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EVALUATION OF STRATEGIC BUILDING MAINTENANCE AND REFURBISHMENT BUDGETING METHOD SCHROEDER

Markus CHRISTEN [a,*], **Jules SCHROEDER** [b], **Holger WALLBAUM** [a]

[a] *Institute of Construction and Infrastructure Management, Swiss Federal Institute of Technology ETH Zurich, Haeldeliweg 15, 8092 Zurich, Switzerland*
[b] *Retired, former head of property management of the canton of Zurich/Switzerland*

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ABSTRACT. The method Schroeder is accepted amongst real estate professionals in Switzerland as a near standard for condition monitoring, budgeting of maintenance and refurbishment, and strategic decision support in point of building portfolios. It is based on the devaluation curves of 12 or more building elements. Main results are the actual and the prognosticated future building condition in percentage of its reinstatement value, the residual useful service life of building elements, and the calculation of future maintenance and refurbishment costs. 25 years after its first publication, this paper analyses the assumptions made, compares the method to other methods in this field, and validates the method in several steps, based on scientific or empirical evidence. Furthermore, a desktop simulation of a well-documented portfolio was performed and compared, the answers from a questionnaire amongst users are provided, and the partially controversial conclusions are discussed.

KEYWORDS: Strategic property management; Building portfolio; Maintenance and refurbishment budgeting; Method Schroeder; Devaluation curve

1. INTRODUCTION

In every economy and organisation, the existing building stock forms an indispensable and major asset which needs to be maintained, improved, and eventually replaced. This requires a measurable part of the gross domestic product (GDP) and therefore has to be performed in an economical manner by optimising between minimal costs and avoiding a maintenance backlog while considering aspects of sustainability. Kohler and Yang (2007) have investigated the long-term behavior of this enormous asset stock in a combination of flow- and capital-based approaches and have discussed strategies to influence it.

As a consequence of the importance of the existing building stock, budgeting of maintenance and refurbishment is a commonplace as well as challenging task for property owners and managers. In an industrial facility, the potential loss of production and the following loss of profitability justify adequate maintenance budgets based on technical considerations, even in tight economic situations.

An extensive range of methods and instruments has been developed to support maintenance in industry. In real estate, it is common practice to postpone maintenance for several years to reduce costs in private organisations or to reduce public spending. Today, maintenance and refurbishment decisions for building portfolios are more based on user requirements and market considerations than on predicted durability of building elements. Consequently, portfolio managers need a strategic instrument which shows the consequences of postponed investments in a portfolio in order to justify the budgets they are demanding. Any method to forecast maintenance and refurbishment costs basically relies on the prediction of durability of single building elements. The British Standard BS 7543 (1992) made a noteworthy statement about this: "Prediction of durability is subject to many variables and cannot be an exact science". This, combined with individual strategic decisions and other context, adds to the complexity of the task. In recent decades, several methods to overcome this complexity were proposed (see Table 3). However,

* Corresponding author. E–mail: christen@ethrat.ch

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there are only a limited number of scientists conducting research in this field, consequently publications and data sets are sparse (see section 4). The existing research gap is considerable in light of the size and age of the building stock.

One method which has proven successful in the property market is the method Schroeder, in form of the respective software application called Stratus (in Switzerland) or Spectus (international). Today, the method is used in 100 portfolios encompassing more than 20'000 buildings. 25 years after its publication, this paper analyses the assumptions, compares the method to other methods in this field, and validates the method in several steps based on scientific or empirical evidence.

This paper looks at the terminology in maintenance and the basic formulas in chapter 2, describes the Method Schroeder in chapter 3, and in chapter 4 validates and compares the method to other methods in this field in chapter 4.

2. FUNDAMENTALS IN BUILDING MAINTENANCE

2.1. Maintenance terminology

The term maintenance has several definitions. The definition in this paper follows the new European Standard in Facility Management EN 15221-4: Taxonomy, Classification and Structures in Facility Management (2012). The standard defines a hierarchically structured set of more than 100 facility products. These products have been designed to allocate costs, to define, compare and improve quality and to enable benchmarking in the support services market. To distinguish between annual costs (expenses in the income statement) and investments (listed as an asset in the balance sheet), the standard allocates the first ones to the product "maintenance" and the second ones to the product "asset replacement and refurbishment". Figure 1 shows the relation between the devaluation curve of an asset and the relevant facility products to describe the curve and its values and costs.

It is important to note that this standard acknowledges the fact that refurbishment not only restores the initial value of an asset but, due to better technology available, very often results in a higher standard. A good example of this regards the replacement of windows. New windows are most certainly better than old ones and at approximately the same, or even lower, costs. It should also be noted that in many organisations the line between maintenance and refurbishment is often drawn based on financial considerations and not on technical definitions, e.g. every measure above a fixed amount/threshold counts as refurbishment and is set up as an asset in the balance sheet. Unfortunately, this threshold is determined at individual levels and within a wide range. This fact adds to the complexity of comparing or benchmarking maintenance costs. Another method to distinguish between maintenance and refurbishment is the maintenance signature presented in section 4.

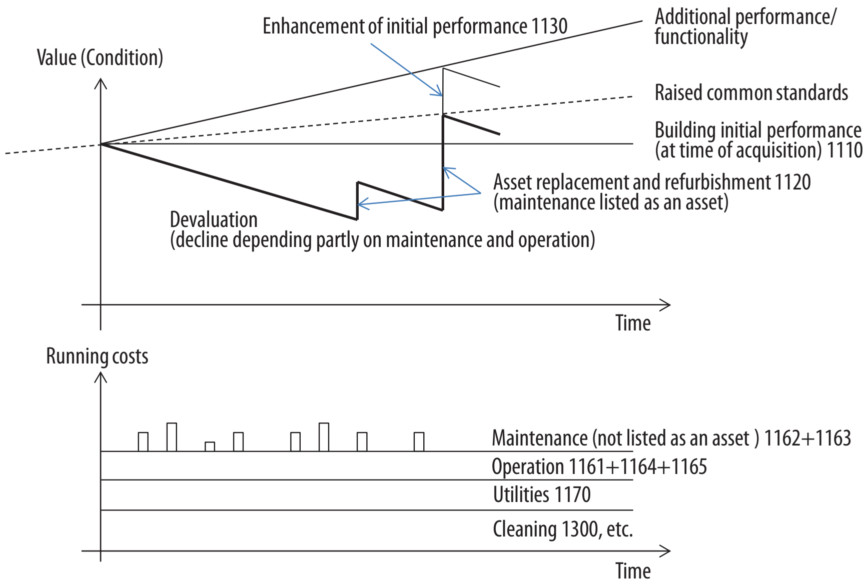


Fig. 1. Relation between maintenance and refurbishment and facility products defined in EN 15221-4 (numbers in the Figure 1 refer to facility products defined in the standard)

2.2. Basic formulas to calculate maintenance and refurbishment

Based on the devaluation model of a building and common knowledge about maintenance and property management, the following formulas are proposed (refer also to Bahr, Lennerts 2010).

Annual maintenance expenses for a building:

$$E_m = E_t * F_s, \tag{1}$$

where: E_m – annual maintenance expenses for a building [% of V_a]; E_t – expenses required from a technical point of view (e.g. 1.0% of V_a per annum) [% of V_a]; F_s – factor for strategic decisions influencing maintenance budgets [–].

Methods to estimate annual maintenance expenses usually concentrate on the technical side because of the individual nature of strategic decisions of organisations.

Refurbishment investment for a building at time t:

$$I_{rb} = V_a * \left(1 - C_t\right) * F_r * F_a, \tag{2}$$

where: I_{rb} – investment needed to bring a building back to its initial condition [currency]; V_a – reinstatement value of the asset or building (also: replacement or insurance value) [currency]; C_t – condition of building in % of V_a at time t [%]; F_r – factor to calculate the required investment based on the total devaluation ($1 - C_t$) to bring the building back to its initial value [–]; F_a – factor for additional investment required to achieve added value if required [–].

3. DESCRIPTION OF METHOD SCHROEDER

In the mid-1980s Jules Schroeder, a property manager for the canton of Zurich in Switzerland, developed a simple to use method for effective and comprehensible budgeting of maintenance and refurbishment in building portfolios. The initial inhouse application was later commercialised and is continuously being improved upon. However, the method itself has not changed since its first publication.

The method was based on the practical experience gained from more than 2'000 buildings, in combination with scientific research at the Swiss Federal Institute of Technology in Zurich (ETH Zurich) in Meyer-Meierling (2011, first published 1994). At the centre are the devaluation curves of building elements like structure, roof, façade, windows, building technique etc. The choice of elements has been an optimization process between minimization of the effort to collect and maintain data and the need for sufficiently detailed data to provide relevant information. Usually refurbished as a package, 12 to 20 elements were found to be optimal (see Annex 1). The method itself would permit a higher number of elements to be used resulting in higher costs for assessment and data management. The condition of these elements is usually assessed by experts or by trained in-house staff to assure a comparable outcome.

The devaluation curves determine the value or condition of the elements in function of the time. An assessed value from the condition survey, therefore, determines a theoretical age (e.g. independent of effective age or other factors) of the element and, following the depreciation curve, the remaining service life before refurbishment is due. The curve has been given an exponential function (C_t = 1 – t^a) and split into two phases in order to better reflect the empirical data (formulas 3 + 4). The empirical functions for different elements have been validated within IP Bau (1991), a government research program, based on a detailed examination of a portfolio containing 120 buildings. The formulas for the two phases of the devaluation curves (Fig. 2) in the method Schroeder are as follows:

$$\text{Condition Phase 1: } C_t = 1 - t_p\left(\frac{1}{t_p}\right)^{a1}, \tag{3}$$

in Schroeder (1989),

Condition Phase 2:

$$C_t = C_{tp} - \left(\frac{C_{tp}\left(t - t_p\right)}{C_{tp}}\right)^{a2}, \tag{4}$$

in Schroeder (1989),

where: t_p – time where phase 1 ends and phase 2 begins [years]; C_{tp} – condition C_t at time t_p where phase 1 ends and phase 2 begins [%]; a_1, a_2 – exponents determining the form of the devaluation curves in phases 1 and 2 [–].

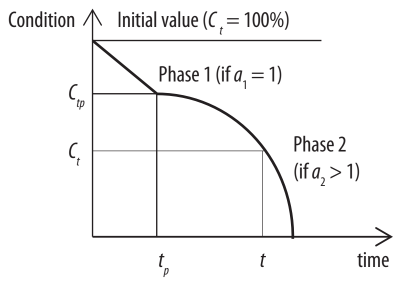


Fig. 2. Exemplary model of devaluation curve of a building element with two phases as a condition-time diagram

After the condition has been surveyed on site, the remaining service life of an element or building is determined with the help of the devaluation curves. The next question is: how much does it cost to refurbish an element, or building at a given point in time, and when is it best to perform this task? Of course it would be great if it were possible to only measure the difference between the actual value $C_{t*}V_a$ and the initial reinstatement value V_a to determine the investment needed for refurbishment I_r. Based on experience, the method Schroeder suggests that this is not so easy. Elements must often be replaced as a whole, not in parts, which means that premature replacement costs more than the calculated depreciation or devaluation. To replace an element often costs more than its initial construction due to additional costs for e.g. scaffolding, adjustments to adjacent elements or accommodation of users during construction work. So, even at maturity, the costs may be a factor higher than the simple difference mentioned above. In order to solve the problem the method Schroeder (1989) uses a refurbishment factor F_r (5), which depends on the condition C_t of the building element for the calculation of the required investments.

Refurbishment factor: $$F_r = 1 + \frac{C_t}{\left(1 - C_{tp}\right)}, \tag{5}$$

in Schroeder (1989),

where: F_r – condition dependent factor to calculate the investment needed to bring a building element back to its initial value [–].

The factor F_r may depend on additional factors like type of building, ambient conditions or occupation as shown by Lavy and Shohet (2007). The software application offers possibilities for individual adjustments for each building and element. These possibilities were not part of the original method Schroeder.

Annual maintenance on the other hand is modelled as an exponential function of C_t between around 0.5% (at C_t = 100% new condition) and 2% (at C_t = 70%). At lower conditions, it is assumed that only minimal maintenance is being performed because the object is potentially due to be refurbished or demolished and replaced by a new construction.

The Table 1 lists the required as well as optional input data that the software application Stratus/Spectus (2012) needs to calculate the listed output data. To support the assessment, external assessment services or training of in-house staff is offered by the provider.

Table 1 shows that only minimal input data is needed to calculate the output required for different strategic decisions. In particular, no historical data, which is often unavailable or hidden deeply in some archives, is required. As an option correction factors can be used to incorporate specific knowledge or experience. The condition of each building and therefore the whole portfolio is automatically recalculated each year based on the devaluation curves of the elements. This simulates the effective annual degradation and indicates the dynamic behaviour of the portfolio. Other functions include comparable benchmarking of the overall condition of the portfolio and the bundling of refurbishment works for different buildings in the years to come.

In Figure 3 an example of the representation of an entire portfolio in a sum curve covering all buildings is given.

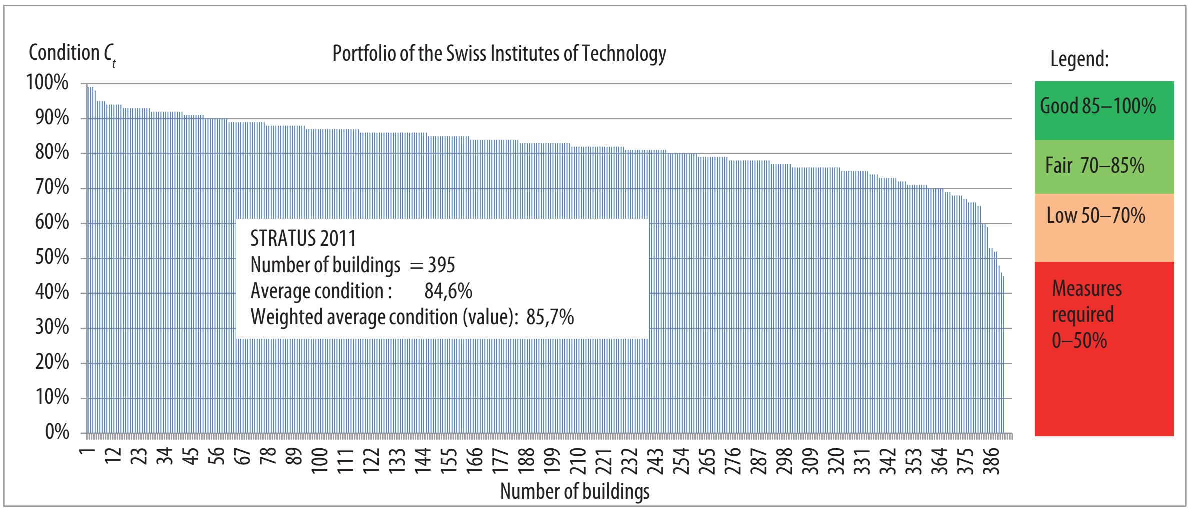


Fig. 3. Typical summation curve of the condition of a portfolio – for those objects below 70% an object strategy is needed (range of descriptions of condition is based on practical experience)

Table 1. Required Input and calculated output from the instrument Stratus/Spectus based on the method Schroeder

Input Data	Remarks/Description
Building reinstatement value V_a	Estimated replacement, reinstatement or insurance value, the value may be corrected manually by the property manager if needed
Condition survey of 12- max. 20 elements	Standardised and self-explanatory input sheet available, requires approx. 1 hour per building
Volume (m^3) or area (m^2)	Whatever is available
Construction cost index	Taking the development of past and future construction costs into consideration
Optional: effective portion of total building costs of the elements surveyed	Manual correction of standard values for specific buildings possible if required
Optional: type of building and level of installed building technique	Influences the choice of building elements especially in regards to building technique
Optional: effective maintenance and refurbishment works performed	Supports documentation of history of buildings and validation of factors based on experience
Optional: data about energy consumption, earth quake safety, security, etc.	Depending on questions arising from strategic property management
Output Data	**Remarks/Description**
For the entire portfolio	
Average condition of portfolio	The condition of the portfolio can be presented in form of a summation curve (Fig. 3) for all objects
Change of condition in function of time and performed maintenance and refurbishment	Annual devaluation (automatically calculated based on the devaluation curves) and maintenance and refurbishment need to be in a balance if the condition is to be kept at the desired level
Annual costs for maintenance and investments for refurbishment over a selectable period	Main figures to support budgeting
Buildings which need refurbishment	Depending on strategic choices, buildings below 70%, 60% or even 50% are visible at a glance in the sum curve and can be selected for detailed planning
Simulation of effects of different maintenance strategies and shifting time of refurbishment works	Simulation typically covers a period of 25 years, shorter or longer periods are possible
For a single building	
Condition of building in % of initial value at a given point in time	Strategic figure to evaluate the need for more detailed planning and to control the actual value in the accounting system at a selected point in time (e.g. in five or ten years)
Annual costs for maintenance over a selectable period/number of years	Depending on condition C_t
Investment for refurbishment in a selected year	Depending on condition C_t
Refurbishment backlog	Due costs of elements which are rated to be mature for refurbishment
Optional: Building energy certificate, assessment of earth quake safety, risk analysis, etc.	Required by law in some countries
For each separately assessed building element	
Condition of element	Based on condition survey and calculated devaluation based on individual curves for each element
Estimated due time for refurbishment of element	Based on individual devaluation curves for each element
Estimated cost of refurbishment of element in due time	Based on condition of the element and its average portion of total building new value

4. VALIDATION OF THE METHOD SCHROEDER

The validation process employed in this paper encompasses several steps, a different approach used in each. It includes state-of-the-art research, questioning the assumptions, comparison with other products, answers of users to a questionnaire to get a feedback from the market, and comparison to data from two real portfolios where effective data is available.

4.1. State of the review

In general, more research is conducted in the field of industrial maintenance than that of building maintenance, because of the former's immediate effect on productivity and profitability. Building maintenance is seen as less critical and maintenance practices are usually lagging behind industry (Christen *et al.* 2011). The method Schroeder is specifically adapted to the longevity of building elements and therefore less suitable to the short life cycles of production machinery.

Zavadskas *et al.* (2004) compared the average market price of refurbished dwellings and the cost of newly-built dwellings in Vilnius (Lithuania). They found that the market price and, consequently the refurbishment strategy, depend on the area where an object is located in order not to exceed the potential market value.

Bjørberg (2008) conducted an assessment of 10'000, or 40% of all public buildings in Norway, in order to identify maintenance strategies and recommend a budget cost level for long term planned maintenance. In each building, 16 elements were graded into four levels to assess the condition. The grading is quite similar to that used in the method Schroeder. He estimates that a portfolio needs to encompass 40–50 different buildings with around 50'000 m^2 to enable a representative estimate of the annual budget for maintenance and refurbishment. This would have to be debated in the light of the findings presented in this paper.

Kumar *et al.* (2010) identified three principal methods, the probabilistic methods, the engineering methods, and the deterministic methods in order to predict the service life of a building system and their components. Due to the complexity of the other methods, they proposed a deterministic method called capital refurbishment model, which has similarities to the method Schroeder. It uses only six building elements with fixed service life expectancy but spreads the refurbishment costs over a period of 5 years to accommodate variations.

Bahr and Lennerts (2010) compared different maintenance and refurbishment budgeting methods with their findings from a detailed analysis of the costs in 17 buildings over several decades. As part of their findings, they recommend the division between maintenance and refurbishment as found in the method Schroeder and as defined in EN 15221-4. The method Schroeder is represented as propagating a fixed total budget of 1.1% of the building value and this figure is then compared to the combined, fluctuating costs for maintenance and refurbishment from the detailed analysis. As shown in this paper, the method Schroeder is much more differentiated and accurate.

Based on the results of the analysis of the 17 buildings, Bahr and Lennerts developed a new method called PABI (practical adaptive budgeting of maintenance measures) with a similar formula as to the one stated above (1). The method combines fixed percentages for maintenance (1.2%, regular measures) and refurbishment (4.4%, one-off measures) with correction factors relating to age, wear and tear, materials, etc. The result is a fast estimate of average total annual budgets, but only vague information about the future distribution of the costs in time – each differentiated period covers one decade – or the condition and the need for refurbishment of building elements is provided.

4.2. Analysis and validation of assumptions in the method Schroeder

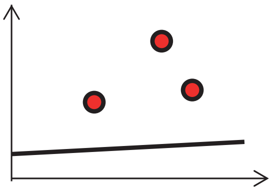
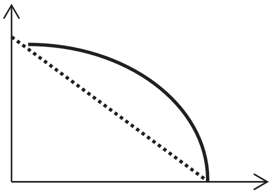
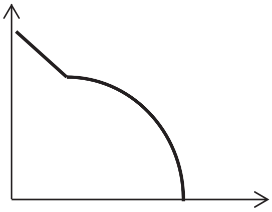
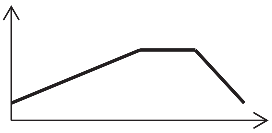
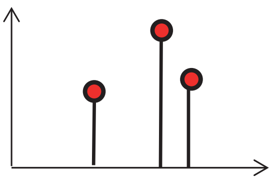
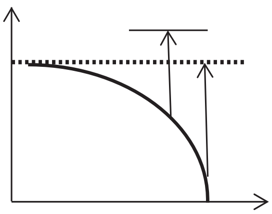
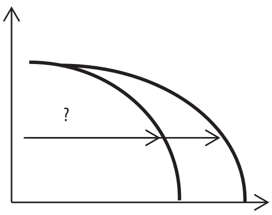
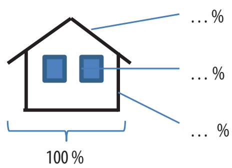
Of the nine assumptions in Table 2, the five assumptions including numbers 1 to 3, 5 and 8, have been validated whereas the other four assumptions are based on empirical evidence. These are likely sufficient for strategic budgeting but more research would be needed for validation. Additional investments to achieve added value (factor F_a) are not considered in this method.

4.3. Comparison with other methods for maintenance budgeting

Mickaityte *et al.* (2008) describe in the context of refurbishment and sustainability different methods for maintenance planning. However, many of these are not broadly applied nor used in the market today. Table 3 provides and comments an incomprehensive selection of instruments covering an array of different such methods.

The list of instruments in Table 3 highlights the differences in their focus and application. To put it into perspective, by looking at the focus of

Table 2. Validation of assumptions the method Schroeder is based upon [units of diagrams]

Assumption	Graphic	Empirical evidence	Scientific evidence
1: Division into maintenance (line) and refurbishment (dots) [costs/time]		The difference between annual expenses and investments with project character are also visible in the representation in the accounting system of many organisations	Bahr and Lennerts (2010) stated in their work that this difference must be obeyed and created the method PABI which factors this differentiation in
2: Non-linear depreciation or devaluation of building elements [condition/time]		The first model using linear curves did not fit the effective expenses in the portfolio the method was originally designed for.	IP Bau (1991) validated the shape of the curves for the different elements based on a detailed survey of 120 buildings.
3: Depreciation or devaluation divided into two steps [condition/time]		Machines often need some time before they reach stable running conditions. Cracks in buildings usually develop shortly after construction.	IP Bau (1991) validated the shape of the curves. Newer evidence found in Caccavelli *et al.* (2003) and Meyer-Meierling (2011)
4: Variable condition based annual maintenance expenses [costs/time]		New buildings need less caretaking than used ones – in older buildings, often less money is spent for economic reasons.	Two exemplary portfolios show different results. Further research is needed to verify the assumed function.
5: Condition/service-life based time for replacement and refurbishment investments [costs/time]		The condition determines the time for replacement and refurbishment of building elements based on their predicted durability or service-life.	The concept of statistical service-life of elements is widely accepted, e.g. in ISO 15686 (2008).
6: The condition of an element is an indicator of the costs for refurbishment or replacement (investment to restore the initial 100% condition) [condition/time]		An empirical factor (F_r) as a function of the condition is applied to calculate effects such as whole elements being replaced and additional costs such as scaffolding. F_r can be adjusted manually depending on occupancy etc. if required.	Lavy and Shohet (2007) found dependencies up to 20% on type of configuration and hence introduced the facility coefficient. Bahr and Lennerts (2010) also found building related factors (e.g. complexity of façade).
7: Analysis of actual condition of an element is sufficient, the effective age of an element does not matter (condition/time)		To know age and condition could improve the forecast in the long run. However, the effective age is often not available.	A budgeting period usually covers less than 5 years. The additional effort to analyse the age is therefore not required.
8: Average portion of elements in percentage of total costs is a function of building type [% of costs]		An individual assessment of construction costs for each building requires a large effort.	Graf (2008) has analysed costs of 228 buildings to verify the standard values for different building types.
9: Maintenance strategy influences maintenance intervals	n/a	Empirical factor to take individual strategic decisions into account.	No scientific evidence to verify this factor was found.

specific instruments and their costs per object, a qualitative rating was performed (Fig. 4).

The rating gives an indication of the application and the required effort of the instruments. It highlights a possible problem in some of them. The deeper they go into detail (e.g. number of elements) the higher the costs per object are. The relation was assumed to be linear. Eventually, the instruments reach the point where they become too expensive for strategic portfolio considerations. For the design of a refurbishment project, organisations prefer to use standard construction and project management tools.

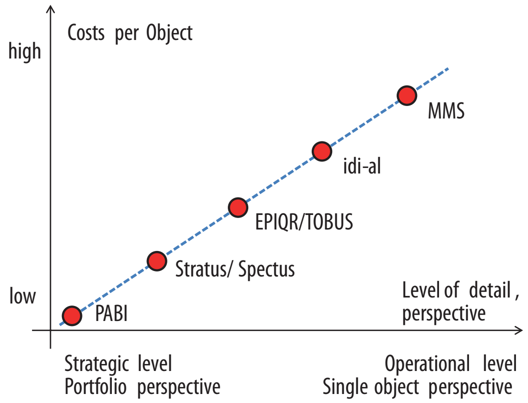


Fig. 4. Qualitative rating of maintenance and refurbishment planning and budgeting instruments

Table 3. Commented list of examples of maintenance budgeting and/or planning methods and instruments

Method/Instrument	Focus	Limitations	Application
PABI (Bahr, Lennerts 2010)	Portfolio level	Empirical evidence of correction factors	Budgeting without on-site assessment
Factor method ISO 15686-2000 (2008)	Building components of a single building or building type	Factors yet to be defined (based on experience)	Budgeting without on-site assessment
Stratus/Spectus (2012) (based on method Schroeder)	Portfolio management, maintenance and refurbishment, energy and others	Not detailed enough for refurbishment design	Strategic portfolio management incl. adjacent functions like energy certificate
EPIQR (based on EU research project and IP Bau) (2012) www.epiqr.de	Single building, includes portfolio functions and energy flow chart	Requires measuring of area and age of about 50 elements	Analytical calculation of maintenance budgets, includes sustainability criteria
TOBUS (based on EPIQR) Caccavelli and Gugerli (2002)	Single building, includes energy flow chart	Commercial buildings, requires measuring of area and quality of elements	Analytical calculation of maintenance budgets
INVESTIMMO (based on EPIQR) Caccavelli (2004)	Portfolio management, investment decision support	Planning 12 years ahead	Portfolio analysis using different criteria
DUEGA (based on IP Bau 1991, 1995) Gredig *et al.* (1997)		Not supported anymore	n/a
SUREURO (2005) www.sureuro.com (website not updated since 2005)	Includes aspects of sustainability and user participation	Residential buildings	n/a
Building diagnosis idi-al (2012) www.bakaberlin.de	Single building of any type	Certified assessors necessary	Detailed analysis resulting in a refurbishment design proposal with alternatives
Maintenance management systems MMS (different products available on the market, e.g. Maximo, visualFM, etc.)	Systems and elements with fixed periodical maintenance intervals based on technical life time of elements	Requires extensive data management; not suitable for building elements due to the large amount of equal elements (e.g. doors, walls) and little periodical maintenance activity performed on them.	Mainly used for important or costly technical equipment requiring regular maintenance intervals
Mathematical methods for industrial maintenance e.g. in Percy and Kobbacy (2000)	Preventive maintenance in industrial production facilities	Less suitable for longer maintenance intervals in buildings, complexity of models	Mainly used for technical equipment requiring regular maintenance intervals

4.4. Questionnaire

65 portfolio managers who all use Stratus/Spectus were asked for permission to use their data for scientific research. A total of 24 gave a positive response and 18 (28%) additionally answered a questionnaire (Annex 3) on their usage and opinion of the software Stratus/Spectus. 94% of the 18 respondents manage all, or the large majority, of their buildings with the system (question 1). 78% regularly update the building condition data following construction or refurbishment projects (question 2). 39% differentiate between regular maintenance expenses and investments in refurbishment by applying a fixed threshold value. This value varies considerably between 5'000 and 300'000 CHF. For almost 50% this differentiation does not seem required (question 3). 50% have checked the fit of the real expenses with the prognosis and agree partly or fully with the results of the software. As a part of this group, 17% have developed a factor of their own to correct the prognosis for their budgeting purposes. There is no clear tendency towards an overly high or an overly low prognosis visible (question 4). 34% have set themselves a goal for the overall condition of their portfolio. These goals are all between 75% and 85% for C_t (question 5). 44% revalidate their portfolio about every five years (question 6). In short summary, the system is neither used in a uniform way nor in the same depths by the respondents. The answers to questions 3 and 4 especially raise some questions and highlight the need for further research (see chapter 5).

4.5. Comparison with effective data of 60 buildings – maintenance signature

The Swiss Federal Institute of Technology in Lausanne (école polytechnique fédéral de Lausanne EPFL) has introduced a comprehensive scheme of building cost monitoring and controlling called INDIANA (INDIcateurs ANAlytiques) wherein figures for maintenance and refurbishment are collected and presented separately. The figures are published annually, the latest in Chatton *et al.* (2011).

The level of detail enables the drawing of the maintenance and refurbishment signatures of the 60 buildings of the EPFL. The concept of the signatures is derived from the known energy signatures e.g. used to calculate energy savings in Zmeureanu (1990). The maintenance and refurbishment signature offers possibly a new way to analyse maintenance costs. The aim is to extract certain patterns from measured data like the dependency of maintenance expenses on condition C_t, and to distinguish between maintenance and refurbishment costs independently from individual accounting practices.

The effective expenses in the EPFL portfolio as shown in Figure 5 have been compared with the results from Stratus/Spectus. Adding maintenance and the constant base of refurbishment (averaged over 3 years) together, a figure of around 1.0% of the reinstatement value for regular maintenance is achieved. This is very close to the recommendation of Stratus for this portfolio. Against the assumptions in the instrument, the effective figures for these 60 buildings show a constant level of maintenance, irrespective of the condition C_t. A possible explanation for this could be the high level of installed building technique that requires a constant level of maintenance activities and the planned maintenance schemes (the level of installed building technique is already a criteria in Stratus to characterize a given building influencing the cost split of building elements). The investments in

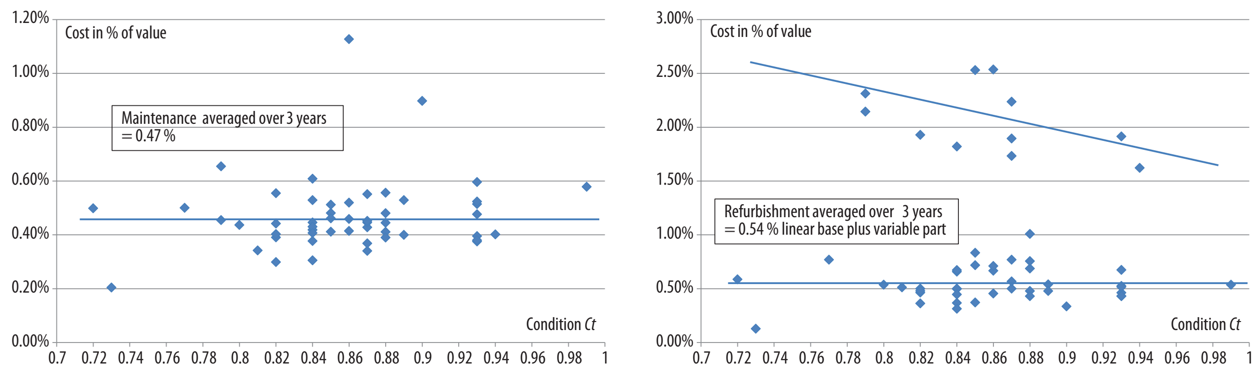


Fig. 5. The maintenance and the refurbishment signatures of the 60 buildings of the EPFL showing average annual costs in percentage of the building reinstatement values over the 3 years period from 2008 to 2010 in function of the building condition C_t according to Stratus (Note: the buildings form part of the portfolio shown in Figure 3)

refurbishment during this three year period were found not to be representative in the long-term due to a prevailing program for new construction.

4.6. Comparison with effective data of 17 buildings

The study of Bahr and Lennerts (2010) is the only one known that provides effective and comparable cost data in this field over several decades. Therefore, a desktop simulation of these 17 buildings (see Annex 2) has been performed on Stratus/Spectus.

The comparison of the results from the detailed analysis of the maintenance and refurbishment costs of the 17 buildings analysed by Bahr and Lennerts with the results from the desktop simulation of this portfolio is shown in Figure 6. The simulation was performed by using the default values in the software tool for 17 virtual buildings of the same type, size and age (all construction dates set at $t = 0$ as in Bahr und Lennerts). It shows a nearly identical sum of total costs over 45 years. The total average costs are around 2.2% per annum with a total difference of only 5% over this lengthy period. Additionally, both curves show some equal trends in the distribution of the costs over this long-term period. Maintenance rises slowly during the first 30 years in both curves. The first replacement of technical building installations (e.g. heating system, sanitary equipment) happened earlier in the effective portfolio than estimated in Stratus/Spectus. This could be due to the construction dates between 1950 and 1980 and the following rapid changes in standards, technology and requirements. Refurbishment works in the effective portfolio are mainly spread over the period of about 30–35 years while the desktop simulation shows distinct peaks for the different building elements according to their assumed durability. The data of the 17 buildings in detail shows more dispersed and partly even larger peaks. The peaks in the calculation of real buildings may differ from the desktop simulation due to the corrections resulting from the on-site assessment of the actual conditions of elements.

In summary, it has been possible to simulate the total maintenance and refurbishment costs of a real portfolio of 17 well researched buildings with astonishingly high accuracy in regards to the total amount of investments while the distribution of major refurbishments works over 45 years shows some differences. In practice, these may be influenced by strategic decisions and amended through periodic on-site assessments. The differences are also put into perspective by the fact that maintenance is not usually planned more than 5 years ahead of time.

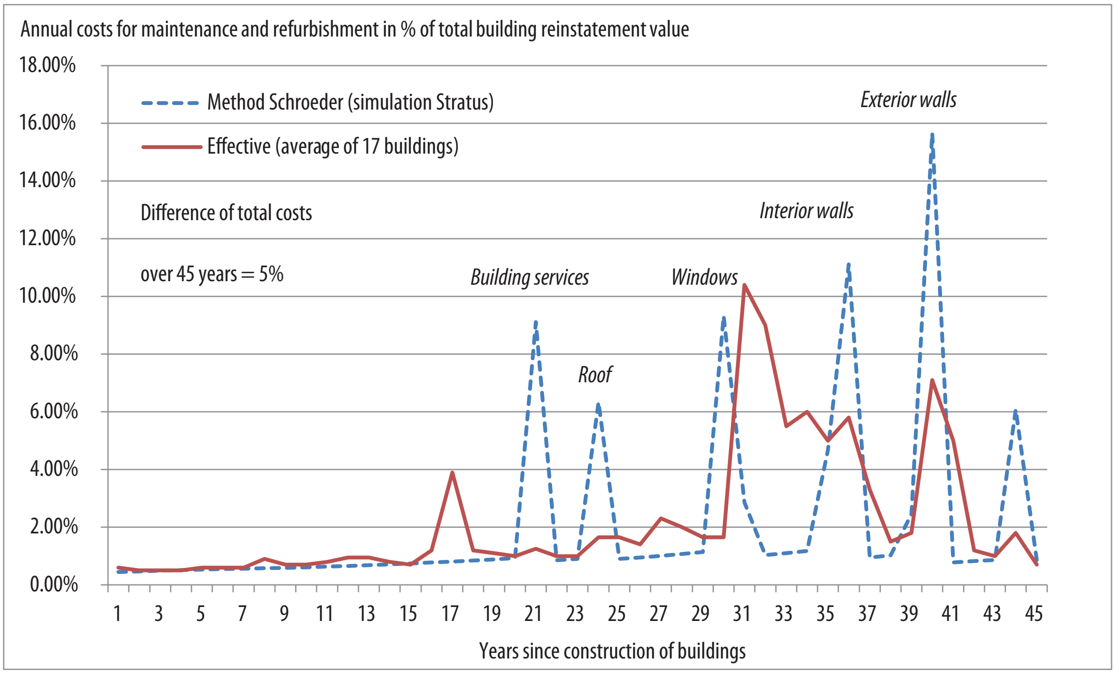


Fig. 6. Comparison of the maintenance and refurbishment costs of 17 buildings analysed in detail by Bahr and Lennerts with a desktop simulation using Stratus/Spectus over a period of 45 years (in Italic: indication of elements causing the distinct peaks in the theoretical simulation)

5. CONCLUSIONS

Maintenance and refurbishment budgeting is not only a technical question but also contains strategic aspects like financial considerations and the need to consider changes in user requirements, market condition and the legal framework. As such, any method to calculate and justify these budgets must be transparent and credible as well as open for strategic considerations.

The method Schroeder implemented in the software Stratus/Spectus has proven itself as a cost efficient, easy-to-use and credible method to support strategic maintenance and refurbishment decisions in property management and to justify the necessary budgets. One limitation is that it is not intended to calculate detailed construction costs of a refurbishment project.

Some of its advantages over most other methods in this field are:

- It is applicable for all types of buildings and can therefore be used for heterogenous/mixed portfolios.
- It is cost efficient to operate as it requires very little input data that is easy to maintain because annual deterioration is calculated automatically.
- It enables a dynamic simulation of the effects of maintenance expenses and refurbishment investments on the condition of a single building or a whole portfolio in the long-term.

Nine assumptions behind the method Schroeder have been evaluated. Five assumptions have been verified. The remaining four are based on empirical evidence and likely sufficient for strategic budgeting, but more research would be needed for validation. The method has also been rated against other methods in this field and out of this rating a possible explanation for its success was extracted. A direct comparison of these methods would require more criteria and is only partially possible because many of those methods have a different focus. The method was originally designed to accurately simulate a given large portfolio. The comparison of simulated budgets with effective cost data of two different portfolios where data was available has found a close match too. This finding is valid for these three portfolios only. The questionnaire amongst users has shown that the standard values used in the application are not equally valid for all portfolios. Different cost calculations (e.g. threshold for maintenance) and characteristics of buildings and portfolios may be the reasons for this. Some of the factors influencing the costs are described in Bahr and Lennerts (2010) or Lavy and Shohet (2007). Caccavelli (2004) mentions 34 cost influencing factors of which the method Schroeder considers only a few. This does not seem to keep portfolio managers from using the method possibly due to other benefits like condition monitoring.

FURTHER RESEARCH

In the field of building maintenance and refurbishment there is only little reliable and comparable long-term data available to confirm any such budgeting method so more research is still needed. There is no general agreement in literature about the proper level of maintenance expenses and refurbishment investments, e.g. expressed as a percentage of the reinstatement value. The new definitions in the EN 15221-4 or the proposed maintenance and refurbishment signatures may help to standardise cost data collection in order to get a better understanding of the long-term behaviour of the system “building portfolio”. For example, the assumption of condition dependent maintenance expenses could have only been verified in one of the two real portfolios where effective data was available. The other one shows a linear distribution. These behaviours are yet to be explained. Another question is if all major cost influencing factors have been considered in the method or if more variables are needed to cover portfolios with specific characteristics.

How the method and its assumptions and parameters can be adapted to different property markets other than those in central Europe also requires further research. The focus of such research should be on the influence of different climatic conditions or different construction standards on the service-life of building elements to adapt the depreciation curves. However, there is no obvious reason why the method itself could not be applied universally.

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ANNEX 1

Table of building elements used in the practical software application of the method Schroeder (Stratus/Spectus)

No.	Element	Specification	Expected service life in years	Portion of total building costs in % 1)
1	Load-bearing structure	light weight – massive	75–120	35
2	Pitched roof	type of roof covering	40–50	4
4	Flat roof	type of roof covering	25–30	4
5	Exterior walls, Facade	type of material	40–55	8
6	Windows	type of material, shading	30–40	8
7	Heat production	primary energy	15–25	1
8	Heat distribution	type of radiators	15–25	2
9	Sanitary facilities	cold, warm, wastewater	15–25	6
10	Electrical system	lightning and machines	15–25	6
11	Other building services	e.g. lifts	15–25	3
12	Interior walls and fittings	–	20–30	23
13	Other interior fittings	–	–	–
14–20	Disponible	–	–	–

1) Proposed standard values, depending on type of building and specification.

ANNEX 2

Table of the 17 buildings simulated in Stratus

Scope of work: Comparison of methods Stratus / Bahr					
Data Bahr: 6 office buildings, 11 school buildings					
Building	Type of use	GFA (m^2)	Year of construction	Technoglogy level (%)	Envelope / cubature (m^2/m^3)
				T	E
AG FDS	Office	1'913	1952	20	0.29
AG PF	Office	4'424	1958	26	0.45
AKS PF	School	22'835	1950	30	0.25
GBS KA	School	11'950	1984	38	0.41
GS BA	School	797	1960	11	0.42
GS BB	School	14'523	1980	38	0.45
GS BŰ	School	829	1958	18	0.45
GS NE	School	1'244	1958	7	0.49
HE SCW	School	15'402	1965	27	0.34
HSL SBW	School	17'802	1963	24	0.40
LG FR	Office	8'146	1965	23	0.19
LG MA	Office	16'859	1970	23	0.16
LG OF	Office	5'823	1956	23	0.28
MORE HN	School	9'960	1979	24	0.41
RA BR	Office	6'153	1979	26	0.26
RWG BB	School	7'897	1980	27	0.49
STLA ET	School	16'595	1967	28	0.26
GFA: Gross Floor Area			min =	7	0.16
			max =	38	0.49
Source:	Bahr (2010)		average =	22.5	0.325

ANNEX 3

Questionnaire added to a letter asking portfolio managers for permission to use their Stratus data for scientific research (respondents: 27 out of 64; positive: 24; questionnaires: 18):

1. Ist das gesamte Portfolio in Stratus erfasst oder gibt es eine Erfassungsgrenze und wo liegt diese?
   E: Do you manage the complete portfolio with Stratus or is there a limit/threshold and what would this limit be?

Answers:

– All buildings	10	(56%)
– Nearly all buildings	7	(39%)
– Majority of buildings	1	(6%)

2. Welche baulichen Massnahmen werden in Ihrem Stratus regelmässig nachgetragen?
   E: Which realised construction measures are being updated in Stratus on a regular basis?

Answers:

– None yet, but planned	1	(6%)
– All projects	7	(39%)
– All large projects	4	(22%)
– Threshold dependent (values from 3'000 to 50'000 CHF)	2	(11%);
– Condition dependent	1	(6%)
– None	3	(17%)

3. Wie werden laufende Aufwendungen (Instandhaltung) und aktivierbare Investitionen (Instandsetzung) unterschieden (z.B. durch einem bestimmten Betrag)?
   E: How are regular maintenance expenses and investments in refurbishment separated (e.g. based on certain amount of the bill)?

Answers:

– Based on a threshold (values from 5'000 to 100'000 CHF)	7	(39%);
– Different budgets for each	2	(11%)
– No differentiation made	2	(11%)
– No suitable answer	5	(28%)
– No answer	2	(11%)

4. Stimmen die im Stratus prognostizierten Werte mit Ihren Ausgaben und Investitionen überein?
   E: Do the prognosticated values for maintenance and refurbishment in Stratus correspond with the actual costs?

Answers:

– Yes	1	(6%)
– Partly yes	5	(28%)
– Applying a factor	3	(17%)*)
– No	5	(28%)
– Don,t know	3	(17%)
– No suitable answer	1	(6%)

*) Factors mentioned are: 0.8 and 1.25 for refurbishment, 1.5 for maintenance;
no correlation with answers to question 3 (threshold) was found.

5. Haben Sie ein Ziel für einen minimalen oder einen anzustrebenden Zustandswert des gesamten Portfolios oder für einzelne Gebäude oder Gebäudegruppen definiert?
   E: Did you set goals for the condition to be achieved, either for the whole portfolio or for a group of buildings or individual buildings?

Answers:

– Yes, numerical	5	(28%)
– Yes, qualitative	1	(6%)
– Not yet	2	(11%)
– No	9	(50%)
– No suitable answer	1	(6%)

6. Wie oft werden die Gebäude neu bewertet? Haben Sie dabei systematische Abweichungen zu den Prognosen in Stratus festgestellt?
   E: How often do you reassess the value of your buildings? Did you find systematic differences between the estimated values and the calculated values in Stratus?

Answers:

– Every ca. 10 years	1	(6%)
– Every ca. 5 years	8	(44%)
– Every ca. 2 years	4	(22%)
– No	3	(17%)
– No answer	2	(11%)

7. Weitere Hinweise
   E: Further comments?

Answers: 3 diverse comments e.g. inviting the authors to a personal discussion.