Validation of Maintenance Cycles for Public Buildings

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Abstract

This paper discusses the planning of maintenance measures. Theoretic models from literature are presented and analyzed regarding maintenance cycles, service lives of building components and the bundling of single measures. The models are verified using real data from 17 exemplary buildings. First, the most cost-intensive building components are identified. The maintenance cycles are examined using the examples facade and sanitary installations. The building component groups stated by IPBau "building envelope" and "kitchen and bath renovation" are validated regarding the measurement packages.

The exemplary examinations show that the maintenance cycles described in literature generally correspond with reality. As asserted by the theories, single maintenance measures are bundled into packages. It becomes, however, clear that the statements given in literature should be validated and adapted using real data.

Keywords: maintenance, maintenance cycles, service life of building components, lifecycle analysis

1. Introduction

Specific maintenance measures can effectively preserve the value of a building for a long time. The planning of maintenance measures requires knowledge regarding the service life of the building components as well as the required maintenance intervals. In many cases, planners refer to the main building components here.

Various models for the determination of the service life of building components and descriptions of maintenance cycles can be found in literature. This paper gives an overview of the models and verifies them using the maintenance data of 17 buildings. It analyzes the real data in order to see if the models meet with real-life requirements.

2. Method

The research is empirical aiming at optimizing the maintenance of public buildings. For this examination, the data of all maintenance measures actually carried out at 17 school and office buildings was gathered over a period of more than 45 years. This allows us to analyze the maintenance history of all buildings regarding each measure and building component over its full life cycle.

Examples were selected regarding several criteria. The buildings should reflect typical building histories. Also, the owners of each building had to provide a full set of documentation data including building plans and life-long cost data. As the analysis required the building and cost data to be complete, the buildings should date from the post-war period. They should also be old enough so that important maintenance measures had been carried out. Therefore, we selected buildings that were built between 1952 and 1984. The collected data gives detailed information about when which measure was carried out to which building component and why. Beside the maintenance costs, geometric building data like gross floor area were acquired and stored in the database. All together, the buildings comprise over 160,000 sqm gross floor area. Nearly 24,000 single maintenance measures were carried out and stored in the especially set up database.

3. Theory

3.1 Maintenance Cycles

In the 1960s, Winfried Zehme [1] was the first one to present an overview of repair cycles. It was referred to in the 1980s by Potyka und Zabrana [2] who presented the idea of periodic maintenance, combined with a 10-year maintenance cycle for recurring repair tasks. In this context, they also suggest combining other compatible tasks which should ideally be carried out every 20 to 25 years, with the work carried out every 10 years. Moreover, they combine repair cycles which, according to literature, should be carried out every 20 to 30 years, to one cycle every 30 years. They call this cycle main maintenance cycle.

The Enquète study „Stoffströme und Kosten im Bereich Bauen und Wohnen“ (material flow and costs in building and living) uses a similar pattern for real estate modelling [3]. It assumes that certain building components are repaired or replaced within the scope of ongoing maintenance work, others in the course of partial or complete renovation projects. According to Enquète, partial renovations are carried out every 20 to 30 years and mostly concern building equipment and surfaces. Complete renovations are carried out every 30 to 50 years and comprise building equipment, exterior shell and interior building components. The real intervals depend on the specific building characteristics; for every age and use class, average intervals and variances are assumed [3].

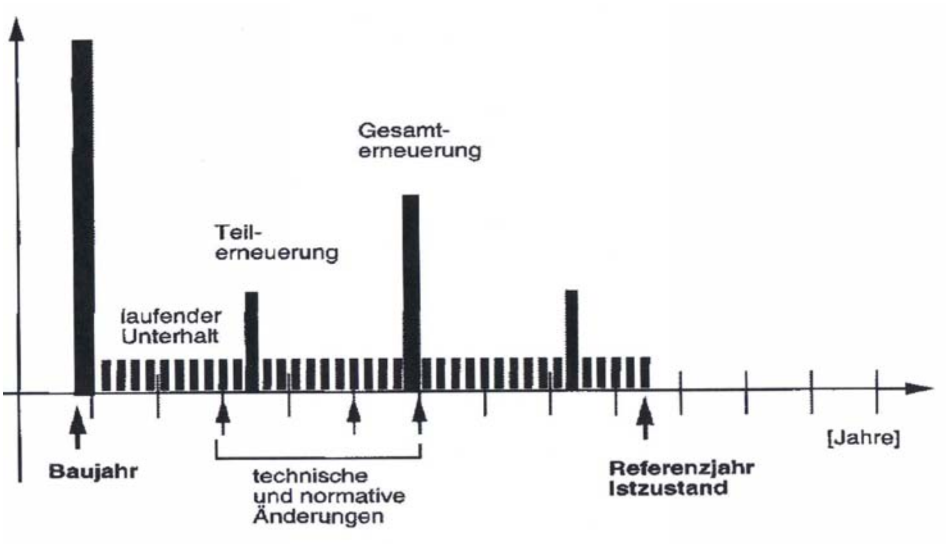

Figure 1: Maintenance cycles according to [3]

3.2 Service Life of Building Components

Data regarding the service life of building components are mostly based on examinations gathered from expert opinions. Literature offers a wide range of service life data as well as catalogs with maintenance intervals. A comparison of these values shows that the data from the different literary sources can vary considerably. Figure 2 shows what service life various sources assume for the building component window.

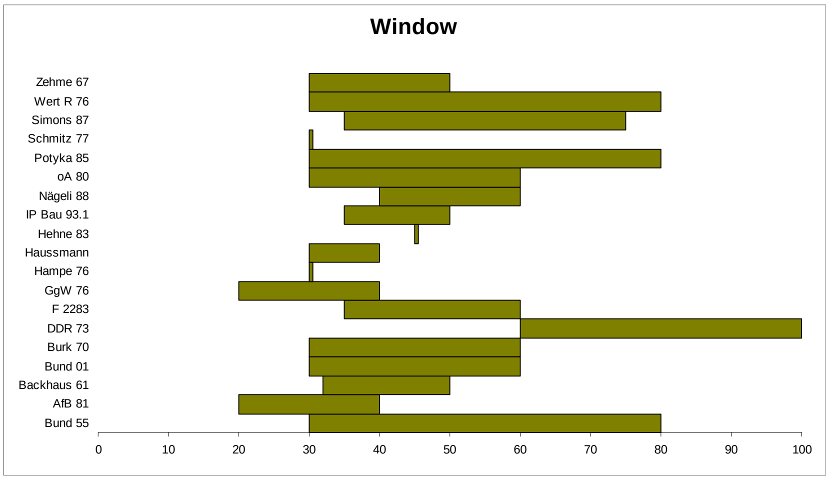

Figure 2: Service life according to different sources, building component window [4]

It becomes clear that the service life figures obtained from different sources for the same building component vary considerably. Many sources give a range between a minimum and maximum service life. Generally, the service life of a building component also depends on its type. A wooden window for example has a different service life than a window made from aluminum. Due to this, many sources provide even more specific values. Taking into account this differentiation, there are still big deviations between the service life values.

The question is which values are „correct". To date, there is no scientifically based answer. Due to the many influences that affect a building as well as the complex interdependencies and interrelations of various parameters, there are no "exact" values. The reason for the wide range and big discrepancies of the values are factors which influence the aging of a building, e.g. material and exposition of a building component as well as its construction or use. Moreover, the quality and intensity of maintenance play an important part.

The variations between the stated values show that more specific knowledge of a building component is required in order to be able to determine its real service life. Several scientific publications intend to calculate the specific service life of building components dependent on different influencing factors. Using so-called correction factors, the average reference service life can be used to determine the specific service life of a building component, depending on the existing conditions.

Today, the most popular factor method is the method ISO 15686 [5] which was published in 2000. This method tries to consider the real environmental conditions of single building components in order to determine their specific service life. The basis for this method is the reference service life of a building component. The specific service life is calculated using the modifying factors shown in table 1.

Table 1: Factors according to ISO 15686 [5]

Agents	**Factor**	**Relevant conditions (examples)**	
Agent related to the inherent quality characteristics	A	Quality of components	Manufacture, storage, transport, materials, protective coatings (factory-applied)
	B	Design level	Incorporation, sheltering by rest of structure
	C	Work execution level	Site management, level of workmanship, climatic conditions during execution of the work
Environment	D	Indoor environment	Aggressiveness of environment, ventilation, condensation
	E	Outdoor environment	Elevation of the building, microenvironment conditions, traffic emissions, weathering factors
Operation conditions	F	In-use conditions	Mechanical impact, category of users, wear and tear
	G	Maintenance level	Quality and frequency of maintenance, accessibility for maintenance

The specific building part service life is calculated via multiplying the reference service life with the factors given in table 1:

$$ESCL = RSCL \cdot factor\ A \cdot factor\ B \cdot factor\ C \cdot factor\ D \cdot factor\ E \cdot factor\ F \cdot factor\ G \qquad (3.1)$$

ESCL *estimated service life*
RSCL *reference service life*

ISO 15686 [5], however, does not state the reference service lives or the values of factors so that this method can hardly be used in real life.

3.3 Bundling of Single Measures

Single maintenance measures are often bundled into measure packages. Technical dependencies play an important part, like the fact that renewing the exterior plaster also requires a new paint coating or that certain building activities may destroy other building parts. Just as important are logistic implications, for example the optimal use of scaffolding or construction machines. In many cases, reducing the side effects like noise and dirt is another aim. The bundling of single measures generally helps to avoid extra costs and increases cost-effectiveness.

According to IPBau [6], maintenance work is often bundled according to certain building component groups. The table below shows these groups according to [6]:

Table 2: Building component groups according to [6]

Group	**Building Components**
Building envelope	Exterior plaster, windows, doors, edges, roof edge and roof surface
Bathroom and kitchen renovation	Electrical installations, heating, air conditioning, ventilation, sanitary installations
Detachable parts	Flooring and lining, surface design, installation of interior doors, curtain boards, sills, etc.

4. Research

In order to verify the theoretic models, the Department for Facility Management, University of Karlsruhe (TH), analyzes the maintenance data of 17 public buildings within the scope of the project “service life and useful life of building components” published by the research initiative „Future Building“ of the Federal Office for building and regional Planning (see chapter 2 “Method”). To prepare this examination, the Department for Facility Management, University of Karlsruhe (TH), carried out extensive data collection within the scope of the BEWIS (Optimized upkeep strategies to maintain value of buildings) project. A detailed description of the project and the buildings with the collected data can be found in[7].

As a first step towards the validation of the maintenance cycles, the most cost-intensive building components are identified via percent analysis: the costs of all maintenance measures carried out are referred to the gross floor area of each building. Then, the costs are arranged according to component and summed up across the complete portfolio. The chart below shows the result of the analysis, arranged according to the amount of maintenance costs.

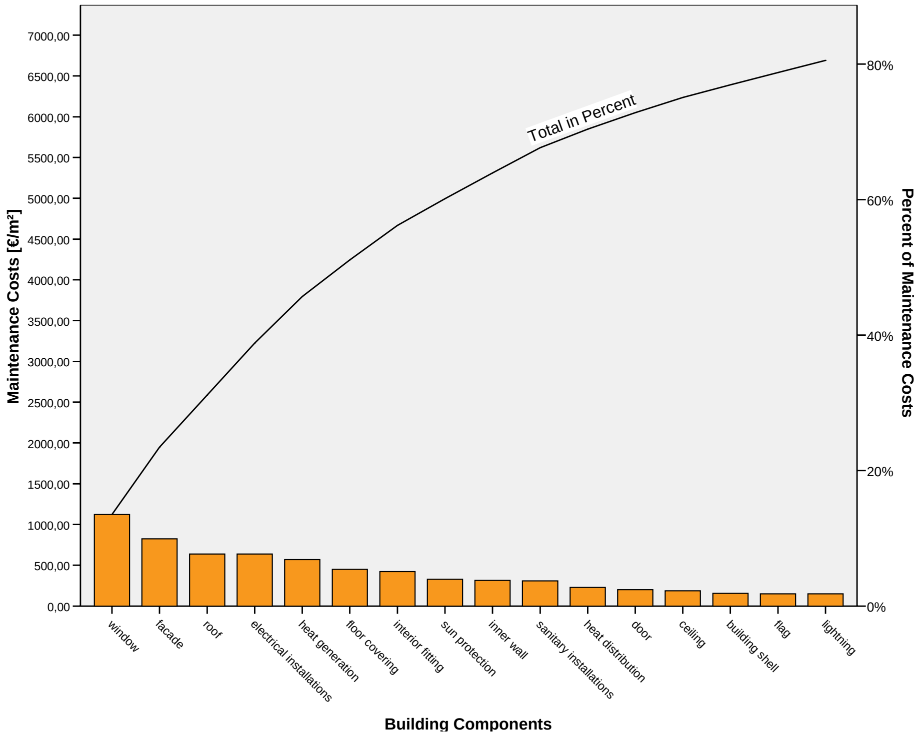

Figure 3: Maintenance cost-intensive building components [7]

Analysis shows that 80% of the maintenance costs are caused by the 16 components displayed.

As an example, the following figure shows the average maintenance costs of the analyzed buildings for the component facade over time. To enable a comparison over the full life cycle, maintenance costs are indexed using the construction price index. The analysis for the example facade shows that the maintenance cycles described in literature are generally realistic, with the partial renovation of the analyzed buildings being carried out after 17 years (Enquète 20-30 years) and the complete renovation after 32 years (Enquète 30-50 years).

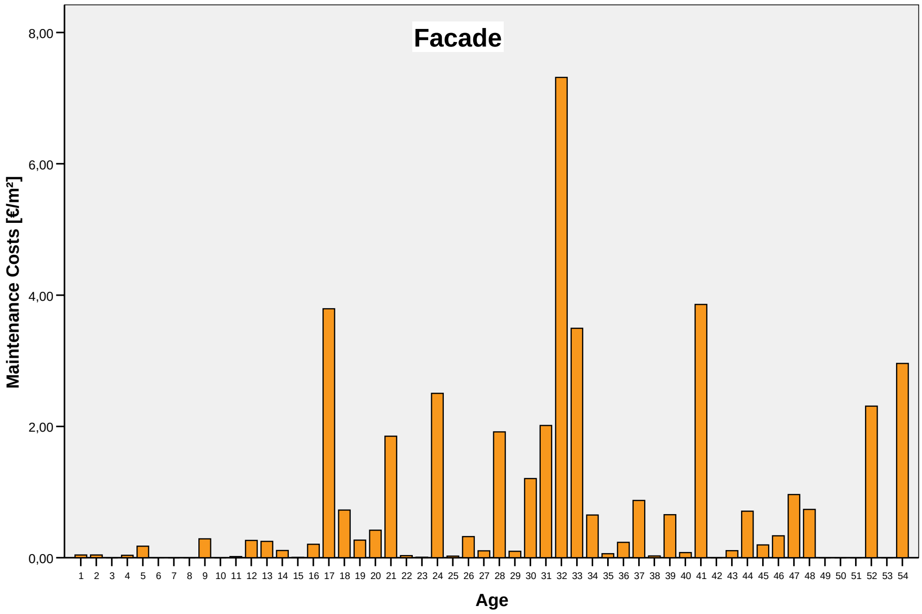

Figure 4: Average maintenance costs of example buildings, component facade

The examples analyzed also allow us to verify the measurement packages recommended by IPBau [6]. For the validation of the package "building envelope", the following chart shows the average maintenance costs for the components windows, facade and roof over time.

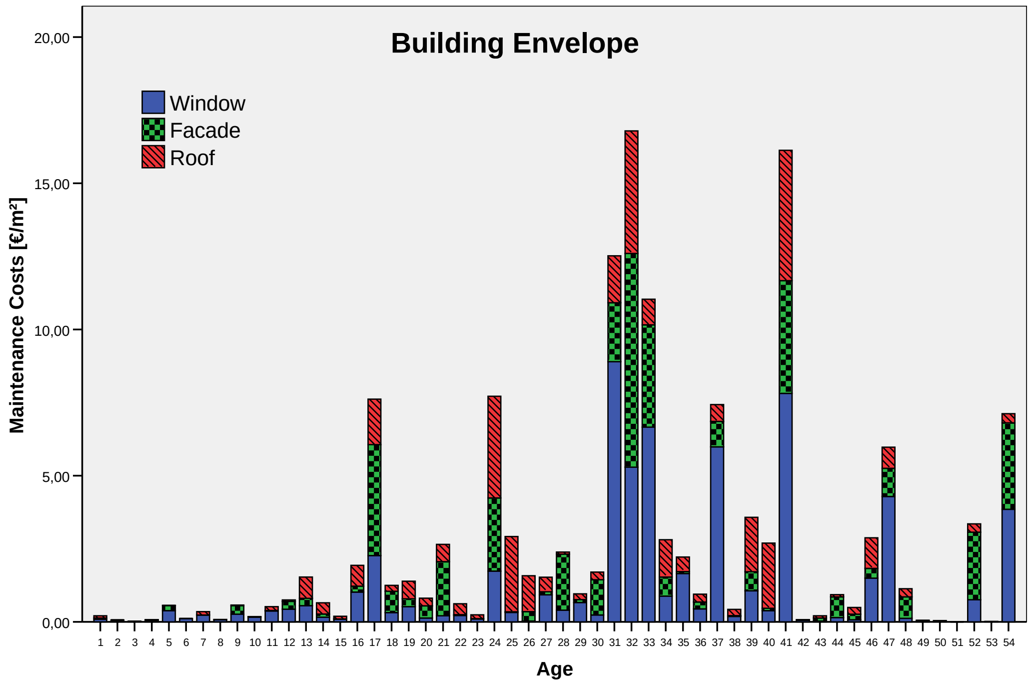

Figure 5: Average maintenance costs; components windows, facade and roof

The chart shows that the maintenance costs for the components windows, facade and roof are mostly carried out in bundles. This means that the real data correspond to the component group “building envelope” as suggested by IPBau [6].

IPBau also suggests a maintenance package that combines the maintenance of the electrical installations, heating, air conditioning and ventilation as well as sanitary installations.

In order to verify if these measures are carried out in combination in real life also, the following chart shows the average maintenance costs for electrical installations, heating and sanitary installations of the analyzed buildings over time.

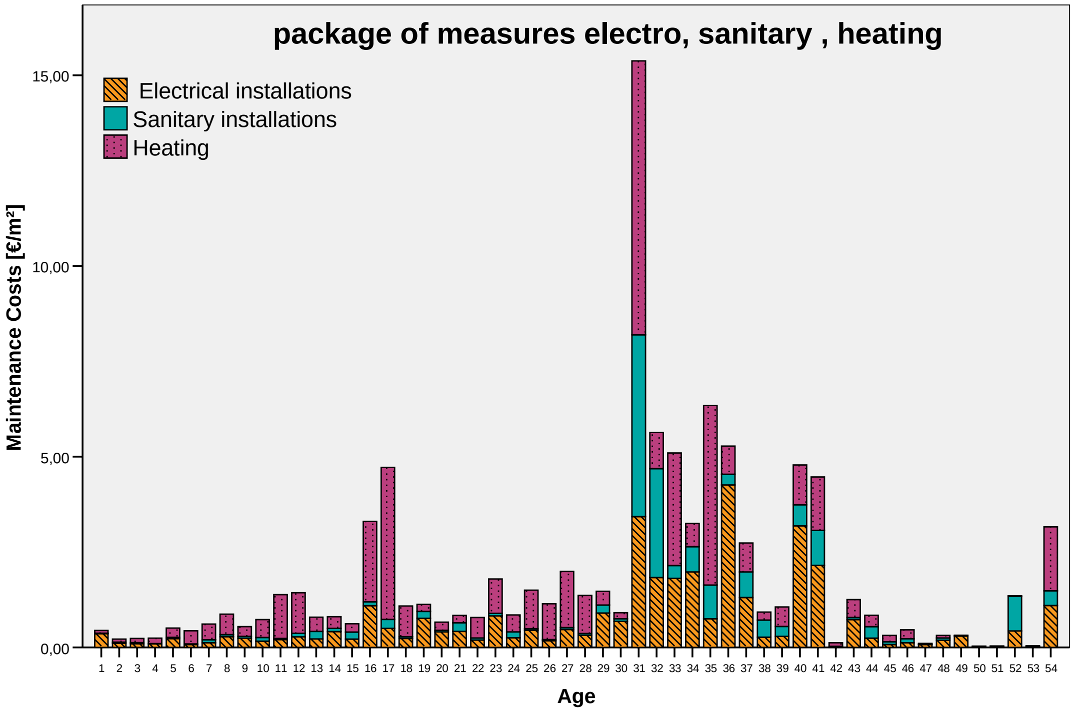

Figure 6: Average maintenance costs; components electrical installations, sanitary installations, heating

The analysis shows that the maintenance measures for electrical installations and heating of the buildings analyzed are often combined, with a partial renovation being carried out after approx. 17 years and a complete renovation after approx. 30 years. Maintenance measures to the sanitary installations, however, only appear within the scope of a complete renovation. We therefore think that they should not be part of the package. The following chart shows the average maintenance costs of sanitary installations over time separated from other costs.

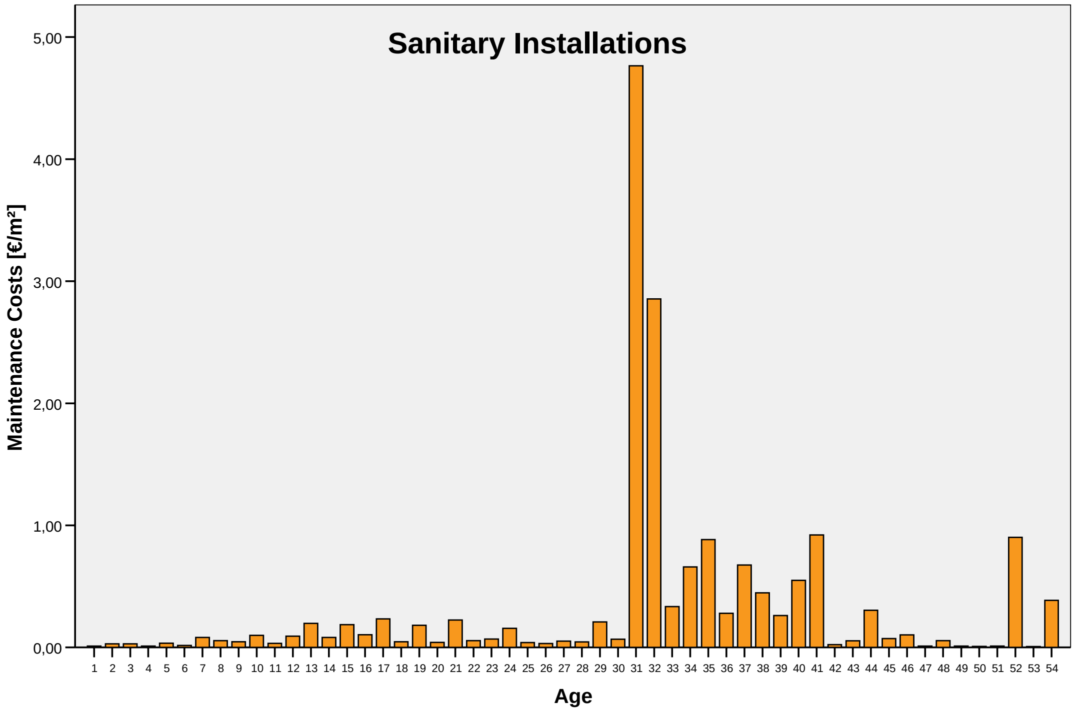

Figure 7: Average maintenance costs of example buildings, component sanitary installations

5. Conclusions

The exemplary analysis shows that the cycles described in literature are in general realistic. Similar to the theory of IPBau [6], the single maintenance measures are often bundled into packages in real life. Our research shows, however, that the values given in literature regarding the different maintenance packages should be verified and adapted using real data.

A survey among housing constructors within the framework of a research project [9], regarding which single measures were usually carried out in bundles, showed that the bundling mainly is done according to real-life experience, technical criteria and interdependencies between work steps (mentioned by 48%). The availability of financial means also plays an important part (36%). The specific service life of the different components is not an important factor (8%) for the scheduling of maintenance measures, according to the housing constructors interviewed [9].

Therefore, the factor method according to ISO 15686 [5], should be specified and simplified and herewith adaptive for real life practice. For instance, the respective influencing factors should be determined for specific component groups. Environmental influences like acid rain for example are only highly relevant for the building envelope, as it is directly affected by them. Component groups for interior material, on the contrary, are affected more by the everyday use of the building. For the maintenance cycles carried out in real life, material influences as stated by ISO 15686, e.g. quality, environmental influences and use, play an important part. Just as decisive, however, are immaterial influences like changes in function or the ageing of technical installations. These however, just like other factors, e.g. legal changes, are difficult to take into account.

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