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DESIGN FLAWS: FLAWS BY DESIGN?

B. Gries and L. Blessing

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1. Introduction

When confronted with the outcome of any design process, it is inevitable that we experience design flaws. This usually happens at a time when the product's development process, which in many cases involves extensive testing of parts, components and prototypes, is considered complete. Still, we all have experienced how products can improve – not only in terms of performance and functionality but also by not featuring the same design flaws as their predecessors.

As trivial as this observation may seem, it raises the question what design-related processes lie beneath this phenomenon, in particular whether these processes were planned. Petroski suggests that many (if not most) products which we are familiar with today have a long history of previously flawed designs [Petroski 1992]. This implies that designers learn from design flaws in both senses of the word "learn": discovering the flaw and utilizing the knowledge gained about it to find a solution.

We regard design flaws as the result of design failures. Being a process which centres around individuals making decisions based on knowledge that is generated by a network that can include thousands of other individuals working geographically distributed and under immense time pressure, industrial design processes are a breeding ground for mistakes waiting to happen.

In this paper, we discuss how design flaws emerge by exemplarily applying results of research into human behaviour in complex situations to the design process.

2. Design flaws

2.1 A case example

Figure 1 shows the picture of the "iPod nano" an ultra-small, pencil-thin MP3-player. Only four weeks after its launch in mid 2005, the first of now several class-action lawsuits was launched against the manufacturer, Apple Inc., following a rash of users complaining about scratched and/or broken screens. Concerning the scratches, the lawsuits allege that the product is too delicate for normal use. The lawyers claim that Apple launched the player regardlessly of knowing that a design flaw would limit its life: to reduce the thickness of the product, the film of resin, which covers the screen and the controls, was made thinner than in previous models (that supposedly did not scratch that easily).

The scratching, however, does not occur out of nothing, but is the result of an external impact, e.g. users carrying the player in their pockets (as the picture in Figure 1 also hints at; given the small size of the product, it is understandable that people were in fact tempted to do so). Apple therefore denies that there is a design flaw in the "nano" and, for the time being, recommends the use of protective cases.

Figure 1. The scratched screen of an “iPod nano” (source: ipastudio.com)

2.2 The influence of design flaws on product design

Figure 2 shows a simplified model of how design flaws influence product design. It describes a cyclic process in which design flaws lead to reduced product quality which evokes feedback from the product customers to the designers. This feedback increases the experience and the design knowledge of the designers which, in turn, should reduce their likelihood of generating (at least the same) design flaws (again).

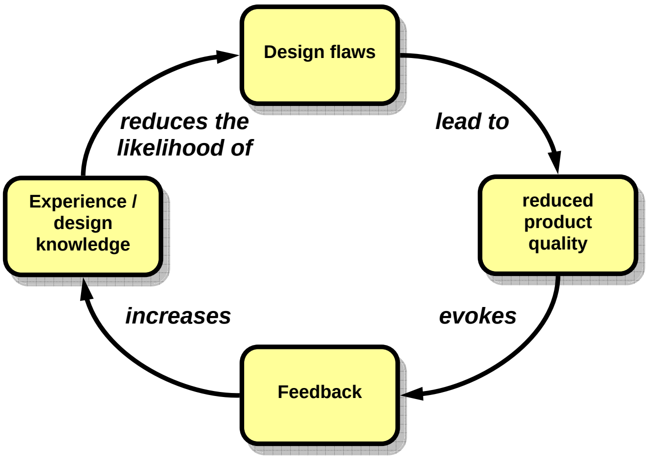

Figure 2. A simplified model of the influence of design flaws on product design

In the following, we discuss two aspects of the model in more detail: the link between design flaws and product quality and the relationship of feedback and design knowledge.

2.2.1 Design flaws and product quality

We define a design flaw as any design-related product property that impairs product quality. What does that mean? A basic definition of quality is the degree to which the *expected* product properties match with the *perceived* product properties. Since it is what we call the *customer* of the product who has certain expectations about the product, there is a mismatch if the designer – who defines the product properties – has been unable to satisfy these expectations. In this context, the spectrum of product properties that influence quality is quite large. It reaches from poor ergonomics (the customer perceives the position of the camera shutter as awkward whereas the designer, for technical reasons, could not place it elsewhere) to the reliability of the product (the customer expects the gearbox not to break down whereas the designer miscalculated the dimension of a shaft). Often, especially when user safety is at risk, design flaws are so serious that companies are forced to recall their products.

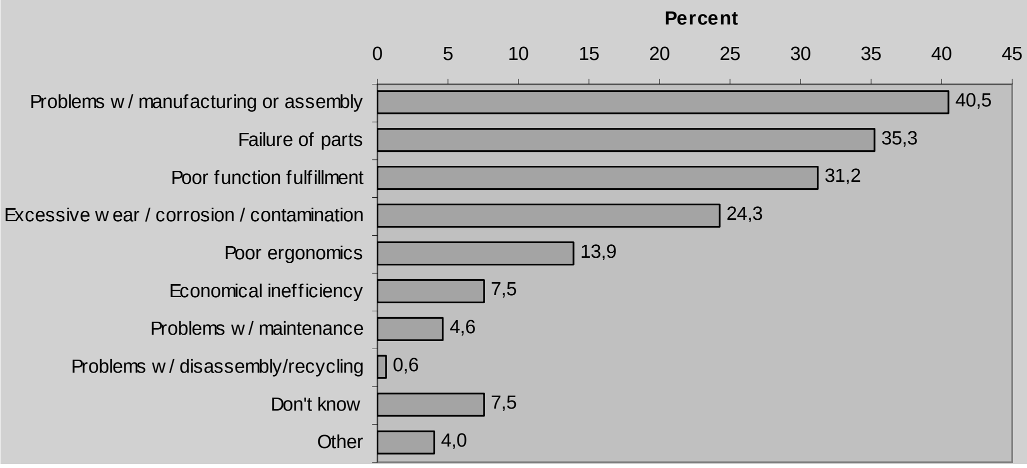

Figure 3. Typical design flaws (n=173, multiple answers permitted)

The above figure shows the frequencies of specific design flaws. The data is based on a survey of the German manufacturing industry [Gries et al. 2005]. "Problems with manufacturing or assembly" being the most frequently selected answer option illustrates the necessity to understand that the role of the product customer is not limited to the classic buyer or end-user of a finished product. There can also be "internal customers", e.g. manufacturing, sales, maintenance, and so on. Therefore, designers always have to take into account the requirements of multiple customers, not only the end-user. In fact, many design flaws are the result of designers modifying product properties in order to remove what is seen as a design flaw from the perspective of another stakeholder.

It is also important to note that quality impairment does not have to the *fault* of design. There are circumstances where product properties are felt unsatisfactory due to the fact that products are used in a completely different way than intended. However, the mechanisms described in our model still apply, more so explain a possible pathway of innovation. Mountain bikes, for instance, can be seen as the outcome of such a process: in the 1970s a growing group of cyclists found that commercially available bicycles were unsuited for taking them off road. Today, around two thirds of bicycles sold in the United States are mountain bikes [v. Hippel 2005].

2.2.2 Feedback and design knowledge

As far as discovering design flaws is concerned, it has been shown that the feedback of those who interact with the physical products in practice – the individuals who manufacture, repair, but essentially use the products – plays an important role. In general, according to [Busby 1997], feedback contributes to:

- the accumulation and retention of knowledge among designers;
- the adaptation of design goals and design practices to a changing environment;
- the evaluation of changes to the design process as a result of new practices or design tools;
- the motivation and maintenance of interest among designers.

Boeing Co., for example, has created common break areas giving design engineers the opportunity to receive first-hand feedback from assembly workers [Weber et al. 2005].

The diagram in figure 4 (which is also based on data from [Gries et al. 2005]), shows that sudden feedback by customers is by far the most important source of information concerning design flaws. Manufacturing and assembly being the second most frequent answer option corresponds with the frequency of design flaws that affect these areas (cf. figure 3). The processing of warranty claims, the third most often stated source, additionally to providing a channel for customer feedback, makes the flawed products accessible to its designers.

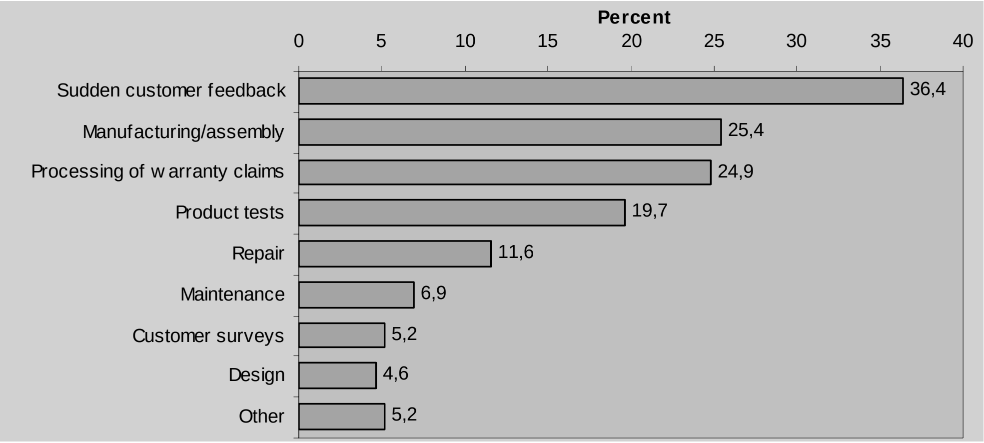

Figure 4. Sources of feedback on design flaws (n=173, multiple answers permitted)

Figure 5 illustrates possible contents of design feedback at some key stages of the product life cycle, also showing the increasing organisational, geographical and temporal distance that this information has to bridge.

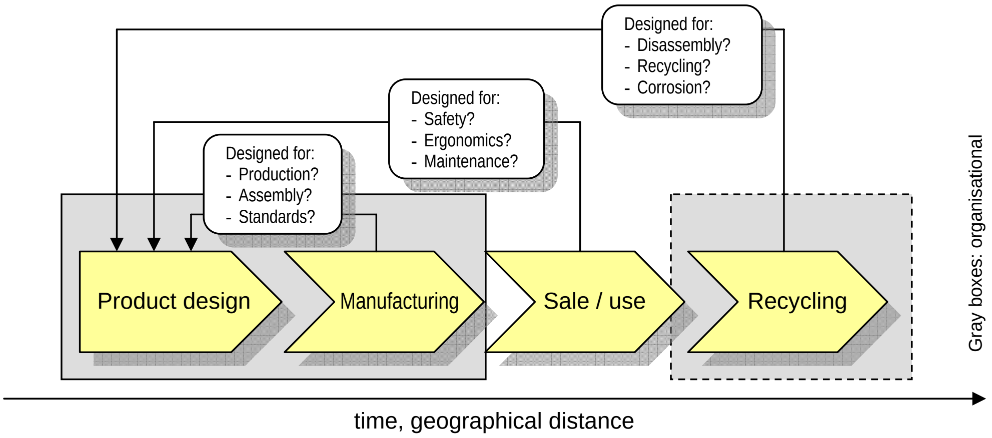

Figure 5. Possible feedback in different phases of the product life cycle [Gries & Blessing 2003]

The potential to develop design knowledge from feedback is influenced by a network of factors related to the product, its customers and the design flaw itself, including:

- product quantity and lifetime
- severity and likelihood of the design flaw as well as the typical life cycle phase of its occurrence
- customer initiative

In order to identify a systematic (or even statistical) pattern of design flaws, both the quantity of products in circulation as well as the likelihood of the design flaw are crucial. Also, the chances that designers will learn about a design flaw depend on e.g. its severity along with the product customers' willingness to report the flaw. Furthermore, design flaws that usually occur late in the product life cycle are difficult to trace back to their designers since development teams may have been assigned to other projects or (if a time-span of several years or even decades is considered) the responsible designers have left the company. In many cases, “late” can mean start of production when design knowledge gained from a design flaw must be retained until major changes in the manufacturing process are feasible again.

Therefore, learning from design flaws that rarely become apparent at the end of the life of a product that has been manufactured in low quantities or even only once (e.g. excessive corrosion on a custom built special-purpose machine) is obviously more difficult than using the feedback about a flaw of a mass-produced product that occurs early in the life cycle (e.g. problems with the manufacturing of a ball pen).

3. Design failures

As pointed out in the previous section, a design flaw is generated when designers fail to create a level of product quality that satisfies the customers. This failure can be either due to “poor workmanship” or to designers having a different perception of the quality of the product than their customers. More precisely, designers can have a wrong concept about how the customers *perceive* specific product properties and/or what product properties they *expect*.

3.1 Contextual factors

To better understand this phenomenon, it is necessary to look at the contextual factors of design problem solving:

3.1.1 Complexity

Depending on the scientific discipline, there are different definitions of complexity. Probably the most general one would be that complexity is the property of a system or a model that makes it difficult to understand as a whole. [Pahl & Beitz 1996] describe complexity in (design) problem solving as the existence of many differently interrelated elements. Today’s design processes are more complex than ever due (but not limited) to the following elements:

- **Newly available technologies and tools:** the spectrum of technical solutions to a specific design problem that designers have to overlook is continuously becoming larger. The same applies to (nowadays usually IT-based) design tools.
- **Design processes becoming more distributed and more interdisciplinary:** concepts like simultaneous engineering, concurrent engineering, integrated product development, etc. all mark a renunciation of what could be called “Design Taylorism”, i.e. the division of a task into smaller subtasks that departments handle successively – the common design process until the 1970’s [Hales 2004]. These days, it is not uncommon that a design process requires designers to collaborate with, e.g., manufacturers, marketers, psychologists and software developers from all over the world.
- **Increased product responsibility:** today, designers, apart from ensuring function and costs, have to consider aspects such as social values and environmental issues. Concepts such as product service systems will sustain this trend.

3.1.2 Dynamics

In systems theory, the dynamics of a system describe its temporal behaviour. Persistent changes of all the elements that contribute to the complexity of design (see above), in addition to time pressure, are a normality in industry. Since design is normally a team activity, these changes happen with or without the individual designer’s participation, making it a highly dynamic process.

3.1.3 Intransparence

In design, it is typical that decisions have to be made without all necessary information being available. When, for example, different solution variants are evaluated, many of their properties are only estimated or even unknown. Knowing that the situation is intransparent (like in this example), makes decisions difficult, whereas greater danger might lie in designers not being aware of any intransparence, i.e. “not even knowing that they do not know” all they need to make a reasonable decision.

3.2 Dealing with complexity, dynamics and intransparence as design problem solving process

According to the above, design processes fulfil all criteria of situations for which e.g. [Dörner 2005] has investigated the mechanisms of human failure. Figure 6 shows his underlying behavioural model.

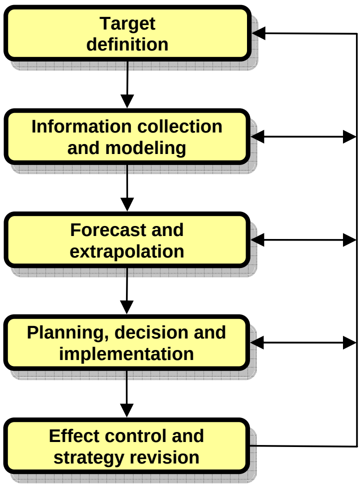

Figure 6. Problem solving process after [Dörner 2005]

3.2.1 Target definition

The starting point of any problem is an undesirable situation. Outlining the desired situation is the essence of target definition.

Having clear targets in mind is crucial at any level of design. On the highest level, it is the product requirements that should act as a global leitmotiv of the whole design process. Its purpose is to decompose a complex of requirements (the development task) into several manageable sub-requirements.

A typical failure on lower levels of design is the ignorance of contradicting requirements. Design measures taken to meet a specific requirement (e.g. use of aluminium to meet weight requirements) can often prevent other requirements from being met (e.g. cost requirements). Still, even if the finished product meets all of its requirements, it can still be flawed if the requirements are wrong.

3.2.2 Information collection and modelling

Information conversion, i.e. raising the level of information, is the central aspect of problem solving [Pahl & Beitz 1996], [Dörner 2005]. It requires information to be iteratively collected, processed and transmitted. With each iteration, the model of reality becomes more complete.

If in design this model is incorrect or incomplete (or both), the resulting products have a high chance of being flawed.

3.2.3 Forecast and extrapolation

Iteratively collecting, processing and transmitting information is not only necessary to generate a model of reality but also to adapt it to changed boundary conditions. Anticipating this change is the nature of forecast and extrapolation.

The ability to extrapolate existing trends is particularly important e.g. in the phase of product planning but also in many other design activities, such as detailing where e.g. the necessary package space can become (apparently) foreseeable even if the design is not yet finished.

3.2.4 Planning and Implementation

Once the boundary conditions are set as described above, an appropriate sequence of actions needs to be arranged which is the process of planning. It has been found that there is the prevailing tendency of people trying to match the perceived boundary conditions with those for which more or less proven plans are already known. In general, however, known and proven plans are applied even if the match is far less than perfect.

In methodical design, which itself can be described as a sequence of actions (e.g. planning and clarifying the task, conceptual design, embodiment design and detail design [Pahl & Beitz 1996]), there are many of such plans: the methods. The improper selection and application of methods – as well as their ignorance – can be a major cause of design failure [Bender 2004].

3.2.5 Effect control and strategy revision

Sooner or later, people will eventually be confronted with the consequences of their actions, giving them the all important opportunity of making corrections to the ongoing problem solving processes (backward arrow in Figure 6). By analysing the reasons for the failure of individual steps, it is possible to learn from mistakes.

Dörner describes a lack of effect control and strategy revision as “ballistic behaviour”. When the confrontation with the consequences is inevitable, learning from mistakes is complicated by, what he calls, “competence protection”. This predisposition of individuals as well as groups to sustain a positive image of their own capabilities is seen as a key factor for failure in complex situations. Typical strategies of competence protection include the attribution of the result to extrinsic factors (“It was the fault of…”) or marginal conditions (“It would have worked if…”) and target inversion (“It’s not a flaw, it’s a feature!”).

As discussed in Section 2.2., in design, learning from design flaws is the most long-term form of effect control.

4. Conclusion

In this paper, we have discussed the influence of design flaws on design and the influence of design on design flaws. By defining design flaws as a design-related product property that leads to reduced product quality, it can be argued that a design flaw is always the result of a design failure – the failure to create product quality.

Design is one of the most complex, dynamic and intransparent human activities imaginable. Therefore, it is prone to human failure. By exemplarily applying a problem solving model to design that is the result of research into human failure in complex, dynamic and intransparent situations (while, of course, acknowledging that there is a lot more of research into human behaviour in design), we have identified possible causes of design failure.

The model’s emphasis on effect control and strategy revision supports our concept that design flaws should be accepted as way of learning from mistakes and a long-term chance for quality improvement: “Mistakes are important. Errors are a necessary transitional stage to awareness. When dealing with ‘true’ complex and cross-functional systems, we have difficulties to realise our errors. They emerge only a long time after we have committed them and we possibly do not recognise them any more as the consequences of our behaviour.” [Dörner 2005].

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Dipl.-Ing. Bruno Gries
Research associate
Technical University Berlin, Engineering Design and Methodology Group
Strasse des 17. Juni 135, 10623 Berlin, Germany
Tel.: +49-30-314 23161
Fax.: +49-30-314 26481
Email: gries@ktem.tu-berlin.de
URL: http://www.ktem.tu-berlin.de