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PATTERNS OF DECISIONS IN DESIGN: LEAPS, LOOPS, CYCLES, SEQUENCES AND META-PROCESSES

Petra Badke-Schaub, Anja Gehrlicher

Abstract

Due to globalisation and technical innovation the engineering environment is getting more complex. As a result requirements in engineering design are changing so quickly that there are hardly any standard procedures adequate for various situations. Thus, we can state that engineering design is a complex problem solving process with the necessity of coping with different types of critical situations [1], [2], [3]. According to this approach decisions can be defined as a particular type of critical situations – among others – which may be concerned with various contents and processes. The decision making process includes activities such as analysing, evaluating, selecting, mainly in a group context. A lot of studies, investigating decision making in complex fields, suggest that human decision making is prone to failures due to the often unrecognised side- and long-term effects of decisions [4], [5]. The consequences of such failures may cause severe problems not only for the product but for the whole organisation, what especially is true for organisations in high risk environments. Early theories on rational decision making are based on the image of the decision process as a consciously deliberated course of actions [6]. However, many studies prove that human rationality often fails, especially in solving complex problems [7], [8]. This paper relates to the questions what are decision processes in engineering design departments like, which characteristics are linked to different patterns of decisions and how decision processes can be improved. An empirical investigation of decision processes in design work is introduced and illustrates that empirical studies are important in order to get an insight in successful and unsuccessful decision making processes. Moreover, the results allow to draw conclusions about failures corresponding to particular patterns in the decision making process, knowing relevant characteristics of different patterns of decisions.

Keywords: patterns of decision making, design teams, step-sequential processes

1. Introduction

In research and industry the assumption of synergy effects in groups is widespread. And it is evidence that there are different mechanisms such as the so-called assembly bonus effects of groups (i.e. aggregation of ideas or resources) responsible for synergy gains. However, observing interacting groups deliver that there are also miscellaneous losses due to the organisation processes in the group, as the following example shows.

It is a quite ordinary working day in a quite normal organisation in Germany. In an ample conference room of the engineering department a project group holds a meeting in order to

find a solution for a particular engineering problem. The room is fully equipped with media and facilities for presentation. Without using visualisation or moderation the group generates and discusses a lot of ideas; in the end nobody knows how to come to a decision. In the following it takes a long time until the group is able to install a procedure how to go on in the decision making process. Meanwhile most of the participants are unmotivated, some leave the meeting to attain another meeting and in the end no decision can be made.

Complex problems such as design problems create different viewpoints for the people involved [9]. This is an important advantage of groups if the task is to generate ideas. But it is surprising that in design a lot of efforts refer solely to the search for solutions but less into the process how to come to a decision in the group context. Often, poor decisions are the consequence of unplanned processes, unplanned in relation to the content as well as to the group process. What are the determining factors of a decision?

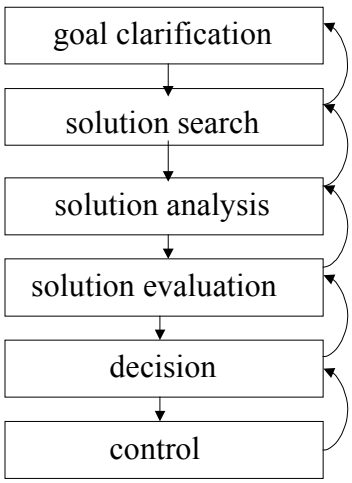

Figure 1. Decisions as one step in the problem solving process.

A decision is one step in the complete problem solving process: Starting with goal clarification (cf. figure 1) what means an attempt to understand the problem and to set the way to go, the further process relates to the creation of the solution space including the solution search, the analysis of the solution(s), their evaluation(s) and at least the decision(s). Step-sequence-theories [10] propose a similar sequence of steps that *individual* designers should follow in order to work out a solution.

But studies reveal that teams as well as individuals rarely follow these proposed steps in order to come to a decision [11]. What they do precisely, however, seems to cover various strategies, which reduce complexity, such as muddling-through behaviour [12] or opportunistic planning [13]. Moreover, many studies [6], [8] have shown that humans in different work domains do not strive to find the best solution but rather strive to find a workable solution with minimum effort. All these strategies are based on limited planning activities. Many authors argue that this behaviour can be explained by the limited memory capacity and the resultant pursuit of cognitive economy [14], [15], [16]. In this paper we want to raise the question what do decisions look like in design departments.

2. Empirical investigations of design processes

2.1. Theoretical background: decisions as critical situations

In a joint research project engineers and psychologists have investigated ten design processes in four companies by compiling detailed records of the design process as well as collecting data on the individuals, the group and external conditions [1]. In a thorough analysis, the observed design process has being differentiated into routine situations on the one hand and critical situations on the other. Critical situations are defined as 'turning-points' with an important influence on the further direction of the design process and the product. Derived from the steps of general problem solving models [6], [7], types of critical situations were differentiated regarding their aim in the problem solving process, such as goal-analysis, goal-decision, solution-search, solution-analysis and solution-decision. Moreover, situations can be important in their social context such as conflicts and disturbances evolving from external disturbances on the design project; these situations require conflict-management and disturbance-management Over all ten projects 895 critical situations were categorised and analysed. In relation to the frequencies the categories solution analysis and solution decisions turned out to be the most frequent type of critical situations, as is shown in figure 2.

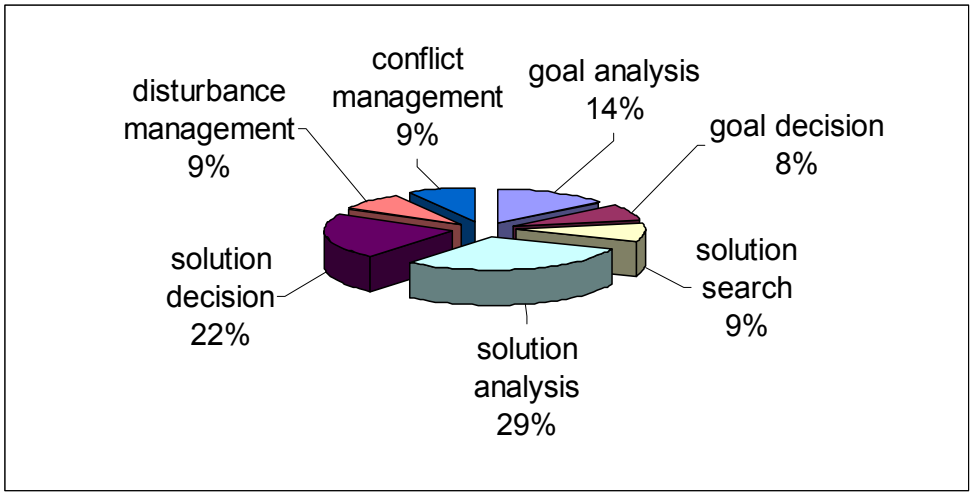

Figure 2. Frequencies of critical situations in ten projects [3].

Furthermore it turned out that decisions in design groups followed very different structures and results. In some situations, the groups discussed alternatives thoroughly before they came to a decision; in other situations analyses were abandoned by immediate evaluations [17]. These and other results led to the following empirical investigation (see chapter 2.2) which was concentrated on questions related to the process of decision making such as:

- What are the constituents of decision making processes in engineering departments?
- Can we distinguish different patterns of decisions during the design process?
- Which characteristics are linked to which patterns of decisions?
- Which patterns of decisions are related to which kind of results?
- How can we improve inadequate patterns of decisions?

2.2. The empirical study of decision making processes in groups

In the same way as the former investigations (see chapter 2.1) also this empirical study focused on a detailed observation and analysis of a single case over two weeks. The single case was an engineering design department of a medium-sized enterprise (in total 800 employees), which supplied automotive devices and system solutions for the automobile industry and their suppliers. The management of the company had initiated a reengineering process three years ago so that the structure of the company can be characterised by interdisciplinary teams and flat hierarchies. The design department consisted of 11 employees, divided into two functional units, designing and testing.

The primary direct method of the study was continuous non-participant observation. A laptop-based 'online' protocol system was used to document the observations in real time. The final protocol consisted of a word-by-word transcription of important dialogues and a description of the entire process. The continuous protocol of the complete design process was necessary because it can not be anticipated in advance whether a sequence will lead to a decision or not and whether a decision is part of routine-work or a critical situation[1]. Additionally semi-structured interviews and questionnaires as well as documents were collected, which provided important information about the design process and the individual evaluations of influencing factors of decisions. These protocols formed the material for the later extraction of critical situations of the type *decisions*.

Altogether 40 decision processes of multiple kinds of complexity have been categorised, described and analysed. According to the data presented in the literature on decision making in groups and according to the results of the former empirical studies each decision process was described by a set of parameters related to the environment of the particular design situation: characteristics of the particular decision problem, of the individual designer and the group as well as the organisational conditions, characteristics of the decision process and the result. The different characteristics are presented briefly in the following table.

Table 1. Matrix of parameters of the 'environment' of a decision making process.

Characteristics of the					
decision	**individual**	**group**	**organisation**	**process**	**result**
issues of decisions	field of functions	size	responsibility	origin and starting point	decision or no decision
time pressure	executive functions	coherence	history of the decision	duration	degree of satisfaction
ambiguity	experience	homogeneity heterogeneity	spatial situation	iterations in the process	achieved objective/s
uncertainty	qualification, competence	communica-tion abilities	structures of coordination	purposeful or random actions	revision(s) of the decision
long-term consequences	aims, goals, preferences	conflict solving abilities	degree of planning	visualisation moderation	

[1] The process of identifying and defining Critical Situations is described elsewhere [1, 17].

3. Results

The results presented in the following are divided into quantitative results with a presentation of characteristics of decisions in the observed design department and into qualitative results where five patterns of decisions are analysed and discussed in relation to different procedures of the decision making process.

3.1. Quantitative results: Characteristics of the environment of decisions

According to the matrix of table 1 we categorised the 40 analysed decisions in regard to a set of different parameters to get an idea about the characteristics of decisions. In the following we present some results of a few selected parameters.

Issues of decisions: The issues addressed in the decision processes illustrate the range of decisions in engineering departments. Most of the decisions are related to design problems, the next frequent issues are decisions concerning coordination and topics related to personnel questions, followed by issues concerning disturbances and testing problems, as is shown in figure 3 left hand.

Participation of different organisational units: The numbers of the different organisational units which participated in the 40 decision processes illustrate the fact that decision making in design is a collaborative process (figure 3 right hand) with several departments and hierarchies involved.

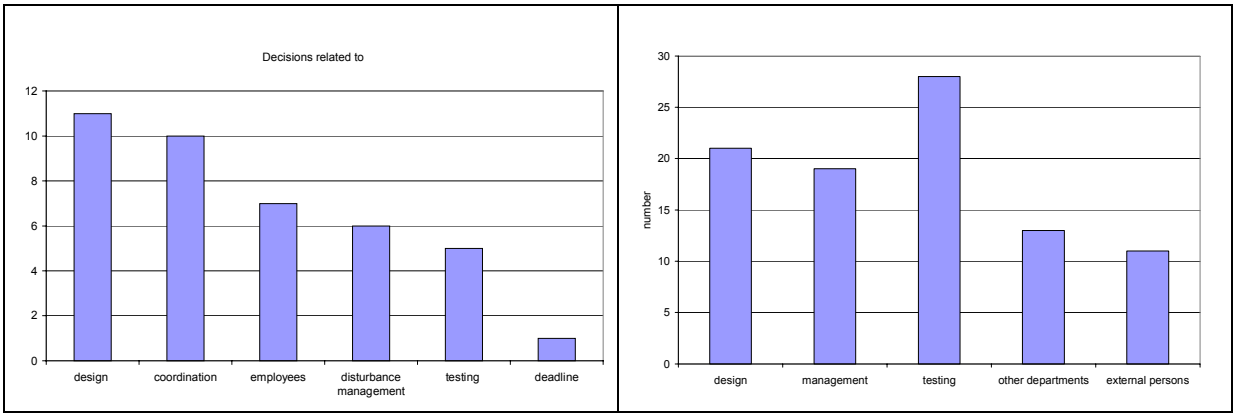

Figure 3. Left hand: Frequencies of different issues of decisions. Right hand: Frequencies of the participation of different *organisational units* in 40 decision processes.

Forward planning of decisions: Another characteristics of decision processes refers to the planning activities. Decision situations were defined as 'ad hoc- planning' when no planning activities came along with the decision. 'Short-medium-term-planning' was rated in situations when decisions were terminated in advance (the same day), and the category 'long-term-planning' was assessed if the decision was announced at least one week in advance and the process covered more than three working days. Figure 4 shows that only 45% of the decisions were planned in advance, that means most of the important decisions were settled without any forward planning or agenda (55%).

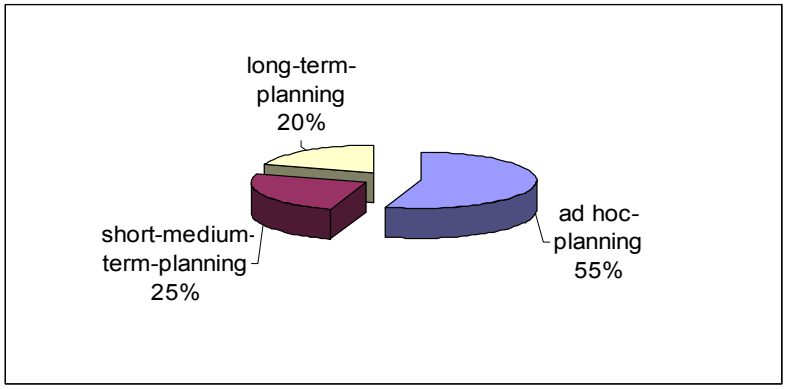

Figure 4. Forward planning of decisions.

The results reveal that most of the decisions in the design department are related to design problems but nearly the same number of decisions deal with organisational topics. Adding the numbers of the process-related decisions (coordination, employees, disturbance management and deadline) and the design-related (design and testing) decisions we even arrive at a ratio of 40% design-related (design and testing) and 60% process-related decisions. Most of the decisions occur in a multi-disciplinary context and are not planned ahead.

3.2. Qualitative results: A typology of decision making processes

Whereas in the previous section we gave some information about organisation-related characteristics we now introduce a typology of decision processes. This typology is the result of the categorisation of decisions according to the defining criteria *sequences of steps in the decision process* (see figure 1). On the basis of this criterion five different courses of decision processes could be distinguished. Each of the 40 observed decision processes was assigned to one of the five patterns: leaps, loops, cycles, sequences and meta-processes. The frequency of the five patterns, the verbal explanation and the related results are presented in table 2.

Table 2. Frequency (in per cent) of the five patterns (N=40), the course of the decision process and the results.

Patterns	Course of the decision process	Results
Leaps= 27%	fragmented process which jumps backward and forward	poor progress in problem solving, 'incomplete' decisions, failures, mostly quick decision processes
Loops= 20%	partial sequences of process steps with reiterations to the same content	in spite of reiterations no concretion, mostly long decision processes, failures
Cycles= 18%	reiterations of partial sequences of process steps but referring to different content	controlled muddling-through, increase of information over time, long decision processes, satisfaction of the group members
Sequences= 20%	step-by-step rational course of decision making	quick decision processes, structured interactions, progress in problem solving
Meta-processes= 15%	moderator guides and structures the interaction and decision process along the step-sequential process	long as well as short processes, satisfaction of the group members, progress in problem solving

Furthermore, these five patterns of decision processes are defined by the parameters specified in table 1. That means, the different patterns of decisions are related to particular individual, group, organisational and situational characteristics and to outcome-related aspects of the decision. In the following the five patterns are described referring to some selected parameters in order to get known to relevant characteristics of different patterns of decisions.

Leaps: Leaps are the most often observed pattern of decision processes. This pattern occurred as a consequence of a confrontation with a sudden problem in situations of time pressure. The decision making group or dyad tried to respond ad hoc with no agenda or planning activities. There is no sequence of an ongoing decision making process noticeable. The discussions were characterised by leaps backward and forward, the issues were mostly non-design topics. The members of the heterogeneous groups pursued different priorities and each group member tried to explain his point of view what caused several 'jumps' during the discussions. Often the desired common goal in the group was not communicated and therefore not clear. In most of the situations a decision was made quickly although the problem was uncertain and new. The consequence was a deficient decision that had to be revised later on. Thus, altogether leaps produced decisions where the progress in problem solving must be evaluated as poor.

Loops: Loops are characterised as reiterations of partial sequences of process steps. Loops occurred in groups with a common goal but with insistence of at least one group member on his preference or opinion so that the discussion often returned to the point of departure. The circumstances of the discussed problem seemed quite transparent to the group members. This illusion of a common mental model might be the reason that the discussions had no agenda and decisions were not planned in advance. Similar to leaps no concretion took place in the decision process in spite of several reiterations. The groups didn't succeed in a detailed goal clarification, especially because the group members had the (wrong) impression of acting in concert. As a consequence these decision processes took a long time to come to a decision – which mostly didn't fit the requirements.

Cycles: Cycles are similar to loops characterised as reiterations of partial sequences of process steps - but with a considerable increase in information along with the reiterations. Decision cycles caused the groups to arrive at a more detailed mental model about the problem. Another important difference compared to loops is that at the beginning of the process a goal clarification phase related to process (for example referring to responsibilities) and content provided a common information base in the group. Cycles had been detected in decision processes of homogenous groups with well-known group members and at least one experienced group member.

Sequences: Sequences reflect the prototype of a rational course of decision making, starting with the clarification of the problem and the allocation of responsibilities following by the creation of a common information pool and the deduction of solution alternatives, ending with the decision at the end of the process. This pattern had been observed only in discussions of strategic decisions of major importance which took place in planned meetings. These decisions were hardly related to particular design issues. The groups were composed by members of different hierarchical levels and there were no obvious conflicts of interest.

Meta-processes: Meta-processes are situations where a moderator guides the decision process during a meeting. This pattern differed from the other four patterns of decision processes because a moderator guided the content and the process. One important characteristics of successful meta-processes was that the moderator had no (did not show) own preferences in regard to the content. In addition all group members were encouraged to

contribute to the decision process. The main method of the moderator was the questioning technique so that the group itself produced the decisions. Table 3 combines the main influencing parameters of the five patterns of decision processes:

Table 3. Patterns of decisions and the main influencing parameters of the various fields.

patterns	decision context	individual	group	organisation
leaps	time pressure uncertain problems new problems non-design issues	different priorities different functions	no clear common goal	no planning no agenda reaction to sudden problems
loops	no time pressure certain problems design-related issues	heterogeneous functions	small size (2-3 group members) common goal	no planning no agenda no goal clarification long enduring processes
cycles	uncertain problems complex problems	experience homogeneous functions	small groups well-known group members	no agenda goal clarification
sequences	no time pressure strategic decisions non-design issues separate room no disturbances	different hierarchical functions	no diverging interests upper and top management	planning and agenda in advance
meta-processes	no time pressure separate room no disturbances mostly design-related issues no new problems	similar hierarchical functions	coherent group	no planning moderation and visualisation continuous meetings

4. Conclusions

The results presented in this paper have several implications for education and training of designers:

Firstly, the results of this study prove that a step-sequential decision process is definitely more successful than other patterns of procedures, even though three different step-sequential decision processes of different quality can be distinguished.

Secondly, the three types of step-sequential decision processes are cycles, sequences and meta-processes. Cycles are the less systematic pattern of sequential decision processes because they include several reiterations. Especially groups seem to be susceptible for reiterations; but these reiterations are not necessarily useless because they may help a self-organised group (with no formal leader) to translate the problem into a shared mental model - what needs time; however, a shared mental model in the group is essential to come to a common successful decision. Although the lack of planning as another characteristics of

'cycle decision processes' causes failures, the outcome related to different criteria is more successful than the outcome in decision processes characterised as loops and leaps.

The most structured sequential decision processes are the patterns we called sequences and meta-processes. Both processes are characterised by a guided way through the defined steps of a problem solving process. Whereas sequences were managed by a formal leader, meta-processes were structured by a moderator, who was not only responsible for the structuring of the design problem but also for the adequate consideration of different views in the group. In so far both patterns are related to very different group dynamic processes. The formally structured sequences with a planned agenda can be characterised by a stepwise reduction of complexity, the moderation-based meta-processes can be described as a tightrope walk between reducing and enhancing complexity with consideration of both, content and process. Knowing that humans generally tend (and need) to apply heuristics that serve to reduce complexity [15], meta-processes seem to balance these two contradicting requirements: Moderator activities structure decision processes in order to fulfil the need for an analytical approach and thus increase complexity; on the other hand complexity is reduced by the structuring of the content and the process by creating a shared mental model in the group.

Thirdly, according to the results of the observed decision processes leaps and loops are the two patterns which should be avoided – but these patterns constitute 47% of all observed decisions. In accordance with other studies [18], [19] the analysis of the parameters indicates that leaps and loops emerge because groups spend minimal effort on the process how to come to a decision and also too little time and effort of connecting different priorities in the team for formation and maintenance of a common goal.

Knowing the specific components of the patterns which are responsible that group decision processes fall back into loops and leaps a training should emphasise the strategies which encourage systematic sequential decision making. The easiest way for a group is the guidance by a moderator who is able to take care of the common goal orientation in the group and the structure of content and process. As a consequence, educating design teams should call attention to the conscious and flexible use of design methods, in the group as well as in single work decisions. Designers should be able to reflect their own thinking processes – in single work and in collaboration – in order to prevent leaps and loops –or better to react early if leaps and loops risk a thorough analysis and thus a successful decision process.

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For more information please contact::

Dr. Petra Badke-Schaub
Institute of Theoretical Psychology
University Bamberg
Markusplatz 3
D-96045 Bamberg, Germany
Tel.:+49 951 8631863, Fax: +49 951 601511
e-mail: petra.badke-schaub@ppp.uni-bamberg.de