IDENTIFICATION OF BUILDING- AND USAGE-DEPENDENT PARAMETERS WITH SIGNIFICANT IMPACT ON MAINTENANCE EXPENDITURE VIA LIFECYCLE ANALYSIS

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ABSTRACT

In order to counteract the further increase of maintenance backlogs, building maintenance needs to take center stage in the upcoming years. Especially owners of large property should try to optimize the maintenance of their building portfolio using a minimum of resources. To this end, the correct calculation of the maintenance resources required is vital.
Within the context of the research project BEWIS (Optimized upkeep strategies to maintain value of buildings), the department for Facility Management of the University of Karlsruhe (TH) analyzed twenty buildings regarding maintenance or value-increasing measures. The analysis concerns all value-maintaining or -increasing measures realized over the complete lifecycle of a building. The specific objective of the project is the development of a calculation tool for maintenance cost. A number of building- and usage-dependent parameters, like the age of a building, its technical equipment or the buildings geometry, have to be considered.
The analysis of real lifecycle data helps to identify parameters that have significant impact on maintenance expenditure.

KEYWORDS

Maintenance of buildings, calculation of maintenance resources, identification of parameters with significant impact on maintenance expenditure

INTRODUCTION

Faced with increasing maintenance backlogs, a focus on building maintenance will be needed in the upcoming years. Especially owners of large property should try to optimize the maintenance of their building portfolio by using a minimum of resources. To this end, the correct calculation of required maintenance resources is vital.
Every year, maintenance experts need to estimate the annual maintenance cost for their real estate portfolio – to date a nearly insoluble question. They lack sound and realistic calculation methods for the prospective calculation of maintenance costs. Therefore, many maintenance experts simply refer to last year’s figures or use very imprecise calculation methods, ignoring vital parameters like the increasing age of a building or rising construction costs. These methods therefore do not lead to realistic maintenance cost calculations; as a result, essential maintenance activities often cannot be carried out due to lacking financial means (Kalusche and Oelsner, 2003). This is one of the reasons why the quality of public property in Germany has been decreasing over the last years.
The question is: Which parameters influence the cost of maintenance and how?

STATE OF THE ART

To date, it has not been clearly defined, neither by research nor practical experience, which parameters influence property maintenance in which way. Regarding construction costs, it is well-known which factors matter for different planning variants. Architects and other planners can obtain comprehensive information from standard works of reference or information centers like the building costs information center of the German Chamber of Architects (BKI) (Elwert et al., 2007), (BKI, 2006). In the area of operating expenses, especially maintenance costs, research data on cost-defining factors is only scarce.
As a result, a number of different budgeting scenarios weigh factors differently or not at all. The method used by the KGSt (KGSt, 1984), for example, includes the age of a building, its technology level and its use, weighting these parameters in the following way for budgeting:

Table 1: Weighting factor "age" according to KGSt

Age [a]	0 - 10	10 - 30	30 - 80	beyond 80
Weighting factor G_A	0,4	1	1,2	1,3

Table 2: Weighting factor "technology level" according to KGSt

Technology level	15 %	20 %	25 %	30 %	35 %	40 %	45 %	50 %
Weighting factor G_T	0,8	0,9	1	1,1	1,2	1,3	1,4	1,5

Table 3: Weighting factor "kind of use" according to KGSt

Kind of use	office buildings	residential house	schools	youth facility
Weighting factor G_N	0,9	0,9	1,1	1,1

According to KGSt (KGSt, 1984), the maintenance budget is calculated as follows:

$$K_{IH} = 1{,}2\ \% \cdot WBW \cdot GF_{tec.} \cdot GF_{age} \cdot GF_{use} \qquad (1)$$

K_{IH}	*annual maintenance costs [€/a]*
WBW	*replacement value*
GF	*weighting factor*

The second regulation on calculation (II BV, 1990) only takes into account the age of a building when determining maintenance costs. The following table shows the cost indicators and respective age grades:

Table 4: Maintenance reserve fund depending on building age according to II. BV

ready for occupancy before	max. maintenance reserve fund [€/m²a]
max. 22 years	7,10
min. 22 to max. 31 years	9,00
min. 32 years	11,50

The Berlin method (Bem, 1976) does not take into account the age of a building. In contrast with the second regulation on calculation, this method includes the technology level, i.e. different lifespans for different building parts with differing wear and tear characteristics. No other factors are used. The maintenance budget is calculated as follows:

$$K_{IH} = WBW \cdot [HBA \cdot 1{,}2\,\% + TA \cdot 4\,\% \; + TA \; \cdot 1\,\%] \quad (2)$$

K_{IH} annual maintenance costs [€/a]
WBW replacement value
HBA Percentage of building construction
TA Technology level
Maintenance percentage: 1 %

The working group AMEV mechanical and electrical engineering of national and municipal administration (AMEV, 1984) also calculates the maintenance budget dependent on the age of a building as well as its use. Like the Berlin method, AMEV only considers the technology level for budget calculation. The following formula shows, however, that the technology level is considered less important than by the Berlin method.

$$K_{IH} = WBW \cdot [TA \cdot 2{,}3\,\% \cdot + HBA \cdot 1{,}0\,\%] \quad (3)$$

K_{IH} annual maintenance costs [€/a]
WBW replacement value
TA technology level
HBA percentage of building construction

The so-called Bavarian method (Bayerisches Verfahren, 1985), which was developed by the building authority of the Bavarian Ministry of the Interior (OBB) in 1985, is the only method to take into account the building cubature. It states that the age, use, technology level and the relation of gross volume - main usable floor space as well as the gross volume itself influence the maintenance costs. Based on this assumption, annual maintenance cost is calculated as follows (König and Schnoor 1988):

$$K_{IH} = RP \cdot BRI \cdot GF_{\mathrm{age}} \cdot GF_{\mathrm{use}} \cdot GF_{\mathrm{tec.}} \cdot GF_{\mathrm{BRI/HNF}} \cdot GF_{\mathrm{BRI}} \quad (4)$$

K_{IH} annual maintenance costs [€/a]
RP price per cubic meter [€/m³]
BRI gross volume [m³]
GF weighting factor

HNF main usable floor space

The ranges of the weighting factors are as follows:
GF_{age}: 0,15 (age > 1 year) to 1,0 (age >18 years)
GF_{use}: 0,33 (production, distribution, storage) to 1,5 (office)
GF_{tec}: 0,9 (percentage < 18 %) to 1,5 (percentage > 42 %)
$GF_{BRI/HNF}$: 0,4 (relation >10,5 %) to 1,0 (relation < 42 %)
GF_{BRI}: 1,0 (BRI > 90.000 m³) to 2,1 (BRI < 1.000 m³)

More on the influence of certain parameters can be found in special literature. The collection of historic life-long maintenance data is difficult. Therefore, the real influence that these parameters have on maintenance costs has in most cases not been proven scientifically.
Many authors state age as a building-relevant factor. They assume that maintenance costs rise with the building's age (BMBau, 1989), (König and Schnoor 1988), (Hampe 1986), due to wear and tear caused by the use of the building parts. Although it seems clear that maintenance costs increase with age, very few studies really prove and quantify this relation. In the 1980s, Simons and Sager realized a comprehensive study in the area of housing construction (Simons and Sager, 1980).
The technology level is another building-relevant factor that many experts consider important. Due to the relatively short lifespans and high service and maintenance needs of technological equipment, a building's maintenance costs rise with its technology level (Kalusche, 2004), (Tomm et al., 1995).
Some studies and publications see the building size as another vital factor, making partly contradictory statements. Simons and Sager (Simons and Sager, 1980) as well as Schub and Stark (Schub and Stark, 1985), for example, assume that maintenance costs per square meter rise with the size of a building. On the contrary, research of FM Monitor (FM Monitor, 2003) and the BMI Special Report 341 (BMI, 2005) shows that maintenance costs per square meter fall with the building size. This can be explained via the economy of scales.
Most publications consider the kind of use of a building a decisive factor for cost calculation. This relation was already shown by Burianek (Burianek, 1973). The municipal centre for administration optimization (KGSt, 1984) and the Ministry for Regional Planning, Building and Urban Development (BMBau, 1989) also see a relation between maintenance costs and type of use. A number of benchmarking studies, for example the BMI Report (BMI, 2005) or the IFMA Benchmarking Report (IFMA, 2005), differentiate between several types of use.

RESEARCH METHODOLOGY

Cost-relevant factors are analyzed using the lifecycle data from the BEWIS (Optimized upkeep strategies to maintain value of buildings) project. The project was initiated in 2002 by the department for Facility Management of Karlsruhe University (TH). The method used is comprehensively described in EFMC Proceedings 2006 (Pfründer et al., 2006) and 2007 (Bahr, C. et al., 2007). Therefore, only a brief outline of the method is given here.

The BEWIS project compiled maintenance data of 20 buildings over their complete lifecycle. The buildings altogether comprise a gross floor area of over 190,000 m² and over 24,000 different maintenance measures. This equals maintenance expenses of € 1.76 billion. The collected data give detailed information on which kind of measure was carried out when to which building part and why. Additionally, the location and the construction costs of all buildings were registered. Beside the maintenance expenses and the general building information, the maintenance backlog in Euros was calculated.

One of the objectives of the research project is the development of a calculation tool for maintenance costs. A number of building- and usage-dependent parameters, like the age of a building, its technical equipment or the building's geometry, have to be considered in detail.

EVALUATION

First, the real data from the project is used to analyze how the age of a building influences maintenance costs. Figure 1 below shows the development of maintenance costs over the lifespan of the analyzed examples. To enable cross-year comparisons, costs were consistently related to the 2004 construction price index.

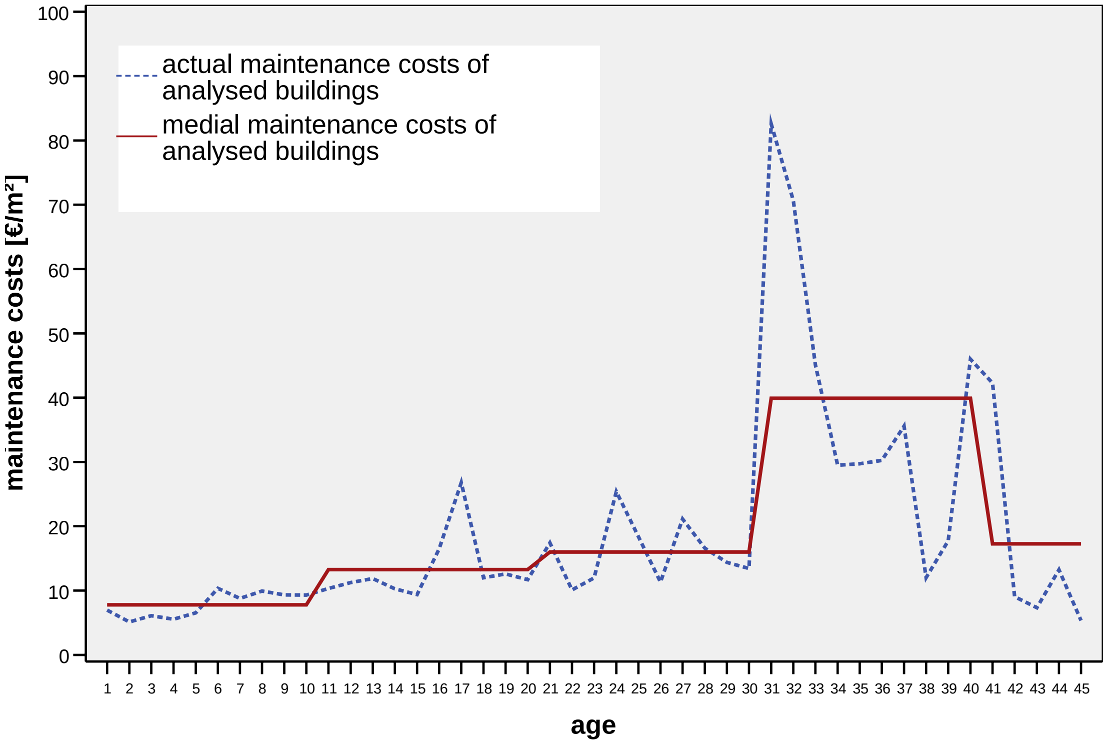

Figure 1: maintenance costs of analyzed buildings

The analyzed portfolio comprises 20 buildings. The graphs show the median development of maintenance costs. The blue dotted line shows the actual annual costs, the red line marks the median values over 10 years. It can be seen that that maintenance costs rise consistently over the first three decades, then jump up from year 30 on and drop to a lower level after year 40.
Maintenance costs were registered exactly per maintenance measure enabling differentiated data analysis. Figure 2 shows which measure was carried out to which building and when. The basic measures of "preventive maintenance", "service inspection", and "corrective maintenance" according to DIN 31051 (DIN, 2003) were summarized as annual maintenance measures.

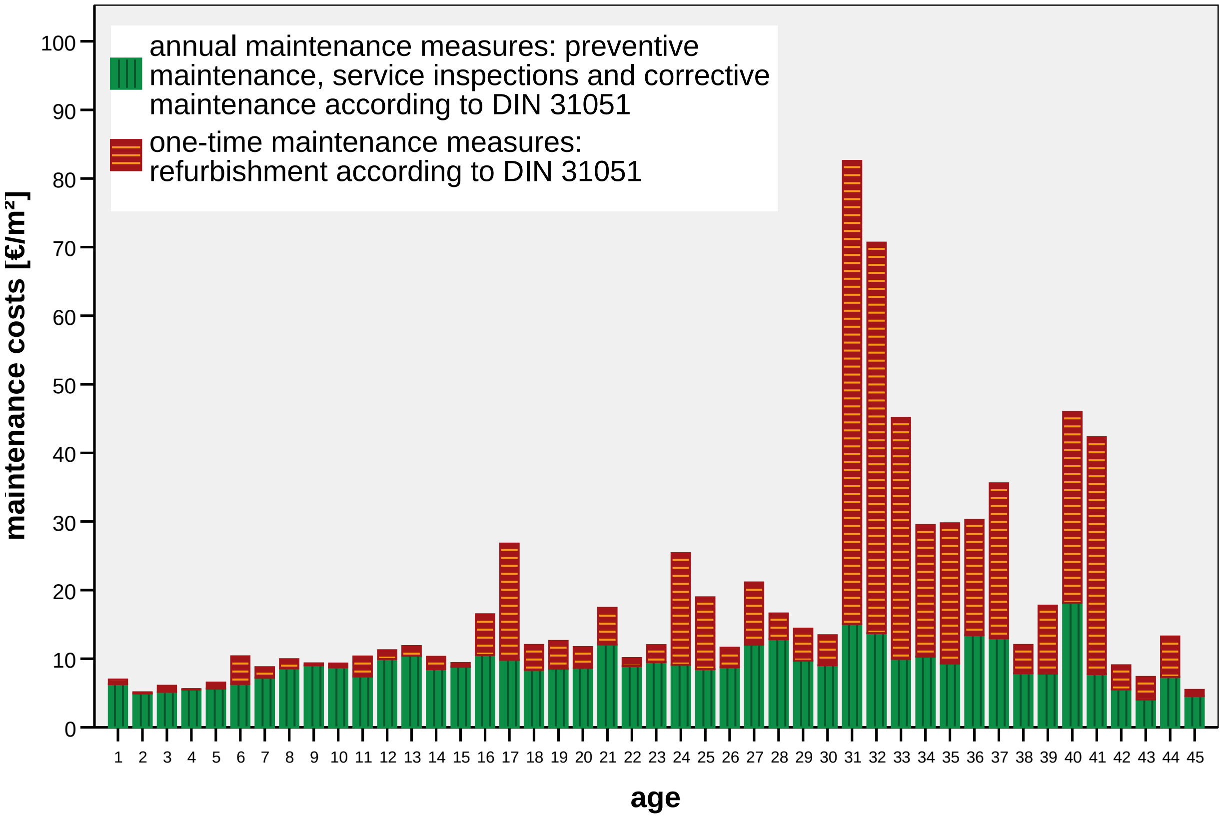

Figure 2: Sum of maintenance costs [€/m²] according to maintenance measure

Analysis shows that major refurbishment is carried out mainly between year 30 and 40. The cost of these one-off measures is substantially higher than the annual maintenance cost for that period.
In contrast, annual maintenance costs are the major cost factor during the first 30 years. This means that the age of the buildings in the portfolio considerably influences the kind of measures necessary and hence the level of maintenance costs.
Especially when setting the budget for major refurbishment measures, the age of a building therefore plays an important role in order to provide sufficient financial means.

Another important factor that is analyzed using real data is the building size. The examples in the portfolio comprise buildings with a gross floor area of between 800 m² and 23.000 m². In order to determine the influence the building size has on maintenance costs, the examples are categorized in two clusters. Cluster 1 comprises all buildings smaller than 10.000 m² (gross floor area / GFA), cluster 2 all bigger buildings. Using these examples, median maintenance cost is calculated. The following figure shows the cumulated values.

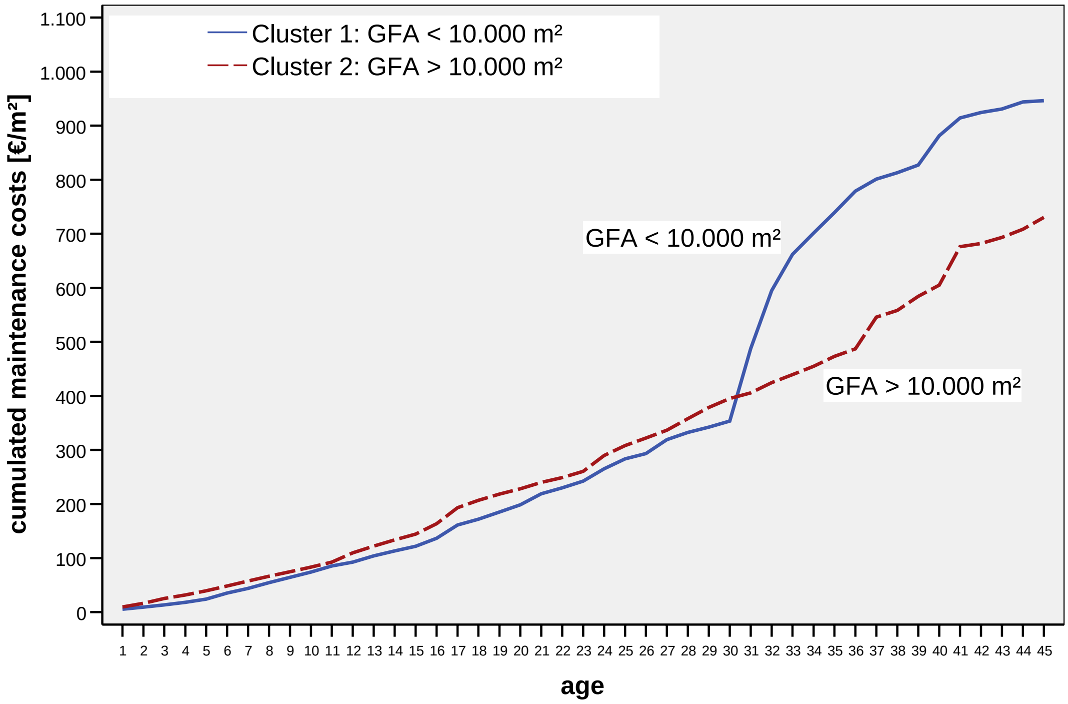

Figure 3: cumulated maintenance costs of buildings, clustered by building size

Analysis shows that maintenance costs for both clusters hardly vary over the first 30 years. During years 30 and 40, the costs start to differ with the costs for the bigger buildings remaining clearly lower than those of the smaller buildings. This means that the building size does not matter for preventive maintenance and service inspection or minor corrective maintenance. For major corrective maintenance work, however, the economy of scales seems to have a great influence which means that the building size is decisive. According to the analysis, the building size does not affect the annual maintenance costs. It does, however, greatly influence the cost of corrective maintenance and has to be considered when setting the budget for such measures.

FINDINGS

Analyzes from the BEWIS project whose results were published in the EFMC Proceedings 2007 (Bahr, C. et al., 2007) show that the prospected maintenance costs obtained using different calculation methods may differ by more than 200% from the real maintenance costs. This great deviation is due to a number of relevant factors whose influence was taken into account in different ways or not at all by the different institutions. Consistent weighting of the main factors could reduce this deviation. To date, there is, however, no consolidated knowledge regarding the cost-defining parameters and how they affect maintenance costs.

Using the real data from the BEWIS project, these main factors can now be determined scientifically. As the analysis in chapter EVALUATION shows, the level of maintenance costs is mainly determined by the building age and size as well as the kind of measure to be carried out.

OUTLOOK

The University of Karlsruhe (TH) will carry out more analyses in order to determine if other factors exist which may facilitate a more precise calculation of maintenance budgets. Also, research will be done on how the parameters taken into account so far really influence the calculation and if this influence has been determined correctly.

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