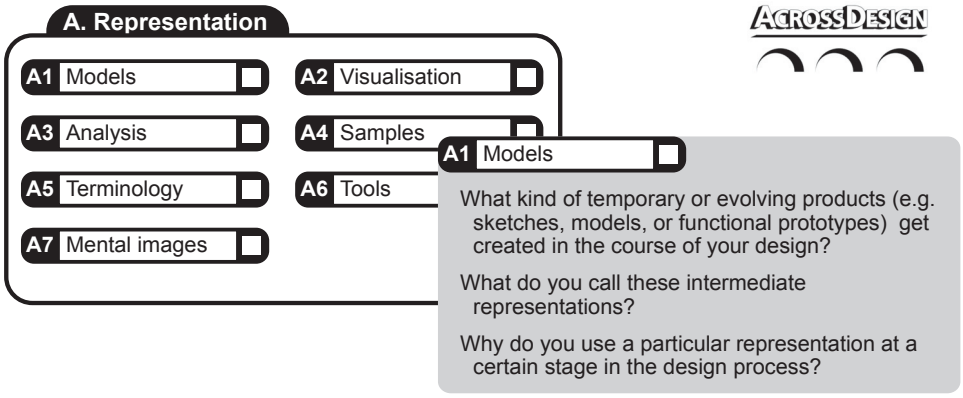

Figure 1. Extract from participant briefing material

The participants were asked "to choose a *single* design project from your experience, and present it to the group as a case study to illustrate the design issues and challenges that arise in your profession", but were also told that "*We do not expect you to address all the issues that we have listed exhaustively*". They were encouraged to concentrate on those issues most pertinent to their own field.

3. The modes and contents of the presentations

Participants were given the same brief for the presentation. Some designers contacted the researchers to discuss their presentations before hand, but most designers chose their own style of presentation. These fell into three categories:

i. PowerPoint presentations with text
ii. PowerPoint presentation of images
iii. Free speaking to illustrations handed around the table.

Some presentation were a mixture, where they had some text on PowerPoint and many images, but also passed images around and diverted from their planned presentation to respond to issues that had arisen earlier in the workshop.

Some speakers used a specific case to illustrate general points, while others completely focussed on that case. Some designers picked current cases; while others picked designs that they were personally proud of, which were a long time in the past, making it hard for others to assess the context in which they worked. Some participants prepared a presentation specifically for the workshop, following the framework as closely as they could, while others modified existing presentations and talked about the issues in the framework. Some designers choose to ignore it entirely, but in response to questions, they addressed most of the issues raised in the briefing document.

The style of presentation matched the style customary in the presenters' domains, reflecting the professional status and self-image of the participants. The engineers and the drug designer were well accustomed to presenting and to talking about their processes to critical professional audiences; they delivered polished PowerPoint presentations using words and rich imagery including video clips. Their presentations were minor adaptations from presentations they had given in the past. They had studied our framework and made on the fly references to the items listed, while telling their own story.

The engineering managers, reflecting their responsibilities as senior executives, focused on how their companies create complex products for demanding customers. They talked about the work other people do, typically thousands of other people, whereas most of the other speakers spoke about work they did personally or with a small group of collaborators. The aim of their presentations was to explain to the researchers, using abstract graphics like flow charts, all the interacting organizations, companies, and technical and non-technical factors that must be considered and balanced during design. In some of these presentations, the product itself was ancillary to the discussion.

All the architects provided us with very well thought through presentations with rich imagery. Their PowerPoint presentations included few or no words, but rich imagery. All were very articulate and explained their processes concisely in easily understandable ways. Giving presentations about proposed or on-going design projects to clients is an integral part of professional practice in architecture. Clients – like most of the researchers on Across Design – need to be educated or guided by the architects themselves. Architects comment that they use any representation they can think of to communicate ideas to their customers and did the same for us in the workshop.

The product designers also provided us with very visual presentations, but were less homogeneous as a group than the architects. One product designer, who works closely with a large number of customers, took our framework as a brief, picking up on a subset of issues, and told a story illustrating his design process with images of design at different stages in the process. This is not dissimilar to his usual discourse, where he would aim to convince customers of his technical and artistic competency by showing them images of past designs and their development while sketching out what he would do in the new project. An elderly well known product designer told us the story of one of his most renowned projects showing us images of its development. As in his professional practice, he had a clearly designed view point which he wanted to communicate, and used images to do so.

The artistic designers showed us a large number of images and described the stages that the project went through in terms of the projects' own development, rather than a conventional representation of the process in their domain. Artistic design domains usually don't have widely known process models with naming conventions for stages as engineers or architects do. They convince their customers through a series of images which must look right to the customer. In the absence of objective evaluation criteria the visual narrative plays a significant role in their process. In order to be successful, artistic designers must work out a process for themselves and develop a set of heuristics

that work for them personally. In explaining this, their presentations were less structured and refined than those of the engineers. As lay people and customers easily form opinions about artistic designed products, such as graphic designs or garments, the aim of the presentations was partly to convey the nature of professional expertise that is in their fields. Most of these speakers brought physical samples of their work to help convey their visual or tactile characteristics.
The two software designers took a very different approach. One introduced us to some of the theoretical ideas in current computer science while talking us through a project he undertook a long time ago. He spoke to PowerPoint slides and did not use visual illustrations in his talk. In contrast the web designer chose to give a presentation in the way she talks to her customers by showing us illustrations of past designs. She brought copies of printouts and sketches of past designs. The filmmaker showed us clips from one of his films and used them to illustrate the process of making it. His process was highly contingent, making detailed advance planning not very useful. He used film clips to show problems that arose and how he solved or disguised them in the final product. While the end product – the film - is an extremely visual medium, he used only verbal techniques in the process of making it.

4. Different fundamental drivers of design processes

All the presenters addressed at least on a high level all the issues covered in the top level of the framework, and provided us with considerable detail about the methods and tools they use and the processes that they follow. There were variations in the emphasis in the different presentations. Different parts of the framework of were addressed by the participants with a varying levels of detail. Some of these differences come from individual styles of presentation or sector specific modes in individual domains. We will not address these differences of interest and emphasis here but will try to isolate the fundamental drivers from the evidence presented. More thorough analysis will attempt to get a more neutral view of the evidence especially through detailed follow up interviews which will set the particular styles and modes of the presentation more accurately in their context.

4.1 Drivers

The stories of the presentations were mainly told around the key drivers of each industry. Drivers are external factors that strongly influence the observable behaviour of a design process. Drivers do not inevitably cause particular consequences, but can make them very likely. The consequences are not independent, and nor are the drivers. However thinking of drivers and their consequences helps to see the causal connections between aspects of process behaviour. Looking at the drivers of a process offers a potential explanation for problems. The direct consequences of drivers are very difficult to change, so companies must embrace them rather than fight them.
Many design processes are subject to the same generic constraints, as illustrated in Figure 2. In addition drivers arise from the generic properties of the product and the industry sector that they are created in. For example all products must be safe, but some industries produce safety critical products, such as the aerospace industry, the healthcare industry or the nuclear industry. Here safety criticality is a major driver of any design process and all processes are likely to respond in a similar way to these drivers. These drivers are likely to lead to some of the same observable behaviour in the design process. For example in a safety critical product, designs are usually done as modifications of existing products to reduce the product risk. Therefore these companies are likely to put effort in understanding the implications of any change and might handle these changes very carefully. The reliability and functionality of safety critical products are tested rigorously. Their design processes might include many tests through the entire process as well as durability tests at the end. This typically leads to rather long design processes. To complete a long process of this type on time, test processes and their integration with design and manufacture are planned carefully. Most safety critical products are subject to certification processes, and therefore behave according to this driver.

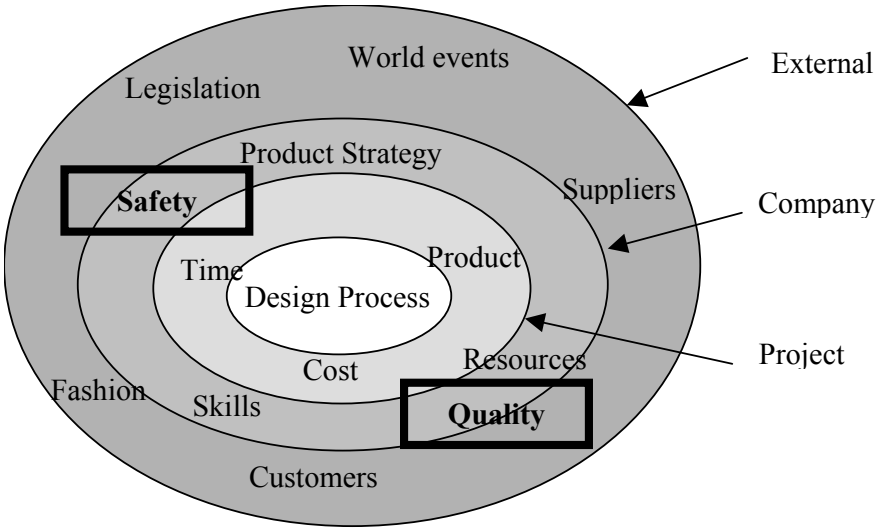

Figure 2. Constraints on the design process

4.2 Drivers in different design domains

Each presentation concentrated on specific issues that are pertinent in the domain of the designer, such as legal issues for the engineers or customer interactions for the urban planner. Table 3 gives an overview over some of the drivers pertinent in the different design domain.

Table 3. Domains and their drivers

Engineering	Legislation, Safety, Customer Satisfaction, Customisation, Enterprise complexity
Architecture	Customer satisfaction, Economic viability
Product Design	Customer satisfaction, Self-fulfilment, Stylistic timing
Software	Functional compliance to requirements
Science	Discovery of chemical compositions, Reduction of side effects
Artistic Design	Stylistic timing, Customer satisfaction, Economic viability
Film	Communication of key ideas, Customer satisfaction

In the limited space available in this paper, we will concentrate on the drivers in engineering and the role of customer satisfaction in many different domains. All four engineering presentations were told around the same drivers. Tightening legislation on emissions (engines), recyclability (cars) and safety (medical devices) in mature technology are forcing companies to think about potential step changes in the product, which could have enormous implications on the product (see Jarratt et al, 2003). All companies are struggling with increasing diversification of the market, requiring multiple versions of the same product. This is partly due to different legislation in different countries and to diversifying market needs. For example the medical device company had offered its product to multiple customers and was required to offer a product that operated in a temperature range of 80º celsius, but could also be used by users with very varying ability. While the same technology was applied for the entire temperature range the requirements of stability (for a product driven around in a car) and ease of access (for elderly patients) were mutually contradictory and required different solutions. Technology is also advancing, and many products will become obsolete if this is ignored.

Customer satisfaction is the constant driver across all domains, but the way the designer determines if the customer is satisfied depends greatly on who the customer is, whether the client is the end-user, and whether the product is bespoke or not. When the product is bespoke, and more so if the product is built to a pre-negotiated contract, the designer can get continuous feedback from the customer before the design is finished. This is true in graphic design as well as in jet engines. When the product is not bespoke but marketed to the public, as is the case of typical manufactured items like cars or ice cream,

one can get customer feedback but only on a sample basis because the thousands or millions of customers will have differing needs and tastes. Both technical and non-technical (that is, specific and tacit) factors are of interest to these customers, who may be unable to verbalize the tacit factors or be specific about them. The designers of these products can do everything right on a technical basis and still disappoint their customers. Designers who have to satisfy an end-user as well as a customer, like to the graphic designer or the web designer, are often torn between conflicting requirements and see it as part of their role of educate their customers about end-user needs.

End-user satisfaction is one of the key drivers in many different design domains, but much less so in component engineering, because component engineers don't have the direct exposure to the end customers. The engine manufacturers are both second tier suppliers, who work with established customers who in turn sell to end-users. They work in close collaboration with professional engineers in their own and client organizations, and have a close and fairly objective feedback loop. This is very similar to the fashion industry where clothes are sold through retail chains. Producing a product that satisfies the needs of their customers, as specified in explicit technical specifications, is a given of any engineering process, but not in other processes apart from software. Customer satisfaction was an indirect issue for most of the products created by the automotive designer, who discussed reducing variability in the product while maintaining customer satisfaction. However his company does have mechanisms for evaluating the needs and desires of their potential customers. Our automotive designer also told us about a particular product that was developed in a skunk works operation almost in parallel to the usual organisation, in collaboration with the local car fan club; he was acutely aware that this modus operandi was highly unusual in his industry. It was appropriate because the product in question has a large, strong, vocal, and loyal group of repeat customers, and the car is considered a trend-setter as well as an attractant for customers who buy other products from this company. Finding out what they wanted was both more important and somewhat easier than it typically is with mass market cars.

In artistic design domains, customer satisfaction goes beyond meeting technical specifications towards expressing customers' tacit needs as well as the style of the moment. Our artistic designers worked mainly directly with their clients, who usually were not the users of the product itself. For example, the graphic designer produced a brochure for an educational unit aimed at teenagers. She had two customers to satisfy. She needed to understand the goals and style of the educational unit through talking to individuals in the organisation and looking at past material, partly for information, but also to integrate her work with existing material. At the same time she needed to bring her own understanding of the fickle teenage market to bear, that she has developed through teenage daughters and teaching undergraduates. Much of her knowledge is tacit, making the issue of customer satisfaction a very personal one. For her it is extremely important to build up personal relationships with her customers. She spends a lot of effort on communicating with her customers, providing them with sketches and early representations. She preselects her design ideas, but allows the customers the final choice while trying to educate them about the technical difficulties. One architect works in almost exactly the same way and addresses almost exactly the same issues.

The two fashion designers were very different. One had been a catwalk designer, who now does art and science projects, where she tries to communicate difficult scientific concepts to the general public. The other creates cutting patterns for leather focusing on efficient manufacturing, but had personally little interest in the stylistic development of garments. However we have previously studied how knitwear and fashion designers design for markets is governed by how they understand markets and the desires of retail buyers and idealised end customers (Eckert and Stacey, 2001). In the textile industry the way customer satisfaction influences process depends on the business model of the organisation and how closely the risk in the project is related to customer expectations (Eckert and Demaid, 2001).

Most engineers will recognise their own issues in these descriptions of customer satisfaction. Our participants, in highlighting different aspects of end user satisfaction challenged priorities of engineering designers and managers. Although it may not always be the issue that shapes their

process, engineers can remind themselves of the importance of their own customer interactions by looking at the importance customer satisfaction has in other design domains.

5. Conclusions

Design processes look remarkably similar over a very wide range of products. Even with this wide range of design activities all the participants recognised aspects of their own processes in each presentation. Everybody was struck by how much they had in common with the other speakers rather than by what was different. Yet the differences are subtle and informative. This paper presents just the first steps towards analysing the similarities and differences between design domains. More workshops, interviews and in-depth case studies will follow.

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