
# DRAFT FINAL REPORT

## 36 MONTH DELIVERABLE

September 2014

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# APPENDICES WP2

# APPENDIX 2.4: Risk analysis by an insurer and the relation with building pathology

### 1.1 Concept of risk and risk analysis

An insurer is dealing with risks of construction processes, actors and products, and uses information from risk analysis for establishing insurance premiums and conditions.

Risk is a function of the chance on an accident, a defect or a failure, and the detrimental effects thereof (for the insurer: having to pay for claims). This is also expressed as: Risk = chance x effect.
For example: the accident can be: fire in a building as a result of …. (lots of potential causes). The detrimental effects can be: injuries (or even deaths), physical damage, loss of functioning etc.

Depending on the kind of insurance, and the phase of the construction process where the accident occurs, the insurer is interested in certain kinds of effects and the underlying causes which led to the accident. Most insurances only cover physical damage (in financial terms), but sometimes also loss of performance of building parts, interruption of the business process of the building owner/user, or even indemnity in case of death or permanent disability of injured people.

It is obvious that the insurer is also interested in the causes of the accident. Not only to know who is responsible/liable for the accident, but also to know the technical background of the accident. This technical background is important in order to be able to formulate prevention measures and insurance conditions for future coverage.

So in fact, the insurer is interested to know the whole risk chain, from the causes of accident/failure to the effects, including the chances of occurrence.

M.W. Merkhofer (Decision science and social risk management. Boston, 1987) illustrates the risk chain for societal and health risks (accidents with nuclear power plants, product injuries, food poisoning, sun burning etc.). The core elements of his risk chain are: hazard (cause), exposure processes, effect processes, and valuation processes. During the valuation process, the risk is weighed as being ‘low’, ‘high’, ‘acceptable’ or ‘not acceptable’, according to individual and social value judgments. See the following picture from his book:

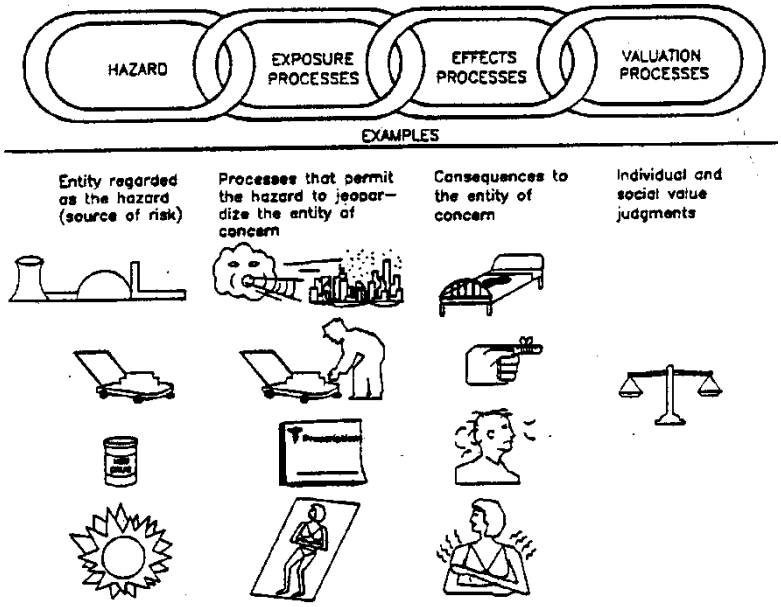


***Figure 1: The 'risk chain' for societal and health risks, with examples (from M.W. Merkhofer, – Decision science and social risk management, Boston, 1987, p.7).***

For the risks of construction processes, actors and products, the risk chain for an insurer looks similar. The 'hazard' (cause) in this case is human errors, omissions, faulty construction products, wrong use, ageing/degradation of materials, etc. The exposure process is the process leading to a defect and/or a failure of a construction component; the effect process is the process leading to a 'loss' (financial, material or human). The valuation process is the internal weighing of the severity of the risk by the insurer.

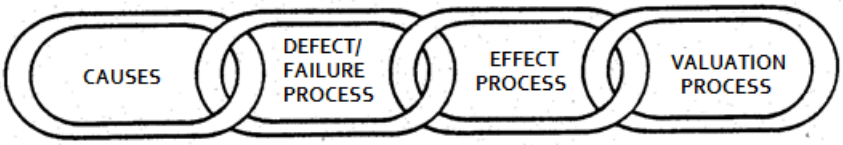


***Figure 2: Risk chain for defects and failures in construction.***

In conjunction with the risk chain of figure 2, risk analysis by an insurer can be targeted on each of the individual chain links, including the probabilities of occurrence, and on the chain as a whole.

### 1.2 Relationship with building pathology

The CIB W086 Publication 155 (Building Pathology: State-of-the-Art Report, 1993) defines 'building pathology' as the systematic treatment of building defects, their causes, their consequences and their remedies.

The science and knowledge of building pathology can play a role in risk analysis for the first three links of the risk chain (causes-defect/failure-effect):

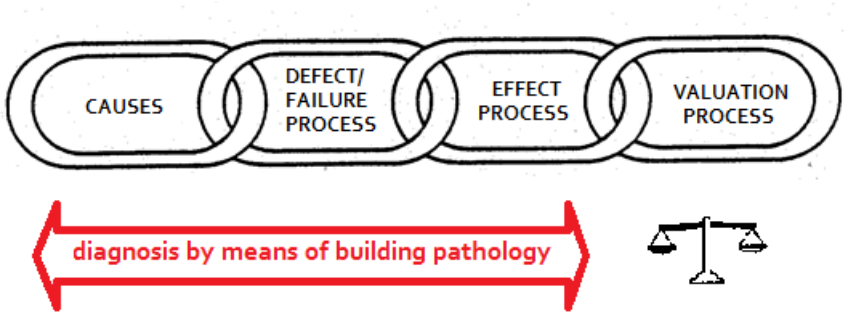


**Figure 3: Diagnosis by means of building pathology for risk analysis.**

According to the CIB-report:

- **'defect'** is a situation where one or more elements do not perform its/their intended function(s), and
- **'failure'** is: the termination of the ability of an item to perform a required function[1].

Though the definitions of 'defect' and 'failure' seem almost identical, they do not have the same meaning. The term defect implies a shortcoming in respect of some normative or even perceived standard or requirement. But the defect may lead – by some means - to a situation in which a specific required function cannot be fulfilled any longer. For example: a crack in a partition wall can be considered as a defect. It depends on the functions of the wall and on, for instance, crack-width whether the wall fails in performing its required functions.

The type of defect may vary widely; from a minor aesthetic crack to a major collapse. Obviously, the latter implies a failure, i.e. the termination of required use.

Diagnosis, which is the basic part of the building pathology discipline, requires knowledge of the decay process suffered by the building components. This process is defined in the CIB Report as the evolution from a performance to a non-performance condition. The decay process is indicated in figure 4:

[1] ISO 15686-1 (2000), Buildings and constructed assets — Service life planning — Part 1: General principles and framework, gives the following definitions:
- Failure: loss of the ability of a building or its parts to perform a specified function;
- Defect: fault, or deviation from the intended level of performance of a building or its parts;

Obsolescence: loss of ability of an item to perform satisfactorily due to changes in performance requirements.

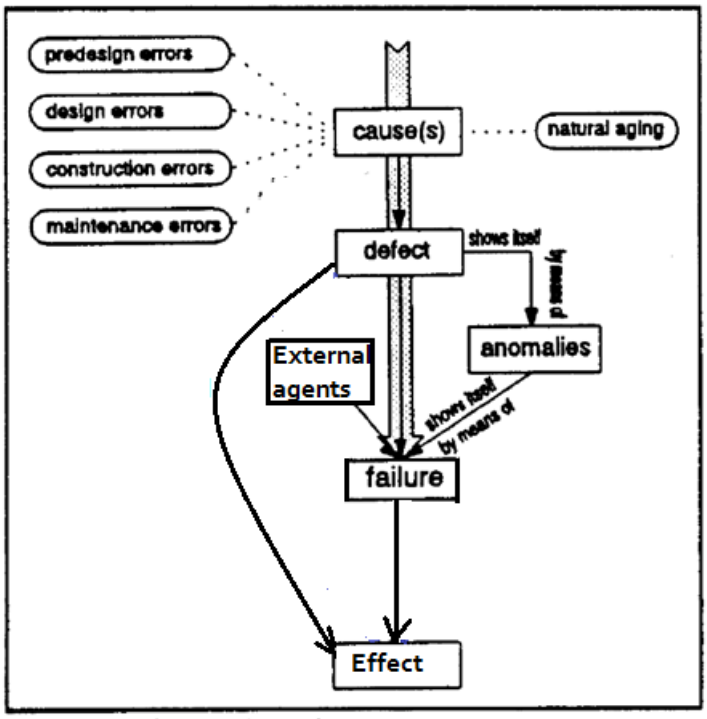


***Figure 4*: The decay process, from cause to effect (inspired from CIB report).**

Any material or building component is subject, by law of nature, to physical or performance decay. This decay cannot be considered pathological as long as it is congruent with the 'economic reasonable working life' which characterizes a certain group of products and components under normal maintenance conditions. This type of decay is defined in figure 4 as 'natural ageing'.

On the other hand, when the physical and performance decay (failures) and related anomalies develop unexpectedly in time and quality, and in complete contrast to the conventional concept of natural ageing, a pathological decay exists, leading to a defect. The pathological decay is mostly (if not always) started by errors or omissions (arising from imperfect human activities) during different stages of the building process.

Of course, defects could also arise directly from errors and omissions during design or construction. Typical errors, connected to human acts over the various construction stages are:

- Ignorance, incompetence or lack of experience leading to underestimating, complicating or neglecting (potential) problems;
- forgetfulness, inefficiency, negligence leading to direct mistakes or to omitting quality checks;
- underestimation or risks and excessive self-confidence leading to mistakes like for instance the use of excessively low safety coefficients, or overlooking the importance of specific checks.

The defect, therefore, may occur as a consequence of either a lack of judgement, a lack of care (mistakes), or a lack of precision.

The defects can either remain in a latent form, or manifest themselves by the action of external agents. Interaction between external agents and defects is the necessary condition for the manifestation of the decay as failure. The failure of building components can be structural, i.e. loss of

certain physical, chemical and technological characteristics. Or it can be performance failure, i.e. the drop of the initial performance level below an established acceptable limit. Or – most commonly – it may concern both aspects.

The decay process needs time to develop and it does not immediately cause components to pass from a performance to a failure condition. (This is highly relevant to the possibility of planning maintenance/repair strategies with a preventive purpose.)

'Anomalies' (*an indication of a possible defect or problem which is directly visible or measurable*) mostly manifest themselves before the final failure occurs. Then the anomaly becomes a sort of symptom which points at one of more (possible) defects.

But of course, besides these slowly developing failures, there can also be immediate and 'catastrophic' failures.

Finally, as a consequence of the failure, the effect (damage, injuries, non-functioning etc.) appears at the end of the process. But also a defect without a failure can lead directly to an undesirable effect.
Assuming that a defect is confirmed by objective signs, the next stage is to search for cause(s) and for measures that prevent or cure the defect. The way of handling may vary from a simple observation to consultation of a knowledge base or expert system (if available), or to a more elaborate investigation.

Building pathology not only offers information to directly involved parties - on some specific defect – but also information for matters like liability and insurance, costs of defects, quality assurance, regulations and the building community in general. This latest kind of information is generally given by way of publications, articles, information sheets, seminars, etc.

**1.3 Cause determination**

It is evident that the cause of a defect should be known in order to take the necessary effective measures. But where does the 'tracing back' stop? In general, any event of situation is the consequence of some foregoing event. This leads inevitably to a conclusion about imperfect human behaviour or knowledge, but does not imply that humans are always to blame.

Assuming that the analysis of cause(s) is determined by the use that is being made of the results, three types of cause descriptions are recognized, thus delimiting the in-depth search:

- technique-oriented descriptions (what caused the defect?)
- liability-oriented descriptions (who caused the defect?)
- system-oriented descriptions (how did the defect originate?)

A technique-oriented description of causes is needed to allow for the formulation of technical measures which will cure the defect or prevent an identical defect. Apart from the direct interests of involved parties, this type of information may well be of interest to interested parties in the construction sector and building 'educators'. In fact, this output of building pathology is generally given in forms like publications, seminars, defect information sheets, etc.

A liability-oriented description may be imposed by reasons of liability and insurance. Such descriptions point to 'faults' of persons or parties. The investigator should pay careful attention to objective evidence, and keeping also in mind that technical descriptions must be well understood and unambiguous.

A system-oriented description is required when causes of defects need to be 'input' for quality assurance (QA) in the building process. It is believed that QA – being a tool for managing a process efficiently and effectively – is most powerful in preventing defects. But QA is basically system-oriented: it deals in a managerial way with systems that aim at controlling matters like organisation, resources, communication, information, means, human resources, motivation and systematic feedback.

This implies that the output of building pathology – i.e. causes of defects – should be described in terms of system failures in order to be useful as input to QA. This way of looking at causes of defects is little practiced by building pathologists. It is hoped that modern QA schemes can profit from more system-oriented descriptions of causes of defects.

The way of getting to the 'sources' of a defect very much depends on its nature. But in general the determination process will follow some strategy of assessing possible causes, setting hypotheses and rejecting or adopting these hypotheses on the basis of facts. Such a process is quite close to the more or less formalized method of the so-called fault tree analysis, which is known from (industrial) processes and reliability analysis of structure.

Insurers are most likely interested especially in technique-oriented descriptions and liability-oriented descriptions.

**1.4 Effects**

- The effects, or consequences of failure may include hazards to health and safety, and it is frequently useful to categorize failures by their consequences. This allows prioritization of avoidance of component failures to be taken into account in evaluating their service lives on the basis of avoiding unacceptable risks to health and safety or other considerations critical to building owners or users. ISO 15686-1 (2000) gives the following table with a suggested hierarchy of consequences.

| *Category* | *Effect/consequence* | *Example* |
|---|---|---|
| 1 | Danger to life | Sudden collapse of structure |
| 2 | Risk of injury | Loose star tread |
| 3 | Danger to health | Serious damp penetration |
| 4 | Costly repair | Extensive scaffolding required |
| 5 | Costly because repeated | Window hardware replacement |
| 6 | Interruption of building use | Heating failure |
| 7 | Security compromised | Broken door latch |
| 8 | No exceptional problems | Replacement of light fixtures |

**Figure 5: Suggested hierarchy of consequences, from ISO 15686-1**

To these categories of direct effects, indirect damage could be added, like interruption of the business process of the building occupant, or non-functioning/non-performance of building parts.

As has been stated before, an insurer could interested in all these categories of consequences, depending on the type of insurance, and the coverage involved.

Some insurance companies may use their own classification of consequences. For example, the Danish Building Defects Fund distinguishes 5 levels of defects[2] and damages:

- **Level 1**: The building element is intact or has less significant building defects or building damage of insignificant extent. Sufficient information was present for all building elements. Regular service is sufficient.
- **Level 2:** The building element has less significant building defects or building damage of very modest extent. And/or information on less significant building elements is missing. Missing information should be provided. Recorded and eventual non-visible defects should be corrected or prevented by increased service.
- **Level 3:** The building element has significant building defects or building damage but with little extent. And/or information on significant building elements is missing. Missing information must be provided. Recorded and eventual non-visible defects must be corrected.
- **Level 4:** The building element has building defects or building damage to a great extent. It is likely that a building damage will develop or that a present building damage will develop further. Repairing is needed in continuation of the inspection.
- **Level 5:** The building element has serious building defects or damage that is of importance for the safety of persons. Immediate intervention is required.

Only the most severe defects (level 4 and 5) are covered by the Building Defects Fund.

**1.5 Chances and probabilities**

To carry out a quantitative risk analysis, in order to be able to estimate the risk in financial terms, an insurer also needs information on chances and probabilities (risk = chance X effect). The insurer needs not only the probability of occurrence of a hazard or a defect/failure, but also the probability of the loss or amount of damage which corresponds to the occurrence of each hazard/defect/failure. By combining these probabilities the risk function expressing the probabilities of the different amounts of loss being exceeded can be obtained.

Insurers usually derive these probabilities from internal databases with statistical information from claims.

Obviously, the more traditional a building product or a construction technology, the more statistical pathology information will be available. For innovative products/technologies there is less or no historical information available. In this case the pathology information for these products/ technologies can only be used qualitatively.

That means that the available information cannot be used for calculating risk premiums, but only for improving the technical knowledge of the insurer on these particular products/technologies. The

[2] Within in the nomenclature of the Danish Building Defects Fund, it is considered a building defect when project documentation, a building material, a structure or a part of a structure lacks abilities which can be expected according to the construction contract, public requirements or good building practice. This means that a defect is seen as a technical problem independently of the cause for the defect and independently of when the defect is observed. Building damage is used to describe unacceptable consequences of building defects.

insurer may use this technical knowledge for formulating strategies for conditions for the acceptance of these products/technologies for insurance coverage.

**1.6 Summary**

Building pathology is the systematic treatment of building defects, their causes, their consequences and their remedies. The science and knowledge of building pathology can be useful for an insurer in his risk assessment of building processes, actors and products. Diagnosis, which is the basic part of the building pathology discipline, is aimed at getting insight in the decay process suffered by the building components: the evolution from a performance to a non-performance condition, identifying the defects/failures and their causes and effects/consequences.

Building pathology information may help the insurer in his risk assessment in two ways: qualitatively and quantitatively.

- **Qualitatively**, by improving the technical knowledge of the insurer on particular products/ technologies. The insurer may use this technical knowledge for formulating strategies for conditions for the acceptance of these products/technologies for insurance coverage.
- **Quantitatively**, by providing statistical information on the frequency/probability of occurrence and the losses that the insurer may use to do the pricing of a cover and propose guarantees.

For innovative construction products, like eco-technologies, there is little statistical historical information available. In that case the pathology information can only be used qualitatively by the insurer.

Building pathology reports can be made directly for the interest of a certain party (for example a contractor involved in a claim by his client, or the court in a litigation process), but pathology information may well be of interest to all building participants and building 'educators', including insurers. In that case, the output of building pathology is generally given in forms like publications, seminars, defect information sheets, data bases, etc., and publically (or against a fee) available.