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Supporting The Design Process Within An Organisational Context

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Abstract: This paper attempts to take what has been essentially abstract thinking about how to support the design process and relocates it within the working and organisational context of design. Through a single case analysis we analyse how organisational exigencies affect design activities and design train of thought. On the basis of this study we consider how tools that have been developed to support the design process do not take account of the collaborative, interactional, and organisational ordering of the design process and make recommendations as to the features that one family of support tools, design rational tools, should poses.

Introduction

We begin this paper with three simple observations about design work. First, design work often involves collaboration. The design of software and computer systems usually involves a design team and this inevitably means that the work of design is, in part, organised in the interactions and negotiations between team members. Second, designers use tools in and as part of their design work. For example, they use development methodologies for structuring and organising their design work; they have originated conceptual tools for ordering their reasoning activities such as, to mention one that will figure in this examination, "design rationale"; and they use technologies such as CASE.

Third, there is often a conflict between the fact that design is done collaboratively and the nature of the tools that are used to support design. The tools do not systematically take account of the collaborative organisation of their work. For example, development methodologies are cohort independent and thus do not take account of the numbers involved in a project. Consequently, whilst they provide for a modularised development process they say nothing about how different individuals or groups within a team can co-operate when the modules are being developed concurrently. Yet, as any engineering team or any observer of such teams will readily testify, communication, collaboration and co-operation between different engineers within the team is essential for the successful ordering of the development process.

Further, CASE technology tends to individuate the development process at a critical point in its cycle: the specification of requirements. As Fisher has suggested with respect to the use of CASE: "The goal is to provide freedom for the lone designer, or the most skilled team member, allowing this person to concentrate fully on developing the requirements and design specifications" (Fisher, 1991: 33).

Concepts that have been used to support design reasoning have also often emphasised the individual designer rather than the design team. One concept that we have become particular familiar with as a result of our work at EuroPARC is that of "design rationale" and design rationale tools. In the main design rational has been articulated with respect to the deliberations and decisions of individual designers. Even where the focus is on team design, less attention is paid to the role of the group *as a group*.

We believe that the contradictions mentioned have their origins in the way in which the various forms through which the design process is supported have been developed by thinking about the design process *in the abstract* as opposed to thinking about the design process as a real worldly phenomenon. Thinking about the design processes in the abstract has tended to separate design issues from the features of working and organisational context within which the design activities are placed, and this in turn has invariably tended to strip the design process of the features through which it is constituted as an organisational phenomena. We believe, from our observations of design teams at work, that an essential feature of that work is the way in which the organisational context is played out in the interactions and collaborations of design teams.[1]

We maintain that our arguments here have a relevance to thinking about CSCW related topics in a number of ways. First, they attempt to make a direct

[1]Our interest in the organisational context of design is also shared by Jirotka, Gilbert and Luff (1992) who examine the social basis of organisations and its relationship to CSCW. Also of relevance is Bucciarelli (1988) who furnishes a good ethnographic description of engineering design and March (1991) who examines decision making in organisations.

allowance for reiteration of phases of the project. However, there were aspects of the scheduling which looked unrealistic. The company has a complex design and development methodology - its Product Development Process (PDP)- and this has a complex pattern of phases and reviews. It looked, from the outset, as if there would be problems in complying with the review process. The PDP procedures very much prescribe that one stage of work be unequivocally and successfully completed before the next phase is undertaken, and it is therefore formally the case that the working out of the design and the preparation for production should be completed before money was made available to initiate production processes. The tight schedule of this project, however, set it in conflict with the formal procedures, since the 'lead times' necessary for the manufacturing processes were so long that their successful initiation would antedate the earliest possible time at which the formal review of the initial design's adequacy could be initiated.

The project had, however, even in its inception, been organised through bypassing the formal development processes. It had been put together through informal agreements with the marketing department. These procedures were to be satisfied, but after the fact. The failure to follow these through, however, meant that at crucial moments within the project there was uncertainty as to what requirements the design needed to satisfy, and there were, in addition, those common consequences of informal agreements within organisational settings: one of the individuals who was an important party to them had moved on.

2 Staffing

This site had recently been through a restructuring, and many staff had been laid off or relocated within the company. The need to reduce staff had taken priority and those who had gone had been those who could and would go, and there had been no way in which the target reductions could be obtained whilst maintaining a balance in the structure of staff available. This meant that the staffing of project teams could be problematic, and this certainly was the case with Centaur which was 'top heavy' with senior and very experienced staff . The skill mix available on the team was not fully congruent with the project's work requirements, and some more junior members of the team were only partially skilled in the work they would be called upon to do. Finally, this site's deficiencies in staffing could be compensated for by deployment of staff from other sites. However, the requirements of different sites are not necessarily either integrated or synchronised, and the capacity of one site to come across with just what the other one needs as and when it needs it is not assured. A site in Holland was required to provide expertise in electronics, but the individual who brought this was not available at the moment at which work began and so a 'stand in' from the local site had to contribute to the early work .

link between design rationale which has been an influential concept in thinking about the design process and the essentially collaborative and organisational context of real worldly design. Second, they attempt to give a concrete substance to the relationship between the design process and organisational context. That is, we are not merely interested in making a programmatic point about context but with actually investigating of what that context can consist of as an empirical matter. Third, we are concerned with explicating actual work practices of design. Fourth we make specific recommendations concerning the features of design rational tools that can support the work of design as that is ordered within an organisational context.

The Project....

The project 'Centaur' (which is producing an 'add on' high capacity feeder for one of the photocopiers the company under investigation produced) was a comparatively small 'fast track' operation. The company was concerned to reduce its inventory, and one of their recent models had not been selling well. The possibility arose that a significant number of machines - a few thousand - could be moved through sale to US educational libraries, where it was considered a good machine for book copying but only if its paper holding capacity was increased.

In use, the machines would be contained within an outer casing in order for them to operate on a payment basis, and the small paper holding capacity meant that such use would make excessive demands on key holders for replenishment. If the machine could be provided with a much increased paper holding capacity, and if it could be marketed at the right point in the purchasing cycles of the libraries, then this could meet a significant demand. If the project was to be undertaken then it would have to be carried through unusually quickly: from the 'concept' phase of the project - in which the design idea was initially worked out - to its launch on the market was to take a little over a year and the target launch date would be a rigid one.

....And Its Problems:

1 Time

Though a schedule could be prepared for the project which showed that it could meet the deadline, there was always uncertainty amongst the project members as to how realistic this could be. It had been designed on the assumption that everything on the project would 'go right the first time' and there was no

3 Costs

The company's projects are targeted against an estimated cost, the 'unit manufacturing cost' (or UMC). Centaur faced the fact that, as conceived, its target manufacturing cost was utterly unrealistic, some hundreds of dollars out of line with the actual cost. The product was aimed at a market which, in production terms, was small, with some 4000 items being projected. Such a production run was nowhere near long enough to defray the costs of tooling it.

Practical Management Of The Design Space.

As the design team saw it, they were faced with two sets of problems. One was to design a specific device, the feeder. The other was to find ways of reducing production costs to a level which would be acceptable and to initiate manufacturing work early enough to meet their launch dates. The first appeared to be relatively straightforward - since this was only the production of an add on to a machine that had already been marketed - though this would, of course, have its own wrinkles. The second looked to be a killer. Given this was the case, the problems readily priorities themselves, with almost all the innovative energy being directed to finding ways of managing the cost and time constraints.

For the purposes of this discussion, we will concentrate on just three of the innovative strategies which members of the Centaur project used to tackle these problems:

1 Improvising on the formal procedures

Within the design organisation which we studied, standard procedures and protocols are used for every stage in the Product Delivery Process (PDP). As we have seen, if Centaur were to have followed these procedures to the letter, it would be impossible for them to have delivered on their targets in time. The team's response was not to disregard the formal steps and processes. Rather, they sought to fulfil them whilst at the same time reducing the constraints they imposed on the team's room for manoeuvre. Here are some of the ways this was done.

a) Informalising the review

One of the major problems was that of bringing the project to a point at which a formal review was possible. This meant both achieving the conditions required for review and organising the allocation of time to be taken from other project work in order to prepare for such a review. One way of dealing with this might be to arrange a relatively early and informal review. In particular, this offered the possibility of a timely commitment to manufacturing spending. By being able to

hold an informal review, the team were able to get "in principle" permission to proceed before they were actually ready to ask for definitive permission.

b) Opportunistically exploiting the black economy

The problem of unit cost was constantly with them. Though it seemed they could not make more than marginal differences to the discrepancy between the target and projected cost, matters of detailed costings were nonetheless carefully attended to. Much satisfaction was derived from anything that was judged 'low cost'. Complaints were registered about and close scrutiny given to anything that made a 'hit' against costs.

A chance conversation between managers at the local site revealed that, as one of the by-products of restructuring mentioned earlier, the Procurements Department was short of work, and was casting about for things to do. Through its knowledge of and relations with suppliers, a 'shadow' operation was set up by which the Procurements Department compiled an alternative costing and scheduling of parts production to that being provided by the official manufacturing operation. The aim was to see if lead times (and costs) could be significantly cut by "contracting out".

c) Massaging the UMC

The UMC was affected by two principal things, the cost of developing tooling for the manufacture of non-standard parts and the size of the production run. Since these were the only two things which could be varied, ways of varying them had to be considered.

The extension of the production run was one possibility. Lifting the run from 4000 to 10000 units, would have brought the UMC considerably closer to target. It would still be high, but by a 'reasonable' sum.

The cost of tooling was usually looked at in two parts: the development of 'soft tooling', that is, tools made out of inferior materials for producing the parts required for the prototype; and the development of 'hard tools' for use in the production run. Since this project had only 'one shot' at the prototype and since the production run was short, the possibility of using soft tools in production was considered.

d) Adopting a deflationary approach to problems

The organisation uses a 'management by problem solving' approach to the conduct of projects. Part of this means that problems are classified by "seriousness". There are three levels: ordinary, major and critical. The 'ordinary' are effectively minor problems: they have not been solved, but only routine measures are required for their resolution. Major problems are ones whose solution will have consequences for the cost, quality or delivery of the product. Critical ones are felt to be difficult to solve and may even be insoluble, and to

which attention must be given. The existence of critical problems calls the continuation of the project into question.

Given the position in which it found itself, Centaur adopted a 'go ahead anyway' approach even to critical problems. They were known to exist and strategies for dealing with them were underway. But they were not as yet resolved. In the meanwhile, it was necessary to get on with the project's other tasks. In addition, Centaur's schedule was, as we have mentioned, constructed on a 'right first time' basis. When things, as they inevitably did, failed to go right first time, it was impossible to halt work on dependent problems because, then, the schedule would slip irrevocably. The net result was that the formal requirements of problem solving were circumvented from the start.

2 Working with and around the normal work practices

The culture of design in this organisation is, as with any work group, composed of the patterns of normative activity and the value systems espoused by those who identify with it. These are what any designer in the organisation knows about how things are to be done. In the course of actual designing, the making of decisions and the solving of problems, this knowledge is deployed not as procedural rules or even as rules of thumb, but as ways of making design sense of the issues on hand, and therefore deciding just what to do. Knowing, then, how long some activity should take to complete or what quality of output from some process one should expect is determined in *media res*. As the design goes along, and as the design tasks are encountered, the configuration of this knowledge changes. In turn, this dynamism resonates back onto the ordering of design decisions, the possibilities explored, and the route to be taken. On the Centaur project, this reciprocal fitting of work practice and workplace knowledge to the design tasks in hand could be seen in a number of ways. We will detail just a few.

a) Cutting corners and watching for potholes became a way of design life

Schedules are usually compiled more in hope than expectation. The interlocking of steps in sequences means that exceeding the estimated time always has knock-on effects which have to be either anticipated or actively managed. One case that occurred on Centaur involved working out the detailed features of the design and the production of the technical drawings. The concern was to get decisions to the point at which technical drawing could begin whilst at the same time attempting both to truncate the process of producing usable drawings and to prevent any slippage at that point. To do this, a policy was adopted of using less-than-finished drawings wherever possible. Where it was thought that the supplier of a part was well enough known to be relied upon to understand and implement a rough drawing, it was agreed these could be issued at an early stage.

b) Problems were traded off against one another

We mentioned that the composition of the Centaur team was affected by the contraction of the site's work-force. The team was made up of individuals all of whom were senior and long serving, and who regarded themselves as equally experienced in project leading as their Project Manager. These individuals treated their mutual relations as delicate. There was a ready possibility for misreading motives, and especially for disagreement to be construed as personal criticism. Any attempt to force disagreements to conclusions in design meetings might well have been taken as attempts to 'show up' the Project Manager in front of colleagues. This does not mean disagreements did not occur, but they were muted. If dissent on some point revealed that the Project Manager had a strong preference, then this was deferred to. This display of restraint as a way of handling this issue had one crucial consequence for the development of the project.

'Timing diagrams' are a particularly important tool for the design of photocopiers. They involve working out the precise timings for the movement of paper sheets through the machine. One important aim in photocopier design is to achieve maximum possible speed in the copying of sheets and, thus, to keep the sheets moving through the 'paper path' as close together as possible, but without leading to overlaps or conflicts and hence mis-feeds or a paper jams. The production of the timing diagram for Centaur was, then, a matter of some importance. However, there was disagreement on just how urgent it was. The Project Manager appreciated the task was important, but did not feel it was quite as critical or urgent as did some of his colleagues.

From the Project Manager's point of view, although working out the timings would be a difficult task, the team had no-one who was experienced or appropriately skilled in it. On the other hand, the feeder was to be compatible with a machine which had already been built, and for which there would or ought to be extant timing diagrams. He also knew there was someone on the site who was experienced in the work. Furthermore, she had done the very timing diagrams for the relevant copier. The Project Manager set about tracking down these diagrams and tried to 'borrow' the relevant skilled person from the project to which she was currently attached. In his view, the diagrams were in hand. He had other more pressing issues to resolve.

Other members of the team did not agree. They regarded the timing diagrams as critically important, and thought that they should be produced as soon as possible. When it became clear that the Project Manager did not share their view, they acceded to his argument, without accepting it for one moment. They foresaw problems resulting from delay in getting the timing diagrams out. However, their choice was between two kinds of trouble on the project; that which would result from late availability of the diagrams, and that which would result from creating personal animosities.

c) Necessity was the mother of re-deployment

Relative to the project's life, the search for the copier's timing diagrams and the negotiations with the other project for assistance in working them out was protracted. The necessary diagrams were eventually found and then only by happy coincidence. The negotiations to borrow the skilled person were not successful, and so the work had to be done — now belatedly — by someone within the team. Even here, the one who had the most relevant skills was not the one who did the work. He already had his hands full with other, equally critical tasks, such as designing the printed wiring boards (PWB). These tasks were not further deferrable, so working out of the timings had to be assigned to someone who had just enough skill to do them effectively, albeit with difficulty, and who had other tasks which could be deferred.

3 Revising the design requirements from within the design

Clearly, one of the ways to find an achievable route through Centaur's design space, would be to relax some of the constraints encapsulated in the design requirements. A several points a number of attempts to relax these constraints were made.

a) Amending the customer requirements

A key feature of the project was that the attachment of the Centaur feeder should not require any communications with the central processor of the host machine. This meant that the design was constrained to use the communications facilities already designed into the host. This gave rise to one of the tricky design problems, namely the use of the host's sensors to communicate the various states of the paper trays. It became apparent that all possible combinations could not be accommodated, and so one of the immediate responses was to see if the range of possibilities could be constricted in some way.

The issue could only be resolved at the level of marketing strategy. The design had been developed on the assumption that the machine was to be produced in the routine way to meet the requirements of various markets of an international company. It would have to operate in different climatic conditions, with different sizes and qualities of paper, with instructions in different languages, and so on. The difficulties in accommodating all these possibilities without independently communicating with the central processor led the team to ask if this was realistic. The project was, as everyone was well aware, designed to solve a specific problem by exploiting a specific market niche, one most prominently based in the USA. How many actual markets, therefore, was the machine to be designed for? How much variability in paper sizes and climatic conditions should be involved? What was the actual pattern of paper use within the main projected market? Answers to these questions might allow a drastic reduction in the range of

alternatives to be designed for. And that might enable them to design the communications systems according to specification.

This example illustrates the ways in which the various strategies the team engaged in, interacted with each other and how problems can move in and out of the foreground of the design team's attention. We pointed out earlier that the project had been initiated relatively 'informally'. This informality now began to have consequences, in that there was no formal mechanism to clarify the actual requirements for the design. There were informal contacts with relevant parties in the local marketing function, but these were rendered problematic by changes in personnel. In the event, an agreement was made with someone in the main marketing organisation to collate information on the actual pattern of paper types, sizes etc. in the target market. The need to obtain clarification of the marketing policy and to establish whether the feeder could be launched in one or two countries only was also recognised. Launching the machine for specific markets offered the possibility not only of restricting the combinations to be designed for — and thus simplifying the task — but also of being able to dispense with the need to design packaging and arrange translations for all the different markets. This promised cost savings. However, though this information was badly needed, it could not be speedily obtained. There appeared to be no easy way to clarify market potential. Personnel in the international marketing arm were changing positions, and the steps involved in moving informal support for Centaur to formal decisions about its launch policy had not been taken.

b) Assuming the best solution will be available

Obviously decisions are interdependent. Designers seek to line them up so that one decision can determine the character of others. On Centaur one issue was how much power it was going to need. This would depend upon the size of motor required which, in its turn, would fix the amount of space available for the installation of the PWBs. Engineering lore lays down that the final size of a motor is always greater than that envisaged or wanted. Hence, the size of the motor could not be determined prior to decisions about the power supply or about the architecture of the boards. The investigation of the available motors, the decision about the power supply and the design of the PWBs all had to proceed simultaneously, with decisions about each involving a certain amount of risk. Allowing for the worst possible outcome with respect to the size of the motor was not possible because there was a constraint on the space into which the motor and PWBs had to go. The risk was in judging what one would get away with in terms of motor size and then hoping that this estimation would be fulfilled.

It is this kind of problem which puts designers in 'no choice' situations. There are things they would like to know, and decisions they would like to have settled, but the speed of the formal 'decision loops' and the time scale of design tasks mean that important considerations cannot be resolved. The designers have no