Perceived safety with regards to optimal safety of structures

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Abstract: The paper gives a critical view about the development and application of optimisation procedures for safety of structures. Optimisation techniques for safety of structures have experienced major progress over the last decade based on, for example, the introduction of quality of life parameters in engineering. Nevertheless still such models incorporate many major assumptions about the behaviour of human and societies. Some of the assumptions and limitations are mentioned in the paper in short. These assumptions heavily influence the outcome of such optimisation investigations and can not be neglected in realistic scenarios. Therefore the authors advice against the application of such optimisation techniques under real world conditions. Finally examples are given to illustrate effects of individual and social behaviour under stressed situations, which are not considered in the optimisation techniques mentioned.

1 Problem

Over the last few years the question about optimal safety of structures has been discussed intensive in the field of structural engineering. This question is of main interest for the development of general safety requirements in codes of practices for structures. Especially the last decades, where the general safety concept has been updated from global safety factor concept to the semi-probabilistic safety concept gave a good starting point for such a debate.

Mainly the question of optimal safety has been answered based on the idea of economical optimal spend resources. Usually the sum of production cost and cost of failure are compared with possible gains of such a structure. The combination of these two cost components gives an overall cost function with an extreme value according to some adaptable structural design parameters included (fig. 1). This overall cost function is based on economic considerations. Sometimes additional measures are incorporated as found in Quality-of-Life parameters. For example the *LQI* by NATHWANI, LIND & PANDEY [21] has become widely used in several engineering fields. This development to Quality of Life parameters could be easily seen not only in the field of structural engineering, but other fields like social sciences or medicine as well (PROSKE [25]).

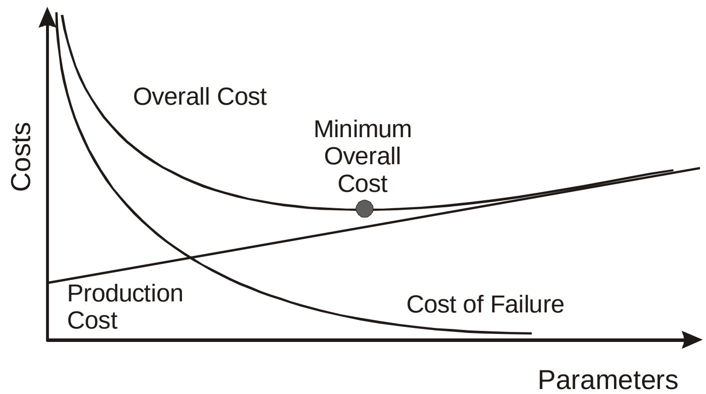

Fig. 1. Widely used function of overall structural cost depending on several parameters

2 Drawbacks of optimisation procedures for safety

2.1 Some limitations of LQI definitions

Although the search for performance measures as basis of optimisation procedures has yielded in many fields to the application of Quality-of-Life parameters, it does not necessarily mean that this strategy has been successful. If one considers for example the history of Quality of Life in medicine since 1948 now a huge variety of such parameters (more than 1000) has been developed for very special applications. Such a specialisation is caused by major assumptions inside the parameters. Considering for example the LQI it assumes a trade-off between working time and leisure time of individuals. Although this might be true for some people, others found, that most people enjoy working (VON CUBE [34]) if the working conditions and the working content is fitting personal preferences. The choice of the live average as major indicator for damage has also been criticized (PROSKE [27]). Fig 2. gives a impression about the dimensions of quality of life (KÜCHLER & SCHREIBER [17]). The comparison between the different dimensions and the simplified definition of the LQI makes limitations visible. For example, many psychological effects are not considered.

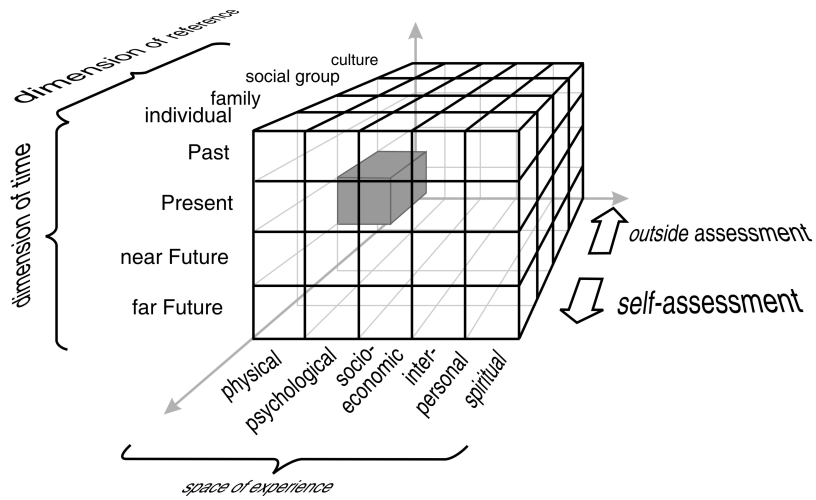

Fig. 2. Dimension of quality-of-life according to KÜCHLER & SCHREIBER [17]

2.2 Some subjective judgement effects

Since people are so affected by there personal experience, this chapter discusses some issues of subjective and psychological judgement of safety. Many works have been done in the field of subjective risk judgement, just to mention FISCHHOFF et al. [9], SLOVIC [29], COVELLO [6], ZWICK & RENN [36] or WIEDEMANN. For a general summary see PROSKE [26]. The authors here define “safety” as a feeling under which no further resources have be to spend to decrease a hazard or a danger (fig. 3 bottom – the change of slope in the function). By definition, this is a subjective evaluation of a situation and therefore the term “perceived safety” is actually a pleonasm. Often the term “subjective risk judgement” or “subjective safety assessment” are used. Nevertheless the term “perceived safety” has become very popular in scientific literature and shall be used here. Since the terms safety considers subjective effects, the property of trust should be mentioned. COVELLO et al. [7] have stated that trust might shift the individual acceptable risk by a factor of 2,000. That means, if one convinces people by telling them that a house is safe, they will accept an much higher risk (no resources are spent), whereas only with a few words trust can be destroyed, spending further resource, introducing a new law etc.

The introduced definition of safety also gives the opportunity to introduce a relationship between the terms disaster, danger and safety and the freedom of resources (fig. 3 bottom). Since safety has already introduced, danger is a situation, where most resources are spend to re-establish the condition of safety (not spending resources). Under an extreme situation of danger, no freedom of resources exists anymore; since all resources are spend to re-establish safety. Actually the term disaster then describes a circumstance, where the resources are overloaded (negative). Here external resources are required to re-establish safety. This indeed fits very well to common definitions of disaster stating, that external help is required. Additionally the introduced definitions can be transferred to the time scale of planning and spending resources (Fig. 3 above).

The time horizon of planning alters dramatically correlating to the states of danger and safety. Under the state of safety the time horizon shows a great diversity ranging from al-most zero to decades or even further. In emergency states, the time horizon only considers very short times durations, such as seconds or minutes.

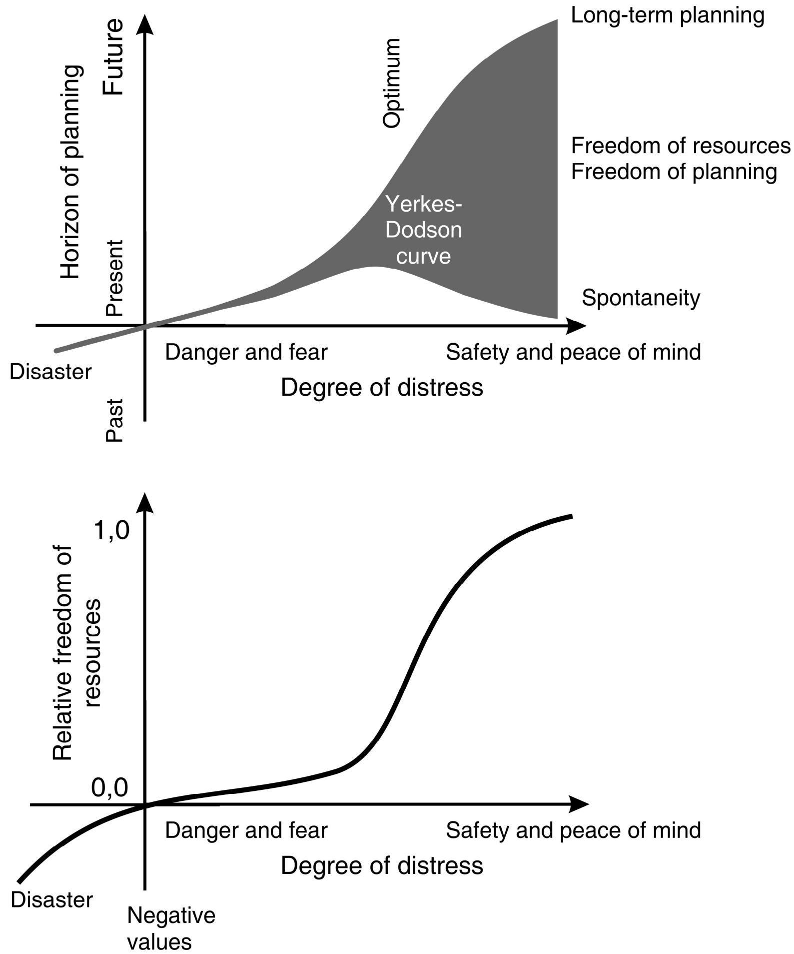

Fig. 3: Relationship between horizon of planning and degree of distress (above) and freedom of resources and degree of distress (bottom)

Also the choice of the time horizon is important for optimizations: It determines the results. MÜNCH [20] has stated that sufficient long time horizons justify ethical behavior as economic consideration. For example, IMHOF [13] has chosen a time horizon of 50 years for the maintenance planning of Swiss railway bridges based on a cost-benefit-analysis optimization. But using such long time horizons introduces major errors by assumptions about the future behavior of the social system. The prediction of traffic in 50 years includes rather high uncertainties.

But coming back from long time horizons to short time horizons, the techniques of the human brain identifying major hazards and therefore ruling resources should be of interest, since political actions were mainly caused by single events.

The awareness of danger depends very strong on the presence of thoughts. In general, the short time memory can only consider up to ten items, but usually only three to seven items are used. This effects obviously limits the comparison of different risks and there consequent spending of resources to the most important ones. Secondly the repetition, for example in media, is important for human memory. Fig 4 shows several thoughts about risk considering the intensity and EBBINGHAUS'es memory curvature. It should be mentioned here, that after several years the amount of information about a certain event is less then $1/10^{12}$ of the original information. Therefore many scientists speak about the invention of reality.

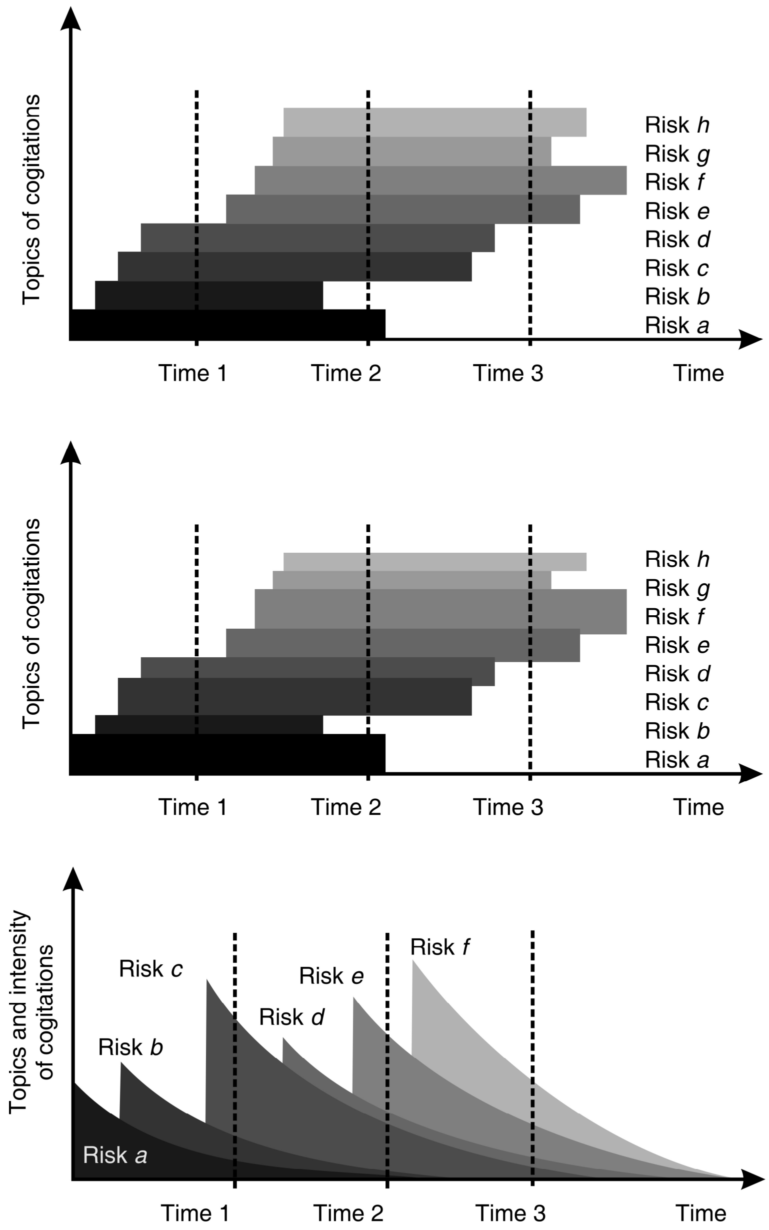

Fig. 4: Risks as topics of cogitations, first only considering the length of the thoughts (above), then considering the intensity (middle) and considering the memory function (bottom)

Fig. 4. fails to consider inconsistency of thoughts, which has been shown by many psychological investigations. Instead of a continuously flow of topics in thoughts, permanent in-

terruptions of the topics can be experienced. Such intrusive thoughts might be considered as positive or negative depending on the situation. So far, there are no techniques for the evaluation of such switching or missing thought in advance. But such intrusive thoughts can heavily influence the perceived safety (FEHM [10]).

Even the intrusive thoughts might cause problems with safety assessments; it seems to be they are rather important for humans. BIRKHOFF [1] has introduced a general numerical measure for aesthetical assessments based on a simple formula. Additionally many scientists have discussed the issue, whether high aesthetical evaluation is strongly correlated with high utility for humans. Indeed there seems to be a relationship, but a positive disturbance of thoughts seems to be one of the major reasons (PIECHA [22], RICHTER [23]). Disturbing elements, such as a decoration on a table might increase efficiency over the long run: a sparkling idea might be caused by the disturbance.

The only very short mentioned psychological effects are to the knowledge of the authors not included in the optimisation techniques for the safety of structures, but have heavy influence on the way, how decisions under real world conditions are done.

2.3 Limitations of the economic models used

Most *LQI* consider economy as a system, which functions under all circumstances. For example, assuming a major disaster killing one billion people, the *LQI* assumes that the economy still functions as before. Such assumptions become only visible in extreme situations, like major economical crisis in the last century or the decline of states nowadays like Zimbabwe or Iraq. Only one assumption will be discussed as example.

Many people live in countries where the social conditions motivate people to produce further wealth. This seems to be valid for all developed countries in the world, especially for countries, where scientists investigate the optimal safety of structures. But this is not a concrete behaviour of humans, since one also can detect countries, where the social conditions motivate people to take wealth from other people instead producing the wealth (KNACK & ZACK [15], KNACK & KEEFER [14], WELTER [35]). Those countries can be easily described by a lack of trust into the social system. Here the state as representative of the society is unable to fulfil the duty of safety, the major task of states (HUBER [12]). But how is the property of trust influenced by the actions of a state and can this trust be destroyed? To answer this question a short look into the properties of trust is worthwhile.

Trust is a main indicator of social capital and the basis for developing cooperation with other humans or organisations, as already mentioned in the chapter before. Since the success of economy is mainly based on specialization, which requires cooperation, the success of economy in terms of developing wealth is connected to trust. It is not the main goal of this paper to define trust, just one adapted definitions should be mentioned (CONCHIE & DONALD [5]):

"*Interpersonal trust is a psychological state that involves the reliance on other people in* certain *situations based upon a positive expectation of their intentions or behaviour*."

Coming back to the simple example mentioned: Where potential economic actors cannot trust each other the private returns of predation increases compared to falling return of production. Unfortunately over the long run, this strategy yields to the complete failure of the society and there individuals. So if actions destroy trust, they destroy the social system including the economy.

As one an example the package inserts in pharmaceuticals are mentioned. It is not only considered as information material, but also as protection measure because they inform about risks. But recent investigations have shown, that the inserts actually increase risk, since people in real need for medication refuse to accept the medication due to fear caused by the inserts.

In difference the safety regulations in air planes, like lifejackets on board, increase the perceived safety of the passengers. But in reality the number of people actually saved by the lifejacket is neglect able. Therefore this equipment could be saved and spend for further activities based on optimisation investigations. Nevertheless not only the authorities, but the airlines itself refuse to do that, since the major goal of the lifejacket is not there functioning under real conditions, but creating an atmosphere of carrying and trust. Only if such subjective effects are considered during the optimisation, the procedure can yield realistic results.

The question arises, whether optimisation procedures itself increase or decrease trust. This has not been proved, but simple considerations show, that trust is decreased by optimisation procedures in safety. See also the example at the end.

2.4 System Requirements

Whereas the one chapter discussed mainly some effects of individual information processing, this chapter focuses more on the behavior of social systems, mainly on system theory. The membership of elements, such as humans, belonging to a system might influence required safety levels. First of all, the objectivity of risk assessment depends very strong on the distance of the endangered elements to the damaged system. A scientist usually works in safe environment thinking about the optimization of safety of structures. But what would happen, if the slab inside the office crunches and shows cracks? Would the scientist continue to work or would he spend resources checking the safety of the office? Here the system theory might help: If elements of a system are endangered, the system will spend resources in a short time non-optimal way, just defending the integrity of the system. Only if the hazard exceeds a certain time or damage of the elements or the system exceeds a certain degree of seriousness, then the behavior might shift back considering economical considerations. This has been heavily investigated looking for parent animals protecting there children. Whereas under normal conditions they attack even stronger animals and therefore endangering there life, under extreme situations (hunger, drought) they leave there children without care. Also rules for military rescue actions quite often endanger more people to rescue a small number of military staff. Based on a theoretical optimisation analysis this actions should never be cared out, but under real world conditions it is of overwhelming importance that the people keep there trust in the system.

In general, treating elements of a system in a short time optimal solution can yield to a long time failure of the system, since the elements will not function anymore. The problem of long time efficiency on the other hand can not yet be solved, since that would require the prediction of the behaviour of humans and social systems. Further research especially in the social systems has to be carried out. Where we have NEWTON's law in physics, we do not have yet something comparable for societies and predictions are difficult (fig. 5). In other terms, the behaviour of social systems is highly indeterminated (PROSKE [28]).

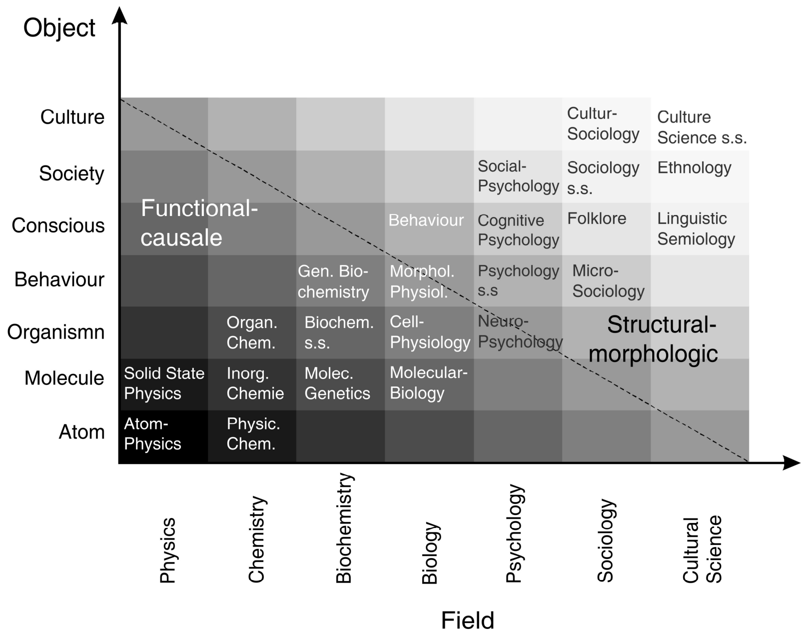

Fig. 5: Causality and field of science: High causality exists at the bottom left (in many cases), whereas low causality exists in the top right area (RIEDL [24])

3 Examples

In the following a few examples should illustrate the considerations.

Fig. 6. Ford Pinto Case in the US

① The famous Fort Pinto Case (fig. 6) in the US in the 70s is a first example. Here the company Ford made an optimisation analysis about changes of the construction of the car concerning the safety against fire and explosion. The analysis recommended no changes but providing finances for compensation. During a court cases (Ford vs. Romeo Weinberger) the analysis become public and Ford was heavily punished in terms of compensation (128 Million US $). During the public discussion the question whether the number of fatalities exceeded a permitted level was not so much of concern, but the idea, that fatalities were accepted anyway was the major critic. General Motor also used such procedure and experienced the same effects in public in the 90s [32]. In both cases the loss of trust or other individual and social effects of the optimisation strategy were not considered, but effected heavily the outcome. The actual optimisation procedure did more harm than common sense.

Fig. 7. Collapsed sport hall in Bad Reichenhall, Germany

② On 2nd January 2006 3:54 pm the sport hall in Bad Reichenhall (fig. 3) collapsed. 15 people, many of them children, died in the collapse, 30 people were hurt. The failure of the structure led to an intensive debate about the safety of public buildings in Germany. First, it was been assumed that snow overload caused the failure, since also in Poland a hall collapsed in this winter. This discussion reminded one very much to a discussion in the beginning of the seventies, when many light weight constructions in East and West Germany failed under snow load. Here first sabotage was assumed in East Germany, but very optimistic assumptions about snow load and the change of the construction material from wood to steel were identified later as causes. The discussion about cause of failure in Bad Reichenhall turned more into the field of maintenance and the required level of safety over time.

"*The question of safety is now answered by business people and legalese, not by engineers.*" said the president of the German Association of inspection engineers in the German television (ZDF) in 2006. He actually complains about an inherent economic based optimisation procedure. Independent from such optimisation considerations the ministers for building structures decided in December 2006 to change the law considering safety requirements of public buildings in terms of additional inspections only based on the individual event in January 2006. Still, even with that event, structures in Germany remained an extreme safe technical product (17,293,678 residential buildings in Germany 2004, 5,247,000 non-residential buildings in Germany, 120,000 bridges in Germany, 20 hours exposed per day [16], [8], [31], less then 10 fatalities per year as average) either in terms of mortality, fatal accident rates, *F-N*-Diagrams or optimisation procedures using Quality-of-Life parameters. As clearly seen from the words by the president of the Germany Association of inspection engineers, the optimisation procedures (using risk parameters) are criticised and not helpful in the case of collapse. One can not simply state after a disaster, that the disaster was an acceptable one and business as usually continues. See here for example the goal of predictions (TORGERSON [33]).

Here trust into the safety of buildings can be identified as major requirement which has to be included in optimisation investigations. It should be mentioned, that the efficiency of trust destroying actions is three times higher than trust building. If optimisation procedures for safety are really considered as trust decreasing action, the procedure itself had to be balanced by much higher investigations. Additionally here ARROWS [1] impossibility theorem should only be mentioned.


Hausarzt

Zu viel verordnet – Zulassung weg

Görlitz. Zum zweiten Mal ist in Sachsen jetzt einem Arzt wegen „unwirtschaftlicher Verordnungsweise" die Zulassung entzogen worden. Dies ist auf Antrag aller Krankenkassen in Sachsen geschehen, bestätigte am Freitag Ulrich Bergk vom Ersatzkassenverband einen Bericht der „Ärzte-Zeitung". Der Görlitzer Hausarzt habe jahrelang die für Arzneimittel-Verordnungen vorgegebenen Richtgrößen um bis zu 300, 400 Prozent überschritten.
Der Görlitzer Arzt hat gegen die Entscheidung des Zulassungsaus-

Fig. 8. Newspaper report in Germany, 2003

③ The Saxon Newspaper (Sächsische Zeitung) from 8th November 2003 reported that the permission to work as a physician has been withdrawn for a doctor due to uneconomic treatment of patients (fig. 4). Currently in Germany physicians have a budget which they can spend to treat people. If the budget is spent, either they work for free and even might fear a penalty or they stop working. Nevertheless it is prohibited to inform patients about the current status of the budget or giving any information about the budget to the patients in the waiting room. Most patients are not aware about such budgets and officials and politicians blame doctors if they refuse to treat people due to exhausted budget. Here an optimisation procedure is carried out but is kept confidential. Obviously there must be a reason to keep it confidential, and the reason might be loss of trust.

So if people are aware of optimisation procedures for safety, they feel a strong damage of trust and develop social actions, which yield to political decisions in terms of laws. Therefore, as shown in these examples, governmental safety requirements might be mainly ruled by single events.

4 Conclusion

In the last few years the topic of optimisation of safety of structures has been of major importance in engineering, especially since the wide application of Quality-of-life parameters. Nevertheless in medicine the application of Quality-of-life parameters is still discussed since 50 years. As shown in this paper, social, psychological and other effects have to be considered in optimisations. The best models considering most diverse fields have the empiricists, who are the only ones able carry out decisions.

One last problem should be mentioned here as well. It is well known, that most structural failures are caused by human failure (MATOUSSEK & SCHNEIDER [19]). But the overwhelming number of probabilistic calculations as input data for optimisation procedures does not consider human failure. In the field of science, additionally many authors actually have turned away from optimisation, looking for substitution parameters, such as robustness (HARTE et al.[11], BUCHER [4], MARCZYK [18]).

A few general things, one should keep in mind when discussing optimisation, is taken from the research project "Robust mathematical modelling" [30].

1. There is no such thing, in real life, as a precise problem. As we already saw, the objectives are usually uncertain, the laws are vague, the data are missing. If you take a general problem and make it precise, you always make it precise in the wrong way. Or, if your description is correct now, it won't be tomorrow, because some things will have changed.

2. If you bring a precise answer, it seems to indicate that the problem was exactly this one, which is not the case. The precision of the answer is a wrong indication of the precision of the question. There is now a dishonest dissimulation of the true nature of the problem.

Finally it should be stated, that within the entire critic, risk investigations can be useful, if applied properly. Here the term risk informed decision making might help (ARROW et al. [2]).

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