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FROM DESIGN ERRORS TO CHANCES – A COMPUTER-BASED ERROR TRACKING SYSTEM IN PRACTICE

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1. Introduction

Designers are facing various challenges in product development: a rising product complexity especially caused by electronics and software components, market demands such as shorter development time and cost pressure as well as communication within heterogeneous company structures. These determining factors lead to an increasing number of design errors in practice. For example in the automotive industry the number of call-backs because of errors and component defects has been doubled within the last 5 years [Möhringer, 2004]. In Europe 11 products per week need to be called back because of errors or safety problems [PriceWaterhouseCoopers, 2005].
This is especially vexing and costly when the sources of errors are discovered too late or when the same errors are repeated due to lack of communication.
The reasons for errors arising during the design process are manifold:

- Information and communication: insufficient documentation, evaluation and feed-back of errors
- Organization: important number of interfaces, unclear responsibilities, long cycle times for changes
- Designers: insufficient technical and methodical skills, no "culture how to deal with errors"
- Methods and tools: missing methods to assure product attributes, no systematic treatment of errors

Existing methodologies e.g. change process (DIN 199-4) or quality management (ISO 9000) do not support the tracking of errors in a broad and continuous way [DIN 199-4, 1981], [ISO 9000, 2005].

2. Objectives

Every error incorporates as well chances to improve the product and the product development process. This potential needs to be opened up in a systematic way. A computer-based methodology – in the following referred to as error tracking system – has been developed and introduced in the industrial context of a medium-sized mechanical engineering company.
It is the objective:

- to record errors in a structured way
- to carry out error correction and the involved actions efficiently
- to analyse errors and transfer errors into knowledge
- to provide this knowledge in the designers situational context

In the following design errors and their impacts to the product creation process are explained. Common error management systems in industrial practice are described and the call for action will be derived. Finally the developed error tracking system and the experiences in daily use will be presented.

3. Error management in practice

The design department plays an important role: especially during the early design phases the influence on the product attributes is very high. The designer is responsible to determine working principles, to chose the material and to specify the geometric and behaviour parameter. With the cumulative determination of the design parameter the influence drops down rapidly. The error detection rate behaves diametrically: it is usually very low in the design phase; errors are detected at a progressive rate during production, start-up and operation of the product. The error costs are increasing exponentially: it is much more expensive to solve errors when the product is already in operation at the customer than doing corrections during manufacturing or even in the virtual stage (see fig. 1) [Ehrlenspiel, 1995].

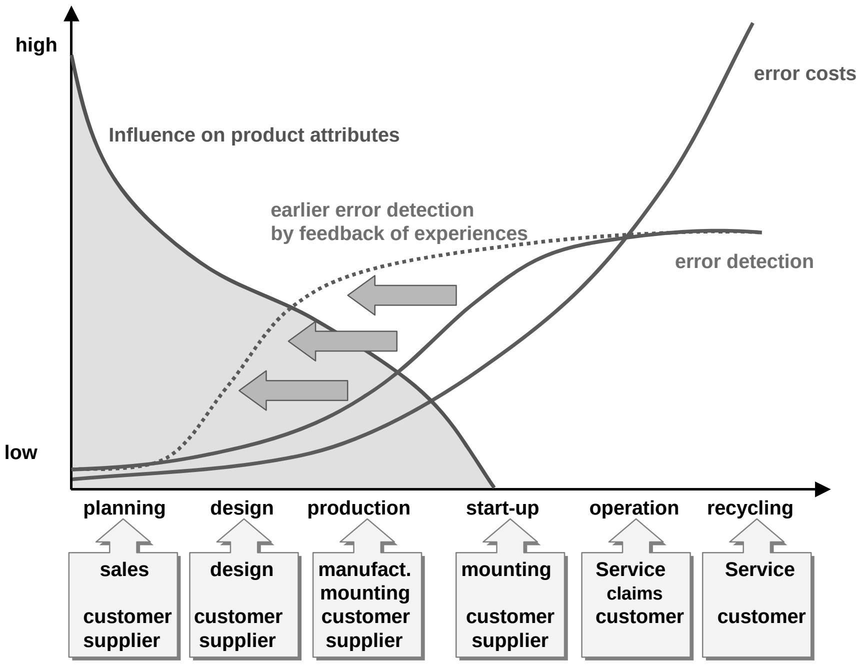

Figure 1. Errors and their effects [Ehrlenspiel, 1995], [Lindemann & Reichwald, 1998]

There are many participants during the product creation process which can detect errors: company departments e.g. design, manufacturing, service, claim management as well as suppliers, customers etc. If one can manage these various error information and initialize a systematic backflow to the design department the error detection curve can be moved to the left side. That means errors can be detected earlier which will decrease the error costs significantly.

In industrial practice however this backflow process is often not managed in a systematic and integrated way. Errors are treated as changes of design according to the change process (DIN 199-4), see fig. 2.

The change process is usually initiated by a reason of change. A proposal for a change is written and will be reviewed. If the proposal has been accepted the change process starts which consists mainly in correcting the involved drawings, documentations etc. and distributing them to the relevant company departments [DIN 199-4, 1981].

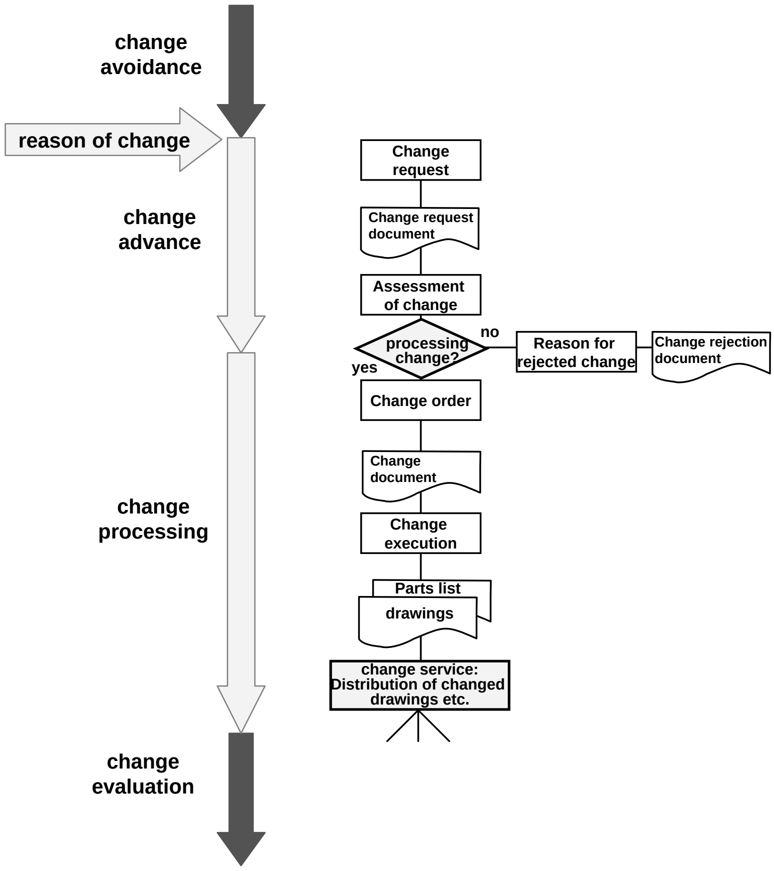

Figure 2. The change process according to DIN 199-4 [DIN 199-4, 1981]

This process has the following shortcomings [Lindemann & Reichwald, 1998]:

- it is characterized as a sequentially oriented process with various interfaces between departments
- the change process is usually organized by the design department and not considered as a key task; the overall interest to solve problems in other departments is missing
- the change process is still often managed in a paper-based way
- the actual status of a change proposal cannot be made transparent
- there is no analyse of changes in the sense of learning lessons from errors
- the preliminary and downstream processes of changes are not supported e.g. change avoidance or change evaluation (see fig. 2)

Lindemann & Reichwald suggest to extend the change process towards an "integrated change management" taking into account the avoidance of changes as well as to learn from changes. Eckert et al. discuss the challenges of change which lies in predicting the effects of such changes [Clarkson, Simons & Eckert, 2004] and in a successful change management [Eckert, Clarkson & Zanker, 2004]. Strategies are offered to understand the state of the design and to avoid unexpected change effort.

This contribution will not especially deal with the change process and involved problems like knock-on effects and connections between changes. The focus and the need for action is seen in the all-inclusive treatment of errors starting from methods of error avoidance up to the transfer of preventive knowledge into the designers situational context. Therefore errors need:

- to be structured systematically
- to be treated and followed up efficiently – supported by information technology

- and to be used as chances (error evaluation, providing error knowledge, feed-back to involved persons)

A computer-based error tracking system can support this process.

4. Computer-based error tracking system

The error tracking process is described as a sequence of process steps which typically need to be passed through when handling errors. Of course the process steps don’t have to be treated in a sequential order, rather according to the situational requirements of an error problem (see fig. 3). Each process step has an information input and produces an information output. The process step is furthermore supported by appropriate methods and software tools. Specification techniques help to describe the results of each process step [Möhringer, 2004].

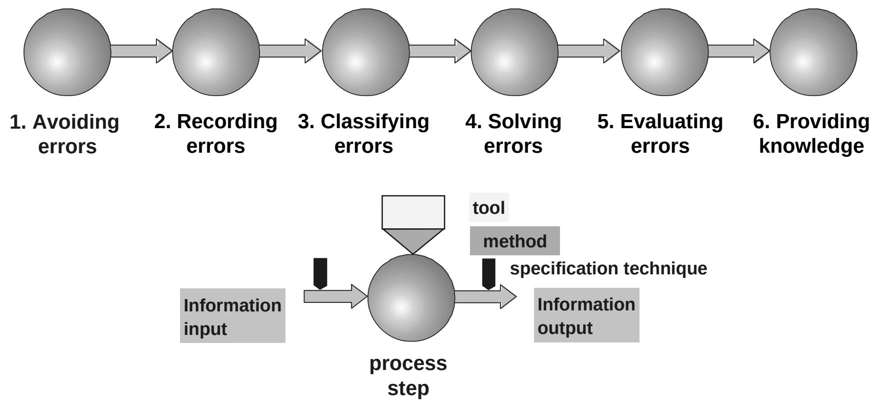

Figure 3. Error tracking process

The core element of the error tracking system is a software which has been developed within the company based on MS Access. It combines database functions with work flow elements. Every error can be recorded into the database supported by pre-defined entry sheets. Additional information e.g. photos, sketches etc. can be loaded and linked. The whole process to treat errors including the knowledge transfer is supported. No additional system e.g. for communication between the involved departments is needed. In the following the computer-based tracking system is exemplified by selected process steps.

4.1 Recording errors and classifying errors

The first step is to identify errors and to bring the relevant information into the system.

The main requirement to this step is an easy and fast handling. Errors very often occur during daily operational work when the available time is short and the priorities are different. Therefore the person who identifies an error expects support in two ways: 1) little time and effort to enter the data, 2) convinced that error will be treated and the necessary actions will be followed up.

Fig. 4 shows the entry mask supporting the record of errors, on the right hand side on top the corresponding information flow, methods and tools (see fig. 3). The person who identifies the error needs only to specify a minimum of input fields: the error context (project, machine part etc.) and the problem description. It is very helpful to add photographs or sketches. The proposal of a solution is voluntary. When finished the record can be saved and the workflow process will automatically be continued: the new data record has the status “to be classified” and appears in the task list of the responsible person for further treatment. By opening the data record a supervisor (e.g. project leader, quality manager) will specify the context of the error more in detail. He can add search keys and he will also decide which department is responsible to recover the error and the milestones for further actions. This classifying process step is very important in order to find errors and their solutions in a situational problem context later.

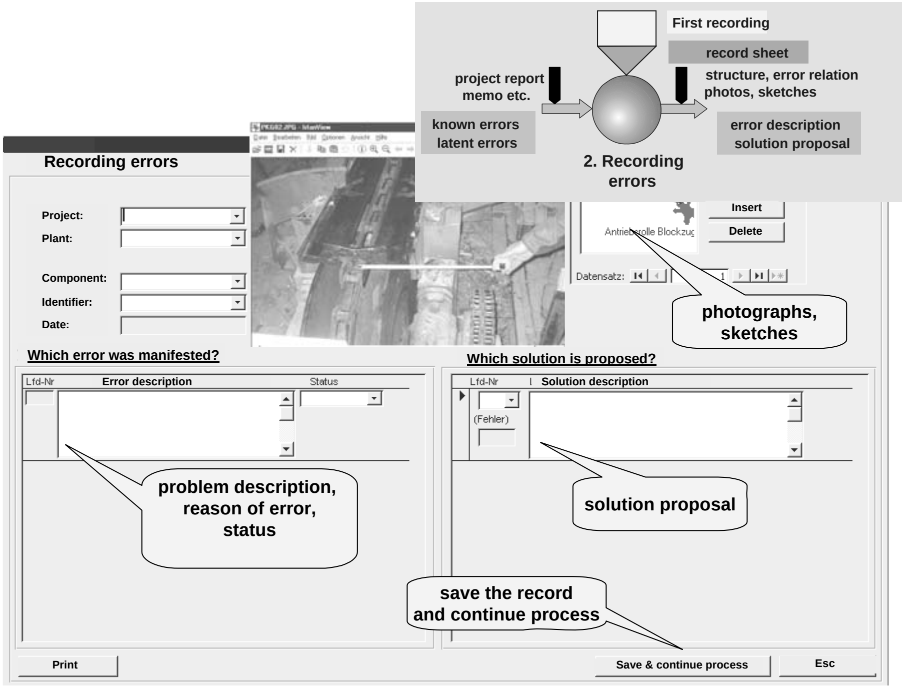

Figure 4. Recording errors

4.2 Solving errors and evaluating errors

The next process step is to manage the necessary actions solving the error. The actions can be described, related to responsible persons and time targets (fig. 5). The experience shows that error solving cannot be organized according to a pre-defined rigid procedure as problem characteristics can be very different. In some cases the error reason and the action to be taken may seem very clear. In this case it is sufficient to describe the actions and to link them with persons and time targets. In other cases there are much more information necessary to understand the problem correctly and to decide about the relevant actions. Therefore communication is supported as well: any participant can address e.g. a question to the identifier of the problem in order to get more detailed information. Other departments can be involved if a problem has a wider focus. This communication is recorded automatically and stored together with the error. The decision process is made transparent and can be followed up later if necessary. A controlling function to check the results, the compliance of priorities and time targets is integrated as well.

After the error has been solved it is very important to evaluate the error. The error reason, error origin and the error costs can be added into the system, the context and the search keys can be refined (fig. 5). Furthermore is has to be decided whether 1) the error had a specific reason which could be solved with the proposed actions and avoided in the future, 2) the error showed a weakness or problem which may concern similar cases. In the second case the database can be analysed to find these similar cases and overall actions (information document or guidelines e.g. checklists for assembly, quality control instruction) need to be taken.

4.3 Providing knowledge and avoiding errors

Last process step is to benefit from errors and solution findings in new projects and similar problem situations. As soon as the error evaluation has been terminated the process status changes into "knowledge": a wide search function allows to scan the data by search keys (search items, object- and function-oriented), projects, components, persons, customers etc. The information and guidelines concerning a specific area can be scanned as well (fig. 6). The designer can check the history of a solution in order to anticipate eventual knock-on effects, relations to other components, practical experience, life time etc. Reports e.g. for error cost evaluation, error costs of a project etc. can be generated. A very important function is to give a regular feed-back to the identifiers of errors. This report shows the number and type of errors identified within a defined period and the actions carried out. The identifier can verify the effects of his own error records. This helps to motivate especially the persons who are not involved in the error solving process and to understand the overall benefit.

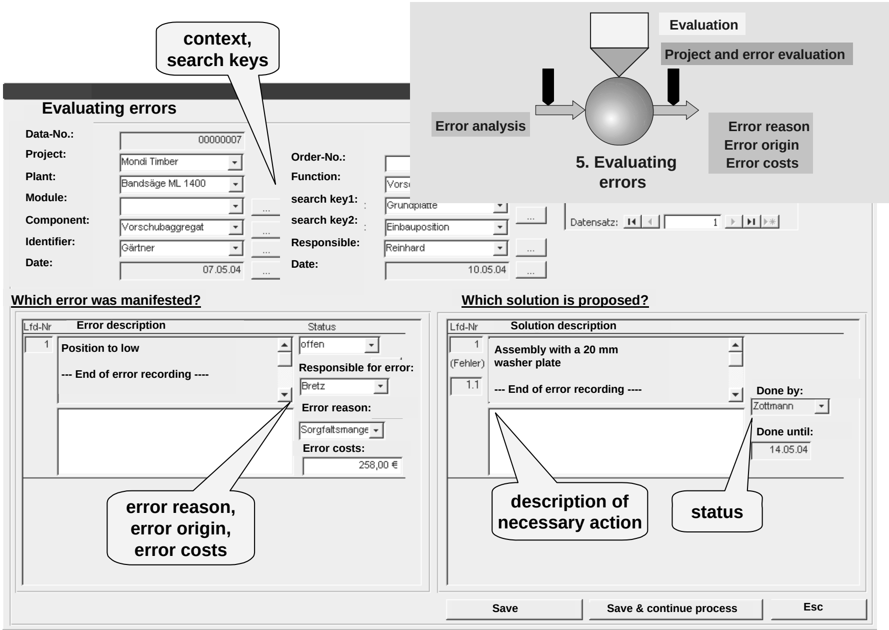

Figure 5. Evaluating errors

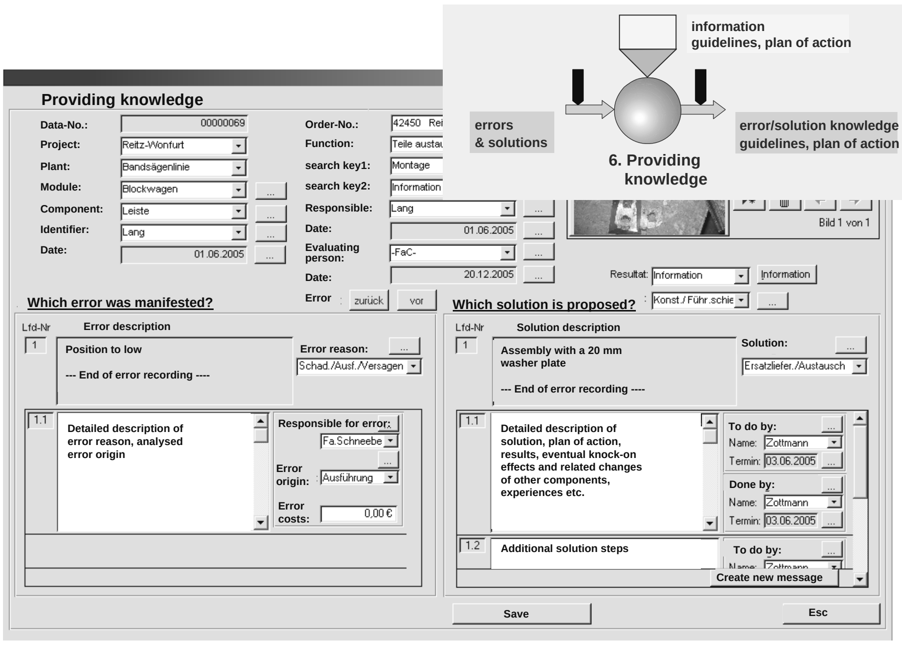

Figure 6. Providing knowledge for re-design

5. Experiences

The computer-based error tracking system has been introduced after a pilot phase company-wide (30 users) in August 2005. The main shortcomings before the introduction have been as follows:

- - missing transparency and traceability whether an error has been effectively solved; the error solving status could not be verified in a fast and concise way
- - lack of motivation to handle errors as a chance for improvement; therefore no systematic recording
- - to many repeated errors based on known problems

The experiences are:

1. **Improved error recording in all company departments**: Thanks to the computer-based system the error recording can be made decentralized in a fast and efficient way during daily work. The number of recorded errors increased considerably in comparison to the classical paper-based change process. As the transparency of the system shows the activity of each person as well a positive competition is stimulated between employees and departments.
2. **Faster process run-through and availability of error knowledge**: The paper-based process has been relatively slow due to interfaces and wait time between the involved positions. Furthermore the result is only available after the process has been completely terminated. The computer-based system increased the through-put time thanks to the direct communication and the ability to work on a problem in parallel with different partners. The results (or only the error description which is already an important information) are immediately available i.e. as well during the running error solving process.
3. **Effective know-how transfer to new situations and persons**: The classic change process considers only errors which can be brought into the technical documentation (drawings, service documentation, process engineering documents etc.) of a specific product (single part, component, assembly group); the transfer to new situations is limited. The computer-based system allows a fast and wide research covering the total range of recorded errors. A particular advantage is the documentation of blurred information (photos, sketches etc.) which may not match 100% with the actual design problem but allow a fast estimation of its transfer relevance due to the context information in the data base.
4. **Base for strategic improvement programs**: The evaluation functions help to focus on weaknesses where errors appear cumulative or error costs are especially high. Depending on the priorities strategic actions can be defined to improve products or departments effectively.
5. **Important source for failure mode and effect analysis (FMEA)**: Incurred errors provide of course the knowledge to avoid the same problem in the future. The aim is furthermore to avoid similar potential problems in new design situations. The error tracking system is very helpful to support the FMEA. Especially with the functional key items potential errors and potential error causes can be selected and used as a check list to carry out the risk analysis of a design FMEA.
6. **Better motivation for error identifiers**: Finally the overall understanding could be improved by closing the loop to the error identifier. In the past an argument was often mentioned: "we already notified this problem but nothing happened…". This process can be made transparent and both – the error identifier and the responsible person to solve the problem – get a documentation to prove the actions and to understand the consequences.

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