

## PROBLEMS IN FAILURE ANALYSIS IN BUILDING PATHOLOGY

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*Abstract: Compared to the emphasis of building pathology the human factors have significant role. These are not able to be eliminated, of course, indeed, the pluralistic society accepts the differences in opinions which derive from personal judgements. However, events occur when the difficulties of decision arising from the divergent appraisals cause considerable financial damage. Decreasing of the divergencies to the minimum is attainable through the decreasing of the subjective factors, what results the ability of comparison of different pathological analysis. The task of this paper is showing and analysing of the important devices of a unified pathological system. The comparison of different methodologies of analysis shows several methods of approach. The exploration of advantages and disadvantages can show the basic points in building an analysis method up.*

### 1. INTRODUCTION

Since the first experiments of home creation of human being to the mechanized execution of the recent building complexes the raised experiences and their application determine the architecture and the building science. Until the industrialization carrying of knowledge about building was a natural progress. The efforts in innovation failed in many times, but the behavior of materials and constructions came to know and the experiences were be able to apply in building.

The development of natural sciences and industrial background discovered new materials which resulted the appearance of new elements in building construction. Their behavior was unable to be defined by the traditional knowledge – the building of the last century had to be counted on scientific basis.

The modern approach in architecture can be characterized by its new elements in expression: flat roof, curtain wall, constructions assembled on site, etc. The analysis of this new elements was insolvable, because the existing tools were not adaptable in their examinations. Scientific examinations and special examining equipments had to be brought on which made the building pathology a science of building failures.

Outside of the area of architecture, the changing of economy is a significant factor in elevating the importance of building failure analysis. The main point of this factor was the oil - boom: the physical analysis of existing buildings had remarkable function.

Nowadays mathematics and the computer-aided modeling improved such level that constructions can be controled in virtual reality and the effects which influence them during their life can be foreseen. Nevertheless, the exact knowing of the behavior of the innovations, the new materials and constructions is available only in existent buildings and the experiences which derive from it can be applied by the aidance of building pathology.

During the maintenance of structures the expert of building pathology specifies the failures and their sources. The designer employs the results of examinations in creating new products. In

judicial process expert can be called upon specific examinations for finding the responsible factors of a failure. This enumeration shows that pathology can have many type of tasks, but in fact, one can define its function in decision arrangements.

The determinations of the relationship between building pathology and other parts of building (building trade, technology, designing, etc.) are different in the literature, but the definition of its function bring us closer to find the accurate identificaton of this applied science: decision-making has an important position in the progress of each field of building. Through the decision making the failure analysis is a significant buttress in the management of factories of building elements, for the designers as well as the building engineers and the maintainer companies.

The pathological experts in buildings have to perform the obligation of objectivity and skill. But there is a contradiction in their job: as a decision arranger, the expert describes the events and analyses them, but does not evaluate them [1.]. However, in the practice expert often uses reflection for accessing a better quality, influencing the steps toward the ending conclusion. If this reflection blends with inadequate skill, the expert's job makes more damage than the failue made before. Skill in our case means detailed knowledge of the the environmental effects, constructions and their materials.

The analysis prepared for decision making is often compare to alternative analyses for discovering the finest answer of a specific question. But comparing has difficulties, in case of properly made analyses, too. The cause of the difficulties can be found in the use of diverse structural terminologies, the different evaluation methods which result different conclusions. These difficulties are well-known for the research-workers in the field of building pathology. There some endeavors to solve the problem from several ways. Integration and systematization of building constructions, the collection of typical failure of each construction are tasks for research studies as as well as the preparation of a proper fault analysis system. The development of conceptions of integration was initiated by a research team in the Institute of Building Science, Budapest. The team work was suspended before it reached the result why the team was called into existence for. The systematization of building constructions is subject for disquisition in several laboratories of companies and institutes. The accuracy, elaboration and methods are different. The morphological method proved to be an effective instrument in the accomplishment of the system. The collection and systematization is an enormous task in consideration of the big amount of the constructions, their interrelations and effects. The evaluations about synopses of the experiences of the failure analyses and the applied methods of quality assessment – well known from decision analyses – can be useful in preparing a fault analysis system as a apparatus in building pathology.

## **2. PROBLEMS IN DEFINITION OF THE FAILURES**

### **2.1. Naming the building constructions**

At first sight the proper selection of terminologies does not seem to be so difficult. However, one must note that – through the regional and professional differences – same construction often has several names, collocations. For the integrity of terminologies in building a research team was activated in the Institute of Building Science (ÉTI), under the direction of dr. György Kunszt. ÉTI published its research team's main results in 1974 [2.]. The research workers' made their studies for building up the computer-aided information system of the Institute. The whole system is not accomplished, but the guidelines of the research paper can be the basis of the integrity system of building constructions. The thesaurus is a presentive congregation in the connotation of library science which contains every conception of a specific area, giving their main subordinaring relationships, the employable and taboo expressions in case of convertible terms, and occasionally, the standard logical relation (i.e. the frequent associations between conceptions).

The existing thesaurus, which is a part of the study paper, is only a frame, but the systematization can be based on it.

*The operation of the thesaurus [3.]*

For understanding the operation of the thesaurus, knowing of the elements of it has primary importance. The expression of elements came from the library science.

- D – descriptor: describes the conception
- T – taboo word: synonymous expression
- G – generic conception
- S – specific conception
- R – generic relationships between conceptions
- K – associations between conceptions

The main aspect of evolving the thesaurus is that the descriptor which describes the building constructions has to mention conceptions by extension as well as the proper and the synonymous conceptions. Giving an example from the Morphologic System Of Building Constructions [4.] can enlighten the method: the observation of relations of the “ledge” (“corbel”) – “brick ledge” – “wooden ledge” and the conception “ledge covering” guides us to understand the thesaurus.

The “ledge” is an extended conception of the “brick ledge” and the “wooden ledge”, that is why the expression “ledge” has generic connection with “brick ledge” as well as with the “wooden ledge”, from the view of these special ledge. One can say the “ledge” is a generic conception (G) of “brick ledge”.

The “brick ledge” and the “wooden ledge” are two special “ledge”, which means that they have specific connections with the expression “ledge”. Briefly, “brick ledge” is a specific conception (S) of “ledge”.

The “corbel” and the “impost” are synonymous expressions of “ledge”. In the point of view of unambiguous thesaurus these expressions are not allowed. These are the taboo words (T).

The common character of conceptions “brick ledge” and “wooden ledge” is that they are in generic connection with the conception “ledge”. In this case their relation is generic (R).

The conception “ledge covering” is often occurs with the conception “ledge”, but it is neither in generic, nor in specific relation at all. The “ledge covering” is in associative relation (K) with the conception “ledge”.

The statements above can be illustrated easily from the aspect of the conception “ledge” and its circumstances (fig. 1.).

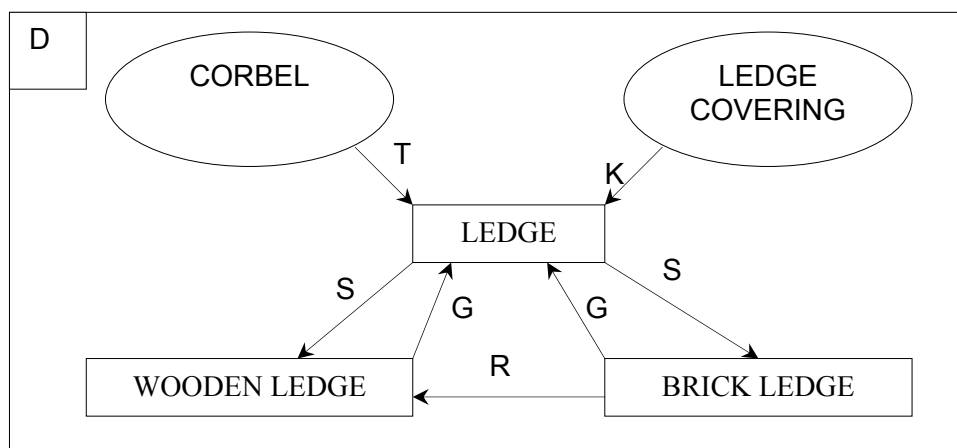


Figure 1. The Relationships in Thesaurus of Building Constructions – Detail

Analyzing the structure of the thesaurus, beside this method one can find other important structural questions. The order of the characteristic indications in description, and other rules in thesaurus building are not mentioned here.

## 2.2. Defining the failures of building constructions

### *Appraisal of failures*

First of all, the main questions which have to be answered by the expert in the process of analysis can be divided in five groups. These types of questions are often raised together but some of them are not subject of examinations in specific cases.

1. Statement of the damage degree of failure
2. Possible ways of repair or renovation
3. The cause(s) of the failure, and through this question the responsibility
4. Cost of failure
5. Drawing the experiences of the failure

The last group is useable directly in decision-making, but the experiences help the experts in the following situation which they have to analyse.

Comparing the results of pathological examinations meets two essential difficulties. The first is the improper definition of constructions as it is described above, the second one is the divergent methods of appraisal.

Divergencies in the methods of appraisal also can cause confusion in decision-making. Experts who are often asked for valuing the conclusions of their examinations (i.e. under judicial procedures) cannot avoid the using of personal opinion: unimportant factors of a fault can be emphasized and significant events can escape the experts' attention.

To avoid these confusions the drawing a method of building pathology up can be a useful tool in the hand of failure analysers. The basis of this method is a collection of the proper and unambiguous definitions of the failures of structures and the effect(s) or event(s) which can cause the specific failure. Nowadays the failures and their causes form an immense mass which is tried to be systematic by several research institutes [5.]. Keeping the clearness in view the systematization of the failures and effects is based on the morphological system of the building structures. The collection and its systemization is an enormous, time-consuming task, which results the so-called fault catalogue.

### *The fault catalogue*

The fault catalogue is a kind of lexicon of failures in the sight of building constructions. The failures (examined in every possible relation) are stored under the name of related constructions. Until recent times, neither the catalogue nor its frame are established, but the Congress of W086 (Committee of Building Pathology), CIB (International Council for Building Research Studies and Documentation) stated the position of it [6.], (see fig. 2.). To understand the figure the definition of defect has to be known: in building pathology the word defect is used sometimes almost as a synonym of "failure", but preferred meaning is to indicate only a deviation from some (perceived) standard which may, but will not necessarily result a failure.

The catalogue which will be hopefully ready in the immediate future focuses on the structure, the interrelations between structures and the effects of the environment to the structure by listing the faults and their causes. The showing of the links between facts has to be shown for the exact assessment.

### *Problems in the systematization of failures*

Appearance of new materials and constructions in building. The recognition of the failures of constantly forming constructions and increasing variety of materials (constructions reinforced by carbonic fiber, spread of plastic and aluminium structures, etc.) can happen in the practice. Since the building pathology is based on these practical experiences, the examinations – beside the laboratory tests – occur after the application of the new constructions and materials. In the studies of technological assessments experts call this situation as the 2<sup>nd</sup> paradox of introduction of new technology (before the introduction of technology one can act against the failure but does

not know the failure he has to act against, after introducing one knows the failure but he is incapable). That is why the function of pathology in the building as a whole is basically “feedback”. Deriving from the appearance of new materials and constructions the fault catalogue (Database) is a constantly growing factual material. Hence the catalogue can not be a closed system.

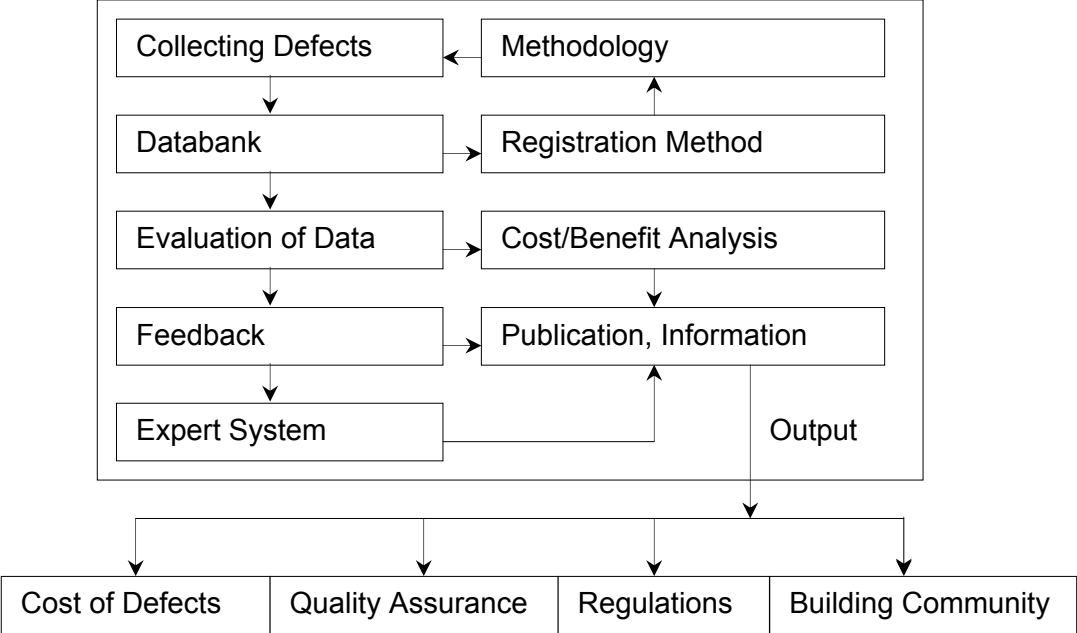


Figure 2. The Method of Application of Experiences

During a systematic analyzing the expert can show such detailing and comprehensive image about the defects, which determines the following tasks with the discussed building or its structure. However, this thorough analysis is not really important in the practice. Expert has to examine the failure from several specific respects. Focusing in different factors of failures needs different approach, and, in many cases the examination of every factor is unnecessary. Considering the statement above the expert’s job can be hindered by the systematic analysing – in spite of its advantages. In certain cases only a part of the analysing method is required, and sometimes the needed detailing of examination is determined in advance.

It is rare that a failure arises alone: many other concomitant phenomena are recognizable. Common defect is often deducible from their collective appearance. The other extreme is when expert can find several causes that evoke the failure. The situation that a defect causes fault only in case of the presence of several other conditions. That makes the representation of the relations of failures and causes difficult.

*Solution of the problems*

The fact of the problem based on the excessively detailed method is an important consideration in user-friendly forming of the catalogue: the optional determining and extending of the circle of the questions to be answered.

The problem of the immense link system can be interpret as a problem of graphical representation. In this approximation the use of the computer technology is a possible solution to the difficulties which derives from the enormous variety of links between failures, defects and effects.

The constantly increasing the database is solvable with a well-built frame of the database by computer.

Summarizing the problems and their solutions one can state that the technological support of our days is suitable for the tasks what comes from the questions of fault catalogue.

### **3. METHODS IN FAULT ANALYSIS**

For approaching the complex system for failure analysis several methods were elaborated. Differences between the methods can derive from the cultural and professional background. The introduction and analysis of them can enlighten the difficulties of failure analysis.

#### **3.1. Károly Möller's Analysis**

The author's booklet about failures was published in the middle of this century [7.]. He collected his practise experiences and then classified them. The detailing categories which exceed the area of pathology give point of reference for investigate the realized buildings thoroughly. The main advantage of this methodology is its suitability for examining the architecture – building technology – industry as a whole. The disadvantage springs from some improper categories, which call for explanation, for example the term “tender claims impossibility” is not really exact. Another fact, that judgement of some categories is excessively based on the personal opinion, i.e. “not sufficient from aesthetical respect”.

The detailing of the analysis can hold the effectiveness of the examination process. That is why one can state that the establishment of specification depends on the emphasis of decision. In the case of more serious analysis this method can be an efficient device in the hand of expert.

The diagram showed below (fig. 3.) is based on the statements of the booklet.

#### **3.2. Failure Analysis in Quality Insurance**

The methods of quality insurance system on the field of technology assessment contain important achievements for building pathology in methodology. Modern management constantly controls the quality of the products, the results of the control are employed in the process of manufacturing (feedback) which improve gradually the quality [8.]. The function of pathology in the building process has similarity with quality insurance in management.

Several methods were elaborated recently. The example now is a simple diagram (fig. 4.) which explore several aspects of failure. Contrary to the previous method this is suitable only for examining the deterioration of the product, it does not take the human, economical factors into consideration. It does not help in finding the relation between failures and defect.

It is worth observing that one can choose primary or secondary cause of the failure (the choice can be “or”; “and”), which makes possible to examine the complex character of the failure. This point of view is important, because this supposes that a failure can lead to another failure.

#### **3.3. Schwachstellen Books**

The authors of the book series [9.] are research team members. They were asked for analyse faults on different fields of building. Beside their tasks they collected their experiences to publish them to the other experts. The research workers were aware of the impossibility of the treatment of every failure and the knew that the relations among the defects of the failure differ in every case. That is why the team made statistics (based on its researches) for determining the relative incidence of the failures among several structures, pointed out the weak points of the building structures (walls, roofs, etc.). Focusing on these structures the examined area was tightened to the essential defects which cause certain failures. The statistics – in spite of its specification – results the effective utilisation of the building pathology, leaving the not frequently occurred errors. An order of significance was made, based on scientific background (i.e. the exterior walls are important subject of examining, the floorings have less importance).

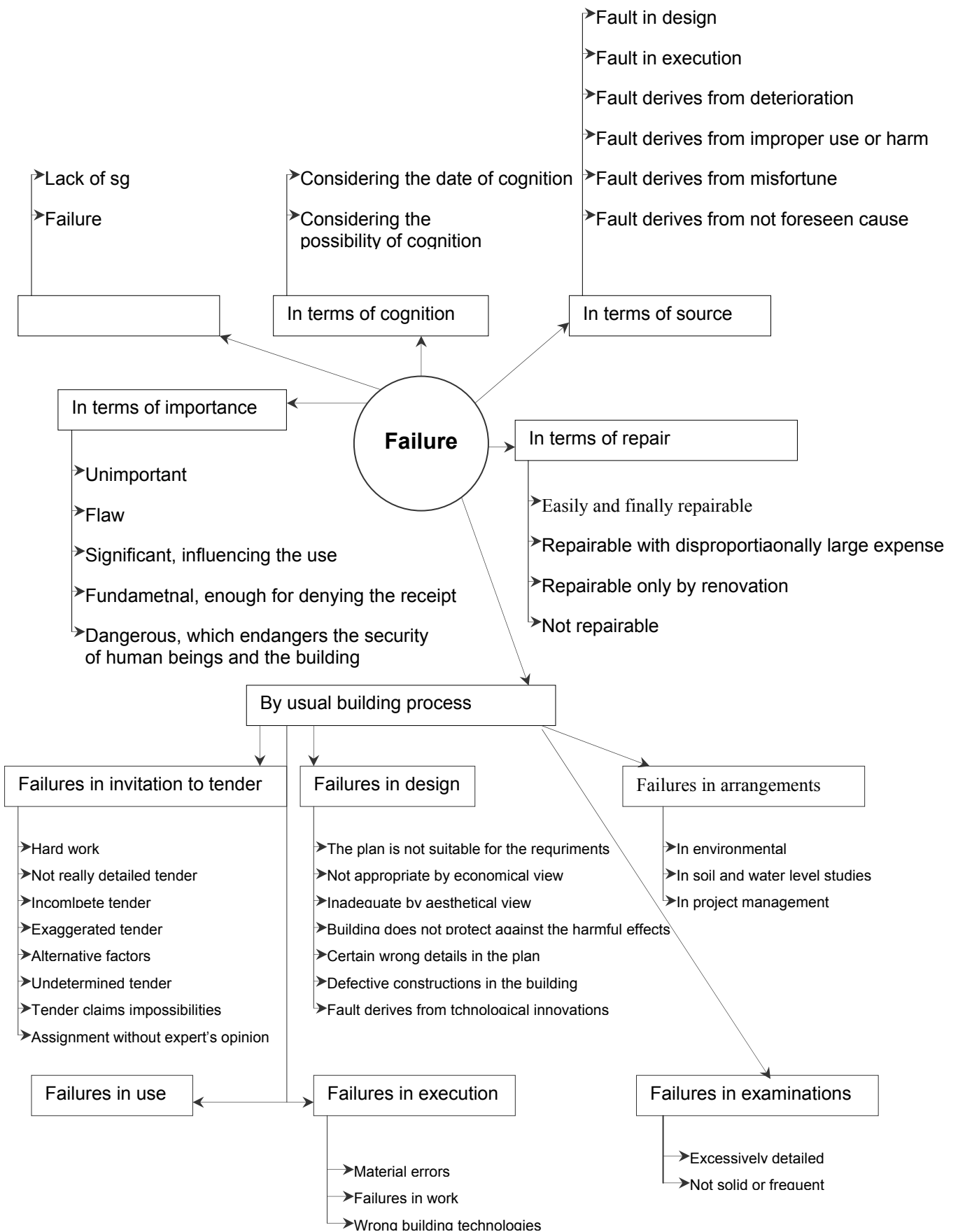


Figure 3. Method of Analysis by Möllers' experiences

The lack of the research paper are the examinations of interrelations between constructions and it does not treat every possible factor (i.e. human and economical factors) which could cause the observed failure. This study is not applicable directly in practice: the result of statistics does not reflect the incidence and importance of failures, indeed, one can state that the team's authority could mainly include the area of exterior walls. The problems of flat roofs are significant in Germany as well as all around the world, but the statistics shows that the exterior walls has six times more importance than the flat roofs. In spite of the arbitrary order the books have a special advantage: the discussed failures are illustrated and beside the circumstances which have to be examined during the process of analysing, a possible solution is illustrated as well.

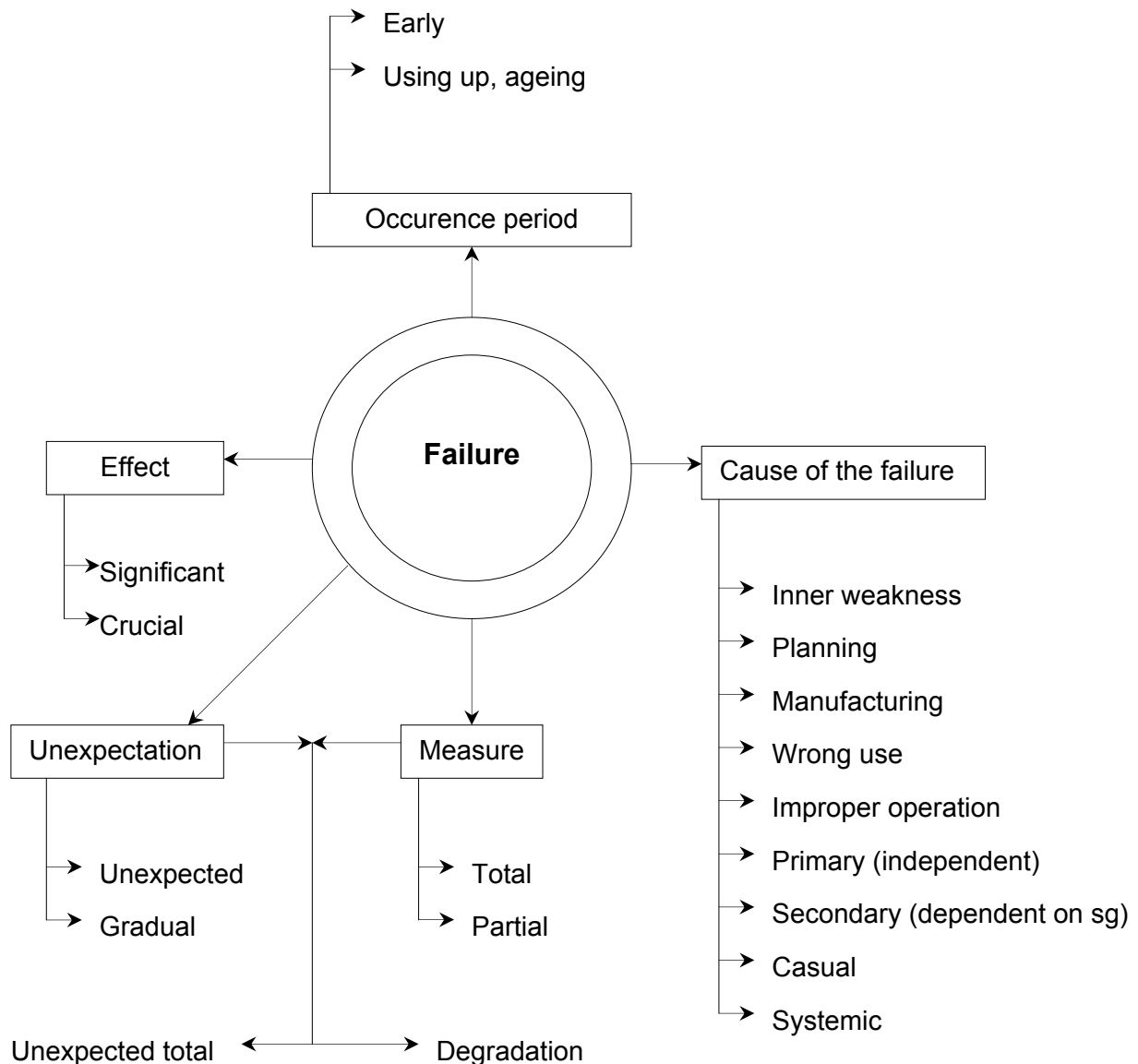


Figure 4. The fault analysis in quality insurance

### 3.3. FAULT TREE ANALYSIS

Similarly the failure analysis in the quality insurance, the fault-tree analysis is also a part of a decision assistance system. The application of computers made possible the spreading of this method. Nowadays it is a successful method in examining whole systems, mostly for ascertaining the errors and their origin in computer networks.



The fault-tree [10.] is a logical diagram, that displays the interrelationships between a potential critical event (accident) in a system and the reasons for this events. The reasons may be environmental conditions, human errors, normal events (events, hich are expected to occur during the life span of this system), and specific component failures. A properly constructed fult tree provides a good illustration of the various combinations of failures and other events which can lead to a specified critical event.

#### *Drawing a fault tree*

Generating a fault tree always starts with the identification of a critical, so-called top event. It is very important that the top event is given a clear and unambiguous definition. The description of top event should always describes what type of critical event is occurring, where and when the critical event occurs. Thereafter the expert has to try carefully to identify all fault events which are immediate, necessary and sufficient to cause the top event to occur. These fault evets are connected to the top event by means of a logic gate. If the user proceed like this, level by level, until all fault events have been developed to the required detail. The analysis is deductive and is carried out by repeatedly asking “What may cause this event to occur?”

The logic gate can be AND, OR, KOON, INHIBIT. The AND-gate is used to indicate that the event will occur if all the Input events occur simultaneously. The OR-gate indicates that the output event occurs if any of its fault events occur. The KOON-gate is used to indicate that the event will occur if any combinations of the input events occurs. The INHIBIT-gate is used to indicate if both the conditional event and the in-going event occurs.

Event can be BASIC, HOUSE, UNDEVELOPED. The BASIC event represents a basic equipment fault or failure that requires no further development into more BASIC events or failures. The HOUSE event represents a condition or an event which is true or false. The HOUSE event may be used to include or exclude the part of the fault tree which is connected to the event. he UNDEVELOPED event represents a fault event that is not examined any further because information is unavailable or because it is insignificant to the result of the analysis.

The Committee of Building Pathology, CIB was dealing with the possibilities of the application of fault tree analysis [11.]. The advantage of this device is the systemic analysis of the interrelationships among failures and defects, and it can give numerical data about the effects of specific events. Some experts pointed on the disadvantage of the method: the analysation has to be built in every case, its conclusions cannot be employed directly in another process. But this disadvantage may be noticed as an advantage, customs can be avoided which can arise from the analyses of frequent failures.

## **4. EXAMPLE**

For the comparison of the analysis methods described above showing their application in a specific example can help. In this case the expert does not meet with new, never seen relations, thus it will be able to show only the differences between methods.

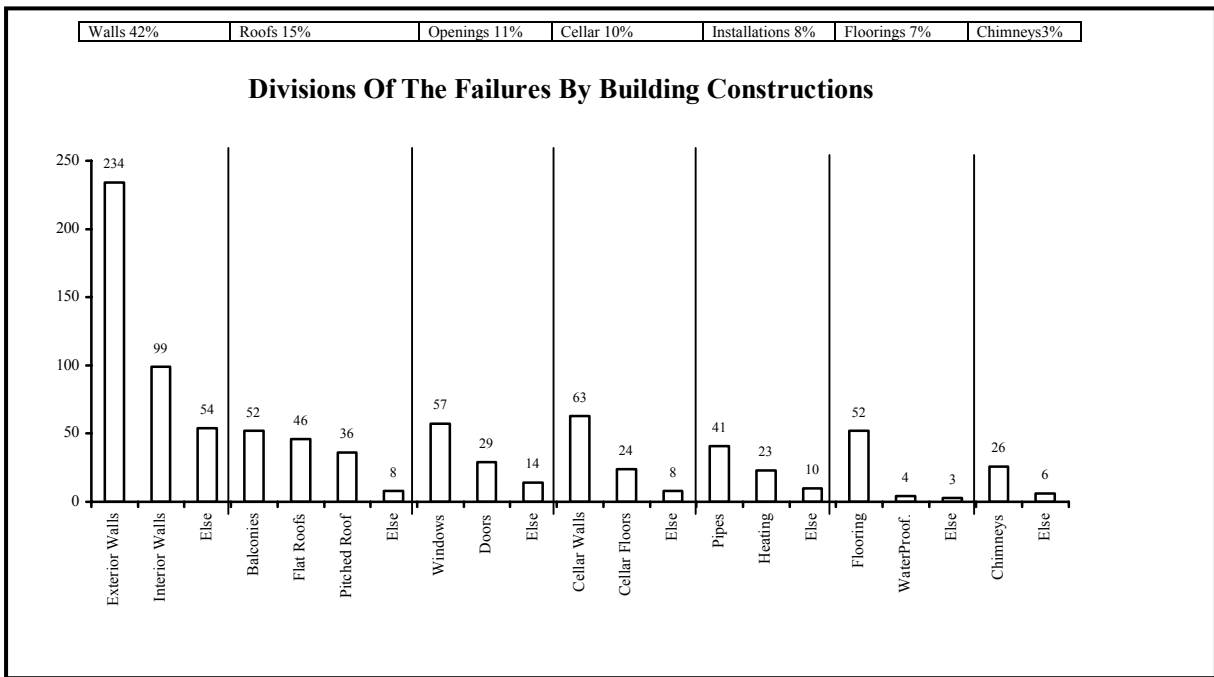
### **4.1. Surveying the case**

Salgótarján Town Court, Nógrád County, asked IMSZB (Judicial Technical Expert Committee) for its expert opinion in a case at law. The writer of this publication has participated in the examination and analysed the observations.

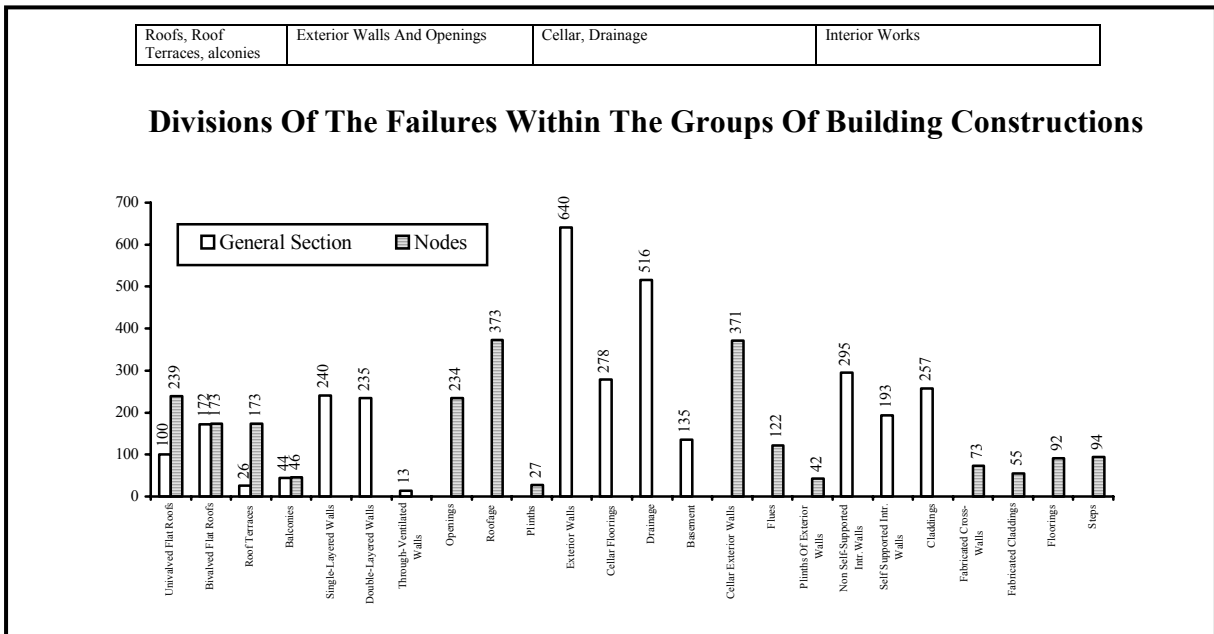
The subject of the case was a mildew problem: the exterior wall of an apartment on the top floor of a multilevel apartment house was mildewing under the window. Experts had to declare the factors which caused the mildew. The examination on the spot, the study of the plans of the building and the documentation of the suit involved the following facts:

Figure 5. Statistics of Schwachstellen Analyses

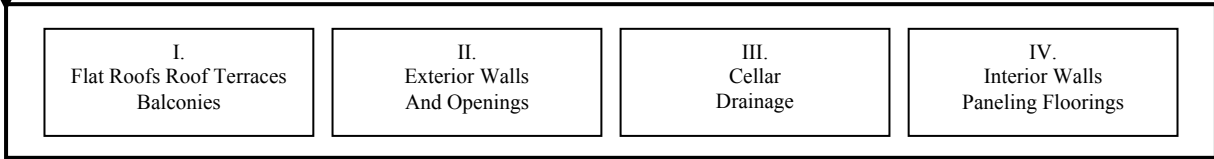
**Phase 1** **General Representative Study About The Failures Of Apartment Houses**  
 Result – Range Of Building Failures - Main Features of Failures In Building – Periodic Dependence



**Phase 2** **The Examination Of The Main Point Within The Groups Of Building Constructions**  
 Result – Frequency Of Failures Of Certain Constructions – Types Of Failures – Failures And Their Causes



**Phase 3** **Display And Analysis Of Weak Points**  
 Failures, Causes, Propositions In Constructions And Execution



**GOAL** USE IN BUILDING PRACTICE – ESTIMATION OF BUILDING FAILURES – AVOIDANCE OF FAILURES IN PLANNING AND EXECUTION

- The building is a five-storied, flat-roofed apartment house. Its construction can be described by its diagonal load-bearing, monolithic reinforced concrete (16 cms) and floors (14cms).
- The facade wall is prefabricated, insulated “sandwich” panel, the details of the plan show 2 cms heat insulation in the structure.
- The openings of the apartment are wooden windows with united casement. The rooms are papered by paper material.
- The handing over of the building was in 1981 and it was suitable for the technical standards of that age. the facade wall of the building is hardly suitable in the respect of heat insulation, it has no thermal reserve.
- The individual heating of apartment does not work because of the suspending use.
- Mildew was visible on the inner surface of the facade wall, under the window, from wall to wall, but the location of the mildew seemed dry (see fig. 5.). Mildew was also noticed on the ceiling of the bathroom. Painting was peeling off from the ceiling. The casement of the windows was decayed, missing of wadding was clearly visible.



Figure 5. Mildew traces on the facade wall

#### *Facts about mildew*

Serious existence of mildew is harmful to health. The literature of the mildew problem is enormous, nowadays experts certainly know all the facts from which the problem arise. From the results [12.] of this type of examinations the main components and events appear at the high raised apartment houses:

- Adverse heat streaming at the corner of the panel elements and the join of the window in the facade wall;
- Lack of efficient air ventilation and low interior temperature (wrongly construed energy-saving);
- Existence of high relative vaporization (streaming of the humid air from the bathroom to the rooms and sometimes drying of the washed clothes in the rooms);
- Inadequate heating insulation.

It is stated that the appearance of mildew can only happen in case of common existence of components described above.

## 4.2. Analysing the Discussed Failure by Several Methods

Before the treatment of the case expert has to know that the plans and the execution was proper by the standards of their age. Since then a new standard came into force, in our time the insufficiency of the former thermal standard is proved.

### *Möller's analysis*

Based on the method, the mildew is:

- Failure (by legal categories);
- Noticeable without skills, after the expiration of the guarantee date (in terms of cognition);
- Not possible to state the origin (in terms of source);
- Significant, influencing the use (in terms of importance);
- Except of arrangements and examinations errors occurred in every building process.

### *Analysis by quality insurance*

The factors of mildew, as a failure are:

- The cause is: inner weakness, planning and wrong use. This failure is primary (independent) and systemic.
- Measure is partial. The failure was manifest itself gradually in the early period of the structure.

### *Statements by the Schwachstellen analysis*

The statistics point on the fact that this failure often occurs and the problem can arise from the weak points of exterior walls and openings as well. That is why expert can find experiences from previous examinations and, provided that there is no same situation, he can apply them.

The available data indicates that the causes have to be found in either the improper joint between the bottom of window-sill and the concrete wall or in the insufficient insulation in the general section of the wall. The analysis and the mildew traces (which is visible on the whole surface in stains) let the observers come to the conclusions that the defect from the point of building constructions is the wrong properties of the wall.

### *Fault tree analysis*

The visualisation of the interrelations among events and the systemic analysis of the discussed failure make the assessment easy. Beside this the recently found events and their relations which were not known before can be fed into the fault catalogue, that is why the fault tree analysis may be an important part of the building pathology. On the diagram the values are invisible, but the mathematical background can measure the probability and the rate of emphasis of events or errors in a fault.

On the figure the fact is spectacular that the basic events can be divide into three parts: environmental circumstances (the existence of mildew spore); structural conditions (The wall has low capacity of water absorption, not "breathing" wall); and conditions derive from the apartment use (high vapor load in the room, etc.). The rate of the conditions are also visible.

## 5. SUMMARY

The great variety of analysis methods shows identity in one question: they are necessary in the process of building pathology. The proper detailing and objectivity of the final conclusion can only make the expert reliable in decision arrangement. The decision-making is effective only if the results of examinations are ambiguous and comparable. For approaching this, consistent vocabulary and method are required.

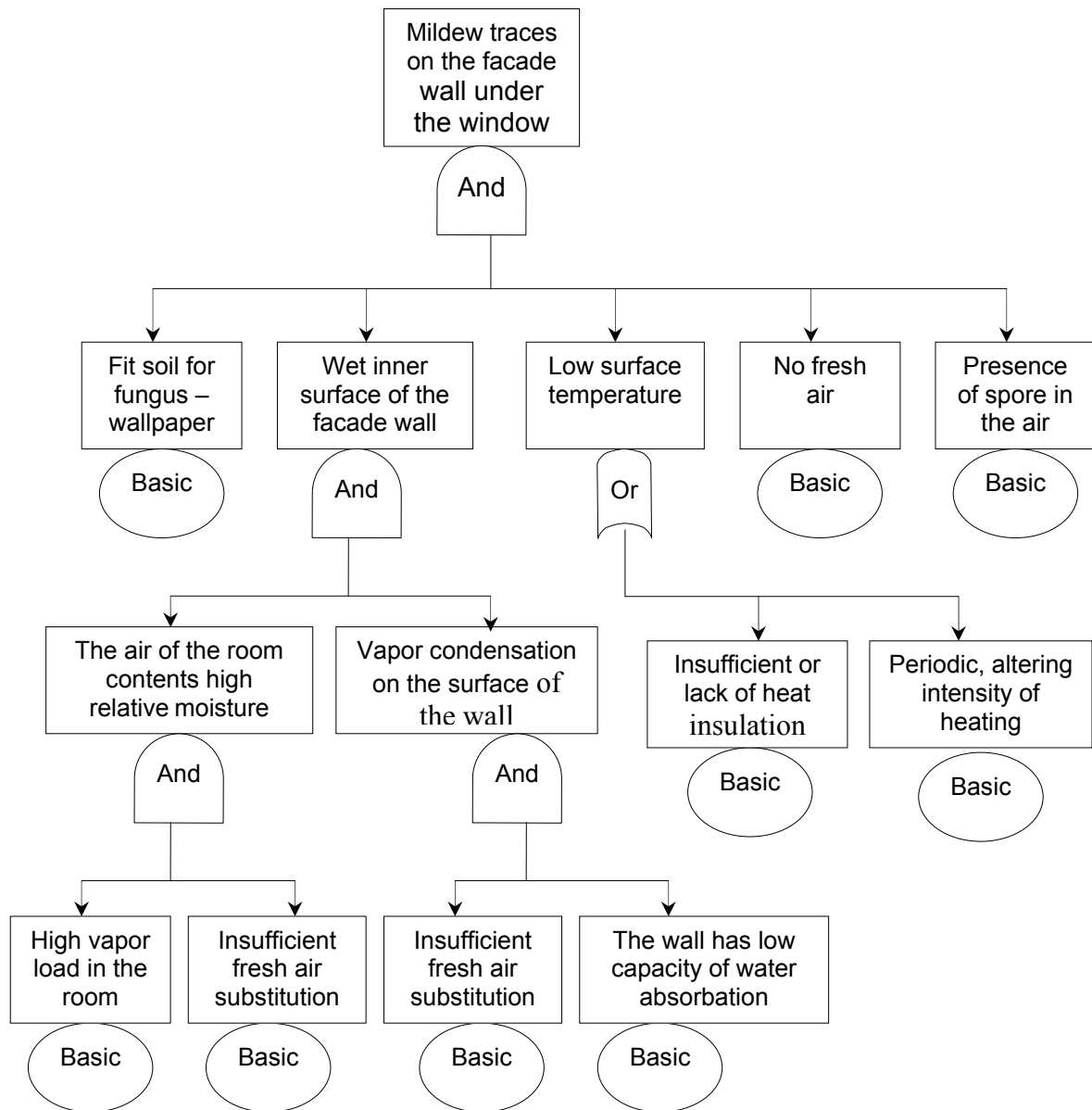


Figure 6. Fault Tree Analysis

For creating the consistent vocabulary the main tasks are to systematize the building constructional terminologies based on the thesaurus method, and to prepare the (illustrated) fault catalogue focusing on the structures.

The choice or creating an analysis method has great importance in the respect of comparison of the results. Each analysis method has advantages and disadvantages in several points. The most suitable method may derive from the application of their advantages, considering the option to determine the detailing and the most significance questions depending on the discussing case by the expert.

The frame of the thesaurus and the analysis method may be built up with the abilities of the computer technology, that serves good solutions in illustrating the relationships between structures and failures as well as between failures and their defects. The experiences from the past and present time may be a part of a useful database for the experts of building pathology as well as the results which will derive from the fault analysis method.

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