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DECISION MAKING IN DESIGN TEAMS: ANALYSIS OF USED AND REJECTED DECISIONS

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1. Introduction

The role of the designer has changed over the last years; nowadays, the majority of designers work as part of a team in their industrial practice. Following this change in work practice, the emphasis in design research has shifted from individual design thinking to design processes on the group level. During product development designers have to make countless decisions. Design decisions constitute critical situations in the product development process (Badke-Schaub and Frankenberger, 1999) in the sense that they have a tremendous impact on the quality of the design solution, costs and consequently on the company's success on the market. Mistakes, drawbacks or limitations resulting from design decisions have far reaching consequences. Thus, decision-making as part of the design process is one of the most important issues that directly influence the success of the product.
This study aims to investigate a collaborative decision-making process by exploring two research questions:

1. Which kind of decisions can be identified in the design teamwork?
2. What are the consequences of previously rejected and used decisions on the design solution space?

2. Design Team Studies

The number of studies aimed at understanding how designers design in teams has been increasing, however current research on teamwork in design does not provide a satisfactory result for a structured taxonomy. In one of the first studies on design teams Tang and Leifer (1988) empirically investigated small group design sessions to understand collaborative workspace activity. The first systematic studies about design teams were presented in a session at the ICED93 conference. In 1994, the seminal Delft Protocols Workshop (Cross et. al., 1996) brought a number of researchers with an interest in design research together to apply different forms of protocol analysis on a common dataset. Valkenburg (2000, p.42) later classified the resulting studies of the workshop according to three dimensions: 'Information processing aspects', 'comparing of group protocols with the individual protocols' and 'team design aspects that do not appear in individual designing'. The last category includes group aspects such as communication (Stemple and Badke-Schaub, 2002, Carrisoza and Seppard, 2000, Chiu M, 2002), collaboration (Kalay 2001), and interaction (Brereton at. al.1996). Decision making issues have been mainly investigated on the level of the individual designer rather than in design teams (but see also Badke-Schaub & Frankenberger, 1999).

3. Decision Making in Design

The focus of this paper is on the decisions as part of the design process. To understand how decisions are made, they should be traced from their emergence to the final decision moment by means of cognitive activities. Obviously, the decision is only one step in the problem solving process (Badke-Schaub & Gehrlicher, 2003) but decision-making is a recursive process and usually in designing the decision is not the final step.

According to Simon (1992) decision making can not be separated from the problem solving activity since a decision is a cognitive step in the context of design process. Simon (1992) states that; “It is work of choosing issues that require attention, setting goals, finding or designing suitable courses of action and evaluating and choosing alternative actions. The first three of these activities are usually called problem solving; the last evaluating and choosing, is usually called decision making.” (p. 32)

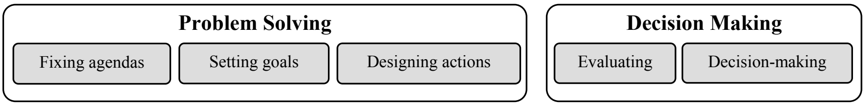

Figure 1. Problem solving and decision making as Stages of Choosing according to Simon (1992)

The design process obviously constitutes countless minor and major decisions and repetitive problem solving activities. Not all types of decisions are of equal value in solving a design problem. Design decisions differ in their influence on the final product. Akın and Lin (1995) “consider design decisions to be any and all intentional declarations of information as valid for the design problem at hand” and categorize design decisions as routine and non-routine decisions that turn out to be critical for the progress of the entire design. Also Badke-Schaub and Frankenberger (1999) distinguish between routine situations and critical situations. “Critical situations are defined as ‘turning-points’ with an important influence on the further direction of the design process and the product.”

4. Methodology

In order to observe and record design decisions, it was decided to set up a group design task in a laboratory environment. The group interaction was recorded, transcribed and then coded. This kind of controlled setting enables the researcher to reduce the impact of context variables that cannot be controlled in a natural setting and allows for replication with the same task in future research. Using a group rather than an individual meant that verbal articulations could be obtained more easily than through think-aloud protocols from an individual. The sample consisted of three industrial design undergraduate students.

4.1 Research Procedure

Before the experiment each participant was given an elaborated questionnaire on their attitudes to team working. After a briefing about the experimental set-up of the study, participants were handed the assignment individually. The assignment was to design a product for the 3rd Leitz Innovation & Design Award Competition. The purpose of the competition was “to develop and submit ideas for new office products for today and tomorrow's working environments. New products can be designed, or existing products and designs as well as their function and use can be optimised - especially integrating new technology and materials”.

The experiment was limited to two hours. Due to this constraint, the assignment was reformulated as **desktop equipment** instead of office equipment although all the specification and criteria of the competition assignment were in use. The final experiment task was “a product for organizing documents to be used on desks in offices”.

4.2 Method of analysis

In this study, protocol analysis was used as method for analyzing the structure of design decisions. Among other methods of data analysis, protocol analysis is accepted as the most efficient approach to gain insight into human cognitive processes and it has been widely used for investigating the decision processes of individuals as well as teams (Cross et al., 1996, Dorst, 1997; Valkenburg, 2000; Stemple and Badke-Schaub, 2002).

In teamwork every verbal utterance is a separate communication message. Thus every message is part of the decision–making process towards the desired goal of the design task. In this study each verbal utterance of the each team member (one or more consequtive sentences, a word or even an exclamation) was treated as a unit of expression. Furthermore, in team processes designers continually use variable explanations in different contexts, even in one expression. That means the same expression may consist of two or more meaningful segments. Every meaningful piece of expression indicates a cognitive action. Protocol analysis requires a segmentation of the transcription into meaningful pieces.
For the 100 minutes teamwork protocol, a total of 753 expressions were identified as segments. We analysed the process in terms of frequency of categories and duration of the corresponding expressions. For this purpose, we developed three subsystems: the *actions coding system,* the *decision components coding system,* and the *design context coding system* . The interrater-reliability of the coding system was tested with a 15 minute part of the transcript, which was coded by another designer trained as urban planner. The percentage of overlapping codes was 86%.

4.2.1 Actions Coding System

The actions coding system comprises acts that include talking, writing, and drawing, listening, and thinking. This coding system was used to analyze the activities of the designers in the team throughout the design process. Although this coding system was not utilized directly for analysing decision components, it is essential for considering their activities.

4.2.2 Design Context Coding System

The design context coding system was developed to trace the decisions and their components by considering their contexts. The context in which a decision occurs determines the importance of that decision in a design solution. Priorities may change in terms of company goals, product specifications, constrains, project management aspects etc. It consists of four different topics: *Project Management, Stakeholders, Product Environment*, and *Product.* As the purpose of this paper is the analysis of design decisions, the categories have been limited to reflect the generic frame of the design task.

4.2.3 Decision Components Coding System

We define the design process as a problem solving activity that consists of different steps of information processing to arrive at satisfying solutions by generating and choosing among alternatives to reduce the discrepancy between the existing state and a desired state. Phases are seen as cognitive components of the design process. The decision components coding system has been developed to cover problem solving steps initiated by Simon (1992).

For the structural components of decisions, 15 categories were developed (see table 1). The decision components were further defined in terms of the interaction between members of the team. Bales' Interaction Process Analysis (IPA) System (Bales, 1950) developed for observing interaction in small groups was used as a theoretical basis basis in order to integrate social evaluation. Many decision process models include the evaluation stage as a step preceeding a choice or decision. This is different in teamwork where evaluation is a continuous activity within other cognitive components since it happens in every stage as an interaction among team members.

5. Results

The team designed a desk ware paper storage product that enables users to punch papers and store them in different layers of the product before putting them in folders at the end of the working day. Folding systems between layers give opportunity for keeping levels closed in unused situations. Depending on the amount of papers to be stored layers can be folded out as required. The product could be seen as innovative in terms of its folding system that enables to optional use and its punching function.

The mean duration of segments was 7.7 seconds. The shortest segment lasted only one second while the longest segment was 40 seconds. In the following the results of the three coding systems will be explained.

Table 1. Development of decision components

Problem Solving Phases (Simon, 1977)	**Problem Solving Phases**	**Decision Making Phases**	**Team Decision-Making Process**
Intelligence	Defining /Analyzing	Goal	Goal
			Problem Definition
Design	Generating	Knowledge	Knowledge Elicitation
			Knowledge Sharing
		Alternative	Alternative Elicitation
			Alternative Suggestion
			Alternative Evaluation
	Synthesizing	Criterion	Criterion Elicitation
			Criterion Suggestion
		Idea Development	Criterion Evaluation
			Design Development
			Integration
		Solution	Solution Suggestion
			Solution Evaluation
Choose	Deciding	Decision	Decision

5.1 Action Coding System: Verbal and non-verbal activities

In terms of verbal and non-verbal activities such as writing, and drawing, the team spent 85% of the time (4981 of the total 5840 seconds) talking and the remaining 15 % (859 seconds) on non-verbal activities, i.e. thinking and drawing. Considering the duration and frequencies of expressions in the whole process, it can be stated that the team were very much engaged in fulfilling the given task.

5.2 Design Context Coding System

The design team allocated the largest proportion of its time (22%) to solving technical details and problems related to their core concept of punching paper and to discussing details of the mechanism. This means that the team spent a considerable amount of their time on technical issues although this criterion was not emphasized in the design assignment. This could be seen as the designers got stucked into a topic and as a consequence neglected other topics of the design problem context and/or lost the overall view.

The Form/dimensions topic ranked second in duration (15.4 %). Only 9.5% of the time was spent on dealing with functions and only 9.8% on the context of use. The material of the product was only addressed with 0.4% of the time. Other important issues, such as manufacturing method, cost, and safety were not discussed at all.

5.3 Decisions Components

The coding results (see Figure 5) reveal that during the whole design process the team made decisions covering 21 different topics that can be classified within 6 contexts. The topics are named according to the concepts the team members dealt with. 71 decisions have been made within 18 of the 21 decision topics. Every decision took 207 seconds on average. The decision topic with the longest duration was '*punching*', which took 1036 seconds equivalent to 17,6% of the total process with 18 decisions. The 'punching topic' was the dominant issue that the entire design concept was based on. The first p*unching* discussion started after eights seconds from start and went on till to the 5th minute before the end. The topic ‘*number of layers’* was the shortest topic: the team decided the number of layers in 25 seconds.

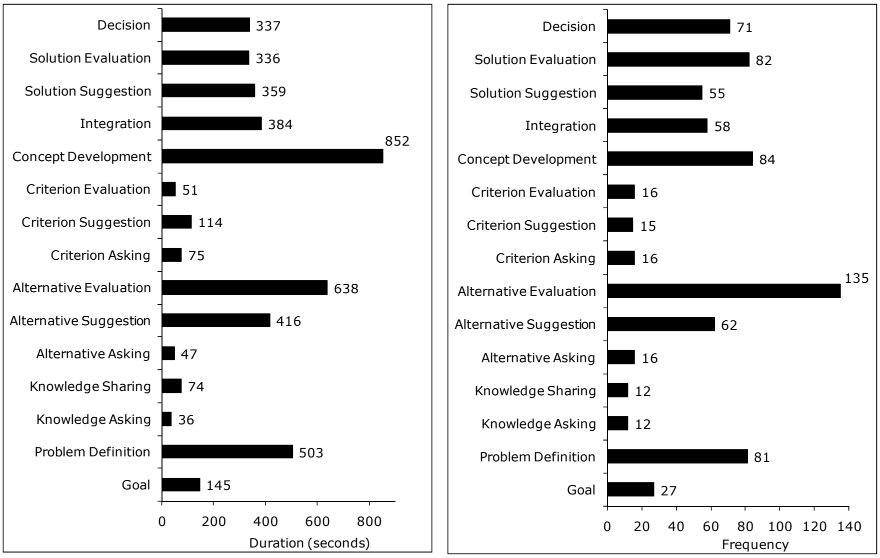

Figure 2. Durations and frequencies of decision components

Concept development, although it *occurred in terms of frequency* almost as often *as solution evaluation,* which has 82 ocurrences, covered 2.5 times more time than *solution evaluation.* Even though these two components showed almost the same frequency their different durations indicate that *solution evaluations* were formed as short judgements whereas *concept development* always had to be explained by the owner to the team members. *Concept development* is used to advance their ideas. The majority of the components dealt with alternative and solution interactions among team members. Another component problem definition besides having similiar frequencies with concept development has relation in two other contexts; one of them is mainly problem definition followed by concept development and as a second affinity, each component was produced by the same members in cross manner.While one member was defining problem of the states the other member was developing the idea subsequent to *problem definitions.*

Decision components display a considerable role of social interaction among team members in the decision making process. An interesting finding was that the majority of the decisions were made by the same person who also contributed most to the category *concept development*s. And it was also the same member who had the fewest utterances on criteria and constrains. This finding shows that individual contributions can vary considerably within a team.

5.4 Used and Rejected Decisions

During the design process many topics are discussed among the team members and many decisions in different topics occur in various manners, forms and numbers – but there are also situations where no decision has been made. Furthermore there were decisions that did not have any influence on the final design. We evaluated the decision topics in two ways; *used* and *rejected* decisions depending on whether or not they turned into a design feature of the product. The major part of the decisions belongs to the category of ‘used’ decisions. 63 of 71 decisions have been materialized as a feature of the final design idea whereas the remaining eight were ‘rejected’ decisions.

Without doubt, every design decision whether used or rejected is connected with previous and latter ones. Decisions, besides being linked to each other, occur at different information levels. In the conceptual phase, nine of 21 decision topics have been discussed that gave rise to 23 decisions. In preliminary design and detail design phases, within 10 topics 51 decisions have been made by team members. In every phase one topic did not result in a decision. As previously mentioned three topics due to their relations with final design and other decision topics might be confirmed they did not involve a concrete decision. Although the team had discussions on ‘Level made from net’, ‘paper placing’ and ‘Mechanism between layers’, they did not arrive at a decision about these issues. 24 decision components were discussed without arriving at a decision.

Obviously, the number of ‘used’ decisions increased gradually from the concept level to the detailed design level, while ‘rejected’ decisions disappeared during the progression of the design solution. Rejected decisions were all discussed in the conceptual phase. The design team made eight decisions under four conceptual design topics. They have spent 856 seconds which make the 17% of the total duration. 117 decision components have occurred during teamwork on rejected decisions. As a noteworthy point, decision components belonging to rejected decisions have been coded at the very beginning of the process and when it drawed to the end.

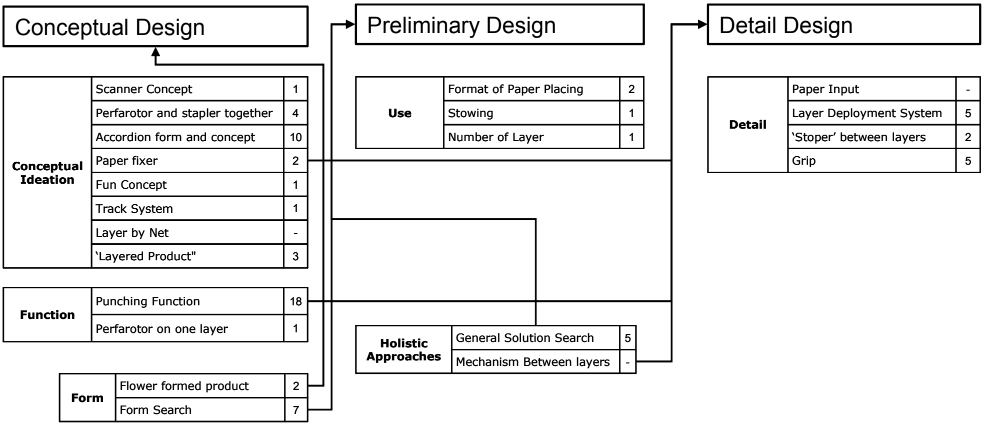

Figure 3. Decision topics and their context

The concept ‘scanner’, which was suggested by one of the team members as an ordinary idea while defining the design problem space, was the first decision topic that covered 333 seconds and reached a unique decision without being interrupted by any other contribution. ‘Scanner’ was also the first rejected decision not materialized as a feature of the final design. Within this topic, the team drew up their design solution space. It was not just an evaluation of the ‘scanning’ functionality. Furthermore the team held intense discussions to add electronic attributions to the product. At the end, while rejecting the ‘scanner’ idea they also rejected to design a product with electronic features product by taking into account project management aspects and objectives of the design task.

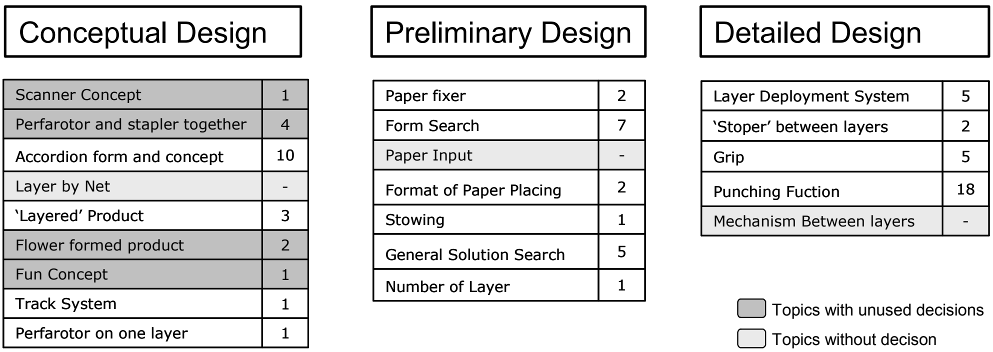

Figure 4. Decision topics according to design process phases

‘Perforator and stapler together’ covered four decisions and 312 seconds. 46 components about idea of using perforator and stapler together occupied 6.1% of the total components. While the design work was carried out resuming this idea they were trying to find technical solutions of the idea. One of the members developed a temporary technical solution only for punching and they never turned back again to the dual function product idea. When they couldn’t foresee any feasible solution for designated ideas and found an acceptable solution even for less than primary objective they came to a consensus without any words.

The third rejected decision topic, the ‘*Flower formed product’,* covered 3.3% of the process, and although two decisions were made, none of them transformed into a design feature of the product. The team initially decided to form the product like a ‘flower’, but two negative decisions about technical problems of adapting the form to the design made them to change their mind. The team developed shared agreement not to deal with complex forms.

The ‘Fun concept’ decision topic entailed one decision, which involved rejecting a design approach. In 25 seconds the team produced nine decision components ending in a concrete decision. Talks about a more entertaining product did not find acceptance among members. These results indicate that rejected decisions set borders of design work and give important clues about the design process. Especially rejected decisions in the conceptual phase denote to the precluded approaches in solving the design problem.

Design team, after developing the conceptual framework for design solution, have consecutively discussed the issues and made various decisions without a rejection. This can be interpreted as reflecting the determining role of rejected decisions on the solution space and on the construction of shared understanding among the team members.

6. Discussion and Conclusions

The aim of this study was to investigating decision-making in design teams in an exemplar setting. We considered decision-making as a process rather than as a step for design problem solving. By acting this way it has been possible to observe influences of decisions on the final product as being design features and inter relations of decisions. Analysing design context gave the opportunity of decomposing process into clusters that enabled us to analyse the floating context of design. Moreover we could track every decision from the beginning to the end moment through decision components.

Some recursive relations were found among decision components. Many iterations occurred between suggestion and evaluation based components. This was not different what we expected. Concurrently decision moments generally appeared after evaluation, suggestion based components and after problem definition component. Decisions also followed by decisions. A gripping result is that sometimes a decision and its predecessor decision component did not belonging to the same topic.

Team members rejected decisions mostly because of not being able to solve the realization problems of that design idea. In ‘Flower formed product’ topic, even though it was within the conceptual context, the decisions were declined due to technical obstacles. However, besides realization problems also the project management aspects play an important role for the development of the design solution space. Alternatively, the ‘scanner’ topic hosted the discussions on defining the approach of making an electronic based product or not. Although the team discussed the ‘scanner’ concept in the context of technical constraints, and questioned the functionality of the scanner -, with this decision they totally precluded the design idea of a electronic device which they put out of the design solution space. Understanding decisions deeper would give presumptions about the objectives team built up and about loss and gains in with the discussions of rejected decisions. Therefore decisions should be decomposed by topics.

It has been observed that not every decision influences the design product that so the rejected decisions do. Accepted design decisions depict the process and the behaviour of the team in reaching the final solution; however, when a decision is rejected that is a real change in direction. Rejected decisions are not just ordinary topics which are not compatible with the design task and goals. This study reveals that rejected decisions are the determining factors of framing the design solution space.

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