eng

MDPI

Article

The Issue of Estimating the Maintenance and Operation Costs of Buildings: A Case Study of a School

Dino Obradović [1,*], Martina Briš Alić [2] and Ksenija Čulo [1]

[1] Faculty of Civil Engineering and Architecture Osijek, Josip Juraj Strossmayer University of Osijek, Street Vladimir Prelog 3, 31000 Osijek, Croatia
[2] Faculty of Economics and Business in Osijek, Josip Juraj Strossmayer University of Osijek, Trg Ljudevita Gaja 7, 31000 Osijek, Croatia
* Correspondence: dobradovic@gfos.hr

Abstract: The operations and maintenance phase is typically the longest phase within the building life cycle. Proper and consistent building maintenance is imperative for several reasons, including extending the life of buildings, improving occupants' comfort and safety, and ultimately saving on long-term costs. Budgets for maintenance should be foreseen. The costs of statutory periodic inspections, the costs of replacing worn materials and elements, the costs of periodic works and repairs, the costs of reactive maintenance and the costs of operation will be shown for the analyzed building—a school. This paper outlines the development of a 15-year maintenance plan and program for the building, covering the period from 2024 to 2038. The plan incorporates a discount rate of 3.64% and accounts for inflation when calculating costs. The present value of the costs of maintenance and operation of the building for 15 years is EUR 1,978,292.20 and the largest share of these costs is the operation cost of the building with EUR 1,599,002.18 (80.83%). A sensitivity analysis was conducted by varying the discount rate and analysis period, resulting in recalculated present values for maintenance costs. The analysis reveals a correlation of 26.73% between the present value of maintenance and operation costs over a 15-year period and the associated capital costs.

Keywords: buildings maintenance; inflation; maintenance costs; maintenance plan; present value

check for updates

Citation: Obradović, D.; Briš Alić, M.; Čulo, K. The Issue of Estimating the Maintenance and Operation Costs of Buildings: A Case Study of a School. *Eng* **2024**, *5*, 1209–1231. https://doi.org/10.3390/eng5030066

Academic Editor: F. Pacheco Torgal

Received: 8 May 2024
Revised: 17 June 2024
Accepted: 24 June 2024
Published: 27 June 2024

1. Introduction and Literature Review

1.1. Introduction

Maintenance has only recently gained its deserved importance. Until the mid-60s, many investors made investment decisions solely on the basis of capital costs. There were many valid reasons for this at that time. Those who provided the capital were often not responsible for operating and demolition costs at a later stage. Some investors, especially in the public sector, had separate capital and current expenditure accounts. For them, the priority was to build facilities with minimum capital costs, in the hope that they would later find the money to cover any operational and maintenance costs that might arise. Some failed to understand the importance of total life cycle costs, while others chose to simply ignore them [1].

Every building requires certain financial resources for construction. The price of a building includes all the costs incurred in order to complete the building. Normally, the price in the contract is expressed by the unit of measurement of the building being built. During the investment, there are various disturbances that cause the price to change for two reasons:

- The price increases or decreases due to incorrect input data affecting it.
- There are changes in the market during the investment [2].

Any of the two mentioned causes require constant control and correction of the price, which brings the price closer to the final one. As the construction of a building consists of a large number of activities, the total price consists of the sum of the prices of all these activities [2]. In addition, maintenance consists of a large number of activities of different types, the sum of which leads to the total cost of maintaining a certain building.

The importance of maintenance, i.e., the high costs of maintenance, is also shown by the following data. The construction budget used to inspect, maintain, or repair damaged buildings in the US is estimated at USD 18 to 21 billion annually. It is estimated that almost 50% of the construction budget in Europe is used for repairs annually, which includes maintenance [3,4]. In the United Kingdom, maintenance work generates almost 50% of production in their construction industry [5]. In the United Kingdom, it accounts for more than 5% of the gross domestic product, which would mean over 30 trillion pounds per year [6]. Building maintenance management has always been considered the Cinderella of the construction industry and has never been recognized in its own right [5,7,8]. It has always been viewed and implemented as a part of another function or discipline, such as architects, surveyors, engineers, or, more recently, facility managers [7]. Maintenance is an important aspect and must be properly managed [7].

In this paper, the introductory part pertains to the maintenance of buildings and the life cycle of the building itself. A brief overview of legal regulations in the field of maintenance is given. The costs of statutory periodic inspections, the costs of replacing worn materials and elements, the costs of periodic works and repairs, the costs of reactive maintenance and the costs of operation will be shown for the analyzed building. The maintenance plan and program were developed for the period from 2024 to 2038. A sensitivity analysis was also performed with regard to the change in the analysis period and discount rates.

1.2. Maintenance and Life Cycle of a Building

The life cycle of a building consists of several phases. The first phase occurs when the need to build a building arises. After that, the planning and design phases of the building follow and then the building is built. The planning phase has a large impact on the success of project realization in the future [9]. After the building is built, a certificate of occupancy is obtained, and the building can be used. This phase covers the longest period of time, depending on whether it is a family house (where the service life can be 50 years) or a bridge, for which the service life can be 80 to 100 years. The maintenance phase of a building in its life cycle lasts the longest, even if the duration of all phases preceding operation and maintenance are added to the demolition phase. The maintenance and operation of a building are important phases, and it is necessary to take care of proper and regular maintenance.

Maintenance is the process of ensuring that buildings and other assets are maintained in good condition and used at optimum efficiency. Improper maintenance can result in deterioration, degradation, and reduced efficiency and can affect the health and safety of users, tenants, and other people in its vicinity [10]. The shortest definition of maintenance would be that building maintenance is a means of ensuring that the building is fit for use. The total life cycle of a building is shown in Figure 1 in a simple way.

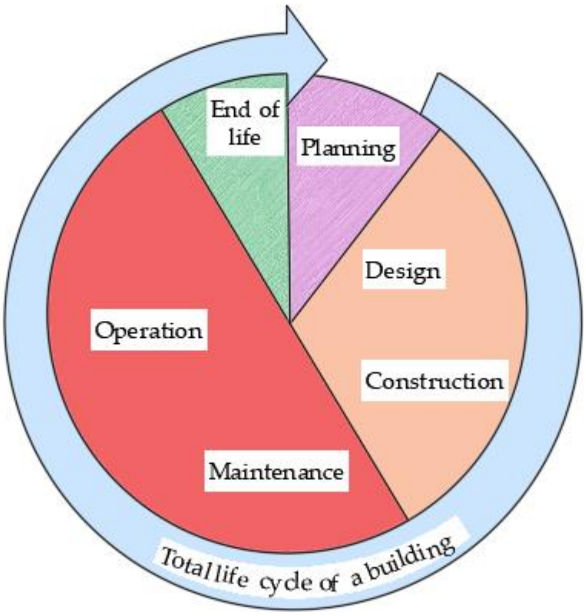

Figure 1. Life cycle of a building (according to [11,12]).

Elements of proper building maintenance:

- Technological advances fully explored and used;
- Very responsive, fine-tuned, individual users have control;
- It is green, low energy consumption, good for the environment;
- Intelligent, customer-centric, not necessarily automated, customized;
- Use of reusable components, standardized systems, methods and materials [13].

1.3. Legal Regulations and Standards

There are many regulations that are necessary and need to be used in building maintenance. Since the analyzed school is located in the Republic of Croatia, the laws, legal regulations, and standards in force in the Republic of Croatia were used. The basic legal regulations which include the concepts of building maintenance, prescribe the procedure and manner of maintenance as well as fines in case of maintenance failure are as follows:

- Building Act (NN 153/13, 20/17, 39/19, 125/19) [14].
- Ordinance on maintenance of buildings (NN 122/14, 98/19) [15].
- Regulation on building maintenance (NN 64/97) [16].

Article 3 of the Building Act (NN 153/13, 20/17, 39/19, 125/19) states what the term maintenance of buildings means. Furthermore, Articles 150, 151 and 152 of the Building Act refer to buildings' maintenance. In Article 150 of the Building Act it is stated that "the owner of a building shall be responsible for its maintenance" [14]. Article 8 of the Ordinance on maintenance of buildings (NN 122/14, 98/19) states what is meant by the term buildings maintenance [15].

The International Organization for Standardization (ISO) is responsible for establishing standards [17]. This organization has developed specific norms that are utilized by maintenance professionals; these standards belong to the ISO 15686 series, and only certain ones have been adopted as Croatian standards.

The following was adopted as Croatian standards of the ISO 15686 series [12,18–21]:

- HRN ISO 15686-1:2011 Buildings and constructed assets—Service-life planning—Part 1: General principles and framework [18].
- HRN ISO 15686-2:2013 Buildings and constructed assets—Service life planning—Part 2: Service life prediction procedures [19].
- HRN ISO 15686-3:2002 Buildings and constructed assets—Service life planning—Part 3: Performance audits and reviews [20].

- HRN ISO 15686-5:2008 Buildings and constructed assets—Service-life planning—Part 5: Life-cycle costing [12].
- HRN ISO 15686-8:2008 Buildings and constructed assets—Service-life planning—Part 8: Reference service life and service-life estimation [21].

1.4. Costs of the Building Life Cycle and Maintenance

Life cycle costing is a process of economic analysis with the aim of estimating the total life costs from procurement, the costs of use throughout the entire life cycle, to disposal costs. This analysis provides essential data in the course of decision making related to design, development, use and disposal [22]. The definition and estimation of total building costs are provided by a series of standards (HRN ISO 15686) and are described in detail in the fifth part of the standard (HRN ISO 15686) called Buildings and Constructed Assets: Service-Life Planning, Part 5: Life-cycle Costing. The specified standard enables a comparative assessment of costs during the defined duration of the building [17,23].

The standards, by determining the cost of a building's life cycle, define that this cost includes all life cycle phases from conception, definition, execution, operation, to maintenance and removal of the building. All factors that have an impact on both the initial capital costs and the future operating costs of the building are taken into account [17,23].

Life-cycle cost (LCC) is the cost of an asset or its parts during its life cycle while meeting performance requirements [12]. Whole-life cost (WLC) encompasses all the significant and relevant initial and future costs of an asset as well as the benefits of an asset during its life cycle, as long as it is meeting performance requirements [12]. The costs of the maintenance and operation phase include all the costs that are necessary for the operation and maintenance of a building during its entire service life as well as the necessary indirect costs for managing this phase [24]. The cost of using the building also includes the amount of depreciation, the costs of raw materials, labor and energy consumption if it is an industrial project. Some of these costs are fixed and some are variable [25].

In this paper, the costs of maintenance will be classified into five categories:

- Costs of statutory periodic inspections;
- Costs of replacing worn materials and elements;
- Costs of periodic work and repairs;
- Costs of reactive maintenance;
- Operational facility costs [24,26].

Figure 2 shows the complete structure of the costs of management, maintenance, and operation of a building.

The literature addressing building maintenance predominantly consists of theoretical studies, lacking empirical data on actual maintenance and usage costs. In this research, the author investigates and presents the costs associated with maintaining and using a school over a 15-year period.

Although it is known that the service life of most buildings is 50 years, 15 years was chosen as the period of analysis because it is clearer to calculate the costs for the specified period, and it would be impossible to display all the graphical representations (graphs) clearly if 50 years were taken for analysis. Also, for a period of 15 years, the value of the discount rate and the inflation rate are difficult to determine; that is, they are assumed. If the discount rate and the inflation rate were assumed for 50 years, it would be very imprecise. Furthermore, costs for a period of 20 years are presented in the sensitivity analysis.

The research aims to emphasize the significance of regular and proper building maintenance, including effective planning of maintenance activities. Adequate budgeting for maintenance is crucial to prevent situations where budgets are insufficient, leading to the inability to maintain the building and denying users access.

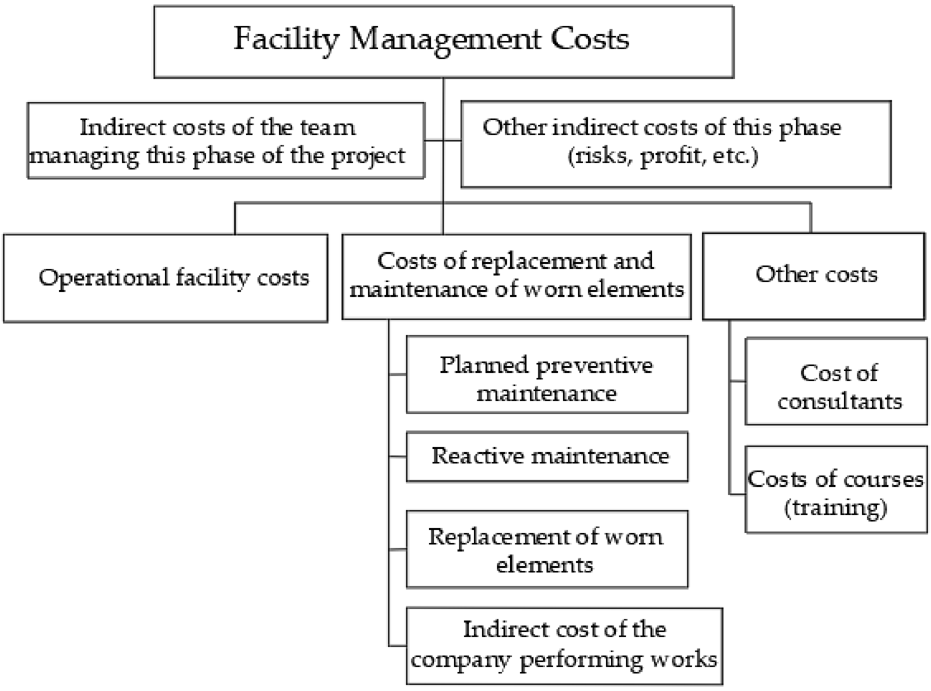

Figure 2. Costs of management, maintenance and operation of a building [24].

Furthermore, the paper's objectives include highlighting the importance of building maintenance, determining usage costs for the observed building, assessing maintenance expenses, analyzing the relationship between maintenance and operation costs and capital costs, and ultimately emphasizing the necessity of strategic planning for maintenance and operation costs.

2. Methodology

Research focused on building maintenance and associated costs was conducted. The research includes a review and an analysis of the existing professional and scientific literature, and certain reports related to maintenance issues and maintenance costs.

The aim of the research is to point out the importance of regular and proper maintenance of buildings, i.e., planning of maintenance activities. It is also important to plan budgets for maintenance so that they are available, the building can be maintained, and the users can use the building. The calculation of maintenance costs was made in MS Excel. When calculating or estimating the service life of an element or assembly of a building, the factor method will be used.

The factor method is a calculation method used to calculate the estimated service life (ESL) of an element or assembly under certain conditions [17,21,27]. The factor method initially originates from Japan, more precisely from the Architectural Institute of Japan (AIJ) [21,28,29], from 1989 [28]. It modifies the reference service life (RSL) by using correction factors for a certain element or assembly by taking into account the differences between individual buildings as well as the differences between certain conditions of use [27]. It is the best-known method that was first published in 2000 in ISO 15686. According to the factor method, seven correction factors should be taken into account for predicting the lifetime of components [30]. An example of the use of the factor method, which was also used in this paper, can be found in [31].

Moreover, as the building maintenance plan is prepared for a period of 15 years, it is necessary to take into account the time value of money. The value of the discount rate that will be used in this paper is 3.64%, and it is given in the Notice of the European Commission on the reference, discount, and recovery interest rates applicable from 1 June 2023 [32].

The impact of inflation (see Formula (1)) will also be taken into account. For the purposes of this paper, an inflation rate of 3.9% for 2024 and 2.3% for 2025 will be used. For the year 2026 and until the end of the analyzed period (until 2038), the basic inflation rate of 2.20% will be used. The details of the selection of the stated values of the inflation rate are given in Part 4. Empirical Results: Building Maintenance Plan and Program.

The formula to calculate inflation is as follows:

$$\begin{aligned}
&\text{for first period (year): } CI_{(1)} = C + (C^{*}r) \\
&\text{for second period (year): } CI_{(2)} = CI_{(1)} + (CI_{(1)}{}^{*}r) \\
&\text{for third period (year): } CI_{(3)} = CI_{(2)} + (CI_{(2)}{}^{*}r) \\
&\text{for n period (year): } CI_{(n)} = CI_{(n-1)} + (CI_{(n-1)}{}^{*}r)
\end{aligned} \tag{1}$$

where

- C—original cost without inflation;
- CI—cost with impact of inflation;
- r—inflation rate;
- $_{(1)}, _{(2)}, _{(3)}, \ldots, _{n}$—period (year).

A sensitivity analysis (SA) will be carried out at the end of the paper. The sensitivity analysis provides users of mathematical and simulation models with a tool to assess the dependence of the model output on the model input and to investigate how important each model input is in determining the model output [33]. It is a special case of what-if analysis [34]. Sensitivity analysis is a method that measures how the influence of the uncertainty of one or more input variables can lead to the uncertainty of the output variables. It is extremely useful since this method improves model prediction or reduces inaccuracy by studying the qualitative and/or quantitative response of the model to changing input variables [35,36] or understanding the phenomenon being studied by analyzing interactions between variables [35].

During the sensitivity analysis, critical variables [25] and parameters of the model should be chosen. Critical variables can be considered those variables whose positive or negative variations have the greatest impact on the performance indicators of the observed project [37].

3. Case Study: Technical Description of the Analyzed Building

The area of the plot where the school is located amounts to 18,318 m^2 [38]. The cadastral plot is of a regular rectangular shape, and its longer sides spread in the north-south direction [39].

The building is a school. Classes at the school are held in a single shift. The school employs 56 employees, and the school was attended by 245 students in 16 classes in the school year 2022–2023.

The building of the school is divided into functional units. The design includes two elongated parts of the school building, encompassing the ground floor and the first floor, with one of the part consisting of a sports hall with accompanying premises at the ground-floor level. In the two elongated parts spreading in the east-west direction, there are classrooms and a space for organizing classes, and in the rectangular part, there is a two-part sports hall bordered by accompanying facilities in the south and another part with classrooms for organizing practical classes in the north. The sports hall is intended exclusively for the needs of the school, and there is a seating area with telescopic stands for about 256 people in the hall [39]. The main entrance to the building is executed from the north side through the school's covered porch.

Basic data on the area and volume of the building are shown in Table 1.

Table 1. Data on the area and volume of the building (made by the authors according to [39]).

Description	Amount
built area of the building (vertical projection of the building)	3465.51 m^2
net area of the building	4644.51 m^2
total volume	25,981.00 m^3

The building of the school consists of three dilations. Expansion joint A represents a concrete building with a ground floor and a first floor. Expansion joint B represents a brick building with a ground floor and first floor. Expansion joint C refers to the sports hall with accompanying facilities located on the ground floor [39].

The building is connected to the municipal water supply and sewage network. Hot water used in sinks and showers is heated in the boiler room. The lighting includes fluorescent lamps. The lighting of the blackboards was carried out using lamps suspended from the ceiling. A telephone and computer network have been installed throughout the building. Bells and impulse clocks are placed in the corridors. There is a TV connection in every classroom, specialized classroom, and teacher's lounge. An amplifier and a microphone have been installed in the teacher's lounge, and each classroom has a speaker. An anti-theft switchboard was set up, to which sensors are connected and placed throughout the premises. A central video surveillance system was also installed. The building has a fire alarm system [39].

The infrastructure for heating, preparation of domestic hot water, ventilation, cooling of a part of the building, gas boiler room, and natural gas infrastructure was installed in the building.

The designed life of the building is 100 years under the conditions of use in accordance with the purpose of the building and regular maintenance. The building may only be used in a manner consistent with its purpose [39]. The energy performance certificate of the building [40] states that the energy rating of the school is *C* according to the specific annual thermal energy required for heating ($Q''_{H,nd}$) and according to the specific annual primary energy (E_{prim}), the rating is also *C*.

4. Empirical Results: Building Maintenance Plan and Program

In the continuation of the paper, the costs of maintenance and operation of the building will be presented in five categories. The actual costs for the building in question were determined, while some data on prices, i.e., costs, were obtained during conversations with people in charge of maintaining similar buildings (experts who conduct tests), using the different literature such as price lists or websites of equipment and material manufacturers, direct contact with material manufacturers and contractors, and some of the costs were determined based on experience. An important source of data on prices was the Bulletin Standard calculation of works in high-rise construction, specifically Bulletin XII 2021 (Q4 2021)—Update I [41].

Furthermore, we are witnessing rapid price changes of various types of products on a weekly or monthly basis, especially price changes in construction, so every cost needs to be determined carefully. There is also a difference in price depending on the brand of the product, building element or material. An effort was made to present the costs of individual activities of maintenance and use of the building as realistically as possible.

Costs of maintenance, and therefore repairs and/or replacement of sports hall equipment (ladders, protective nets, football/handball goals, basketball hoops, gymnastic springboards, mats, etc.), drawing the lines of the basic playgrounds (handball, futsal, basketball, volleyball and badminton) in the hall, outdoor playground equipment (basketball hoops, protective nets), classroom equipment (school desks and chairs, teacher's desks, projectors, projector screens, blackboards), student lockers, and various external equipment of the school (bike racks, trash cans, etc.) will not be taken into account because they are not necessary for the operation of the building and its proper functioning, they are replaceable relatively easily and are considered as equipment of the building.

Throughout the paper, the value of the discount rate of 3.64% will be used, and it is given in the Notice of the European Commission on the reference, discount, and recovery interest rates applicable from 1 June 2023 [32].

Since this paper aims to prepare a building maintenance plan for a period of 15 years and we live in an inflationary economy marked by rising prices [42], the impact of inflation should also be considered. We are also witnessing an increase in the price of energy sources, electricity and gas, as well as the price of building materials, and inflation should also be taken into account. It would not be realistic, and it cannot be expected that the prices in the next 15 years will remain the same as today.

From an economic perspective, inflation is a critical factor directly linked to economic growth [43–45]. However, estimating the precise impact of changes in the inflation rate remains challenging [46].

For the purposes of this paper, an inflation rate of 3.9% was used for 2024 and 2.3% for 2025. For the year 2026 and until the end of the analyzed period (until 2038), the basic inflation rate of 2.20% was used, which is the average annual inflation rate obtained by the analysis of the author of this paper for the period from 1996 to 2022. The formula for calculating inflation is given in Part 2. Methodology.

In the Republic of Croatia, according to the governor of the Croatian National Bank, the target inflation rate is 2%, to which inflation should return to in 2025 [47,48]. The Governing Council of the European Central Bank (ECB) states that it advocates a return of inflation to the medium-term goal of 2% [49,50]. Therefore, the inflation of 2.20% which will be used in this paper is approximately equal to the target inflation rate, yet it is slightly higher, and it is considered that it will be applicable for calculating the costs.

4.1. Costs of Statutory Periodic Inspections

In order for the users of the building to be safe in it and to prevent unexpected malfunctions threatening the lives and health of people, certain periodic inspections are prescribed. The aforementioned inspections may be statutory or prescribed by ordinances and technical regulations. Since the certificate of occupancy for the school was obtained in 2022 and all inspections were carried out at that time, it will be considered that the statutory periodic inspections start in 2023.

The amounts of costs for the individual activities of statutory periodic inspections (Table 2) were obtained from the persons who carry out these inspections by analyzing the literature and reviewing the relevant websites of the companies in charge of such inspections.

Table 2. Costs of statutory periodic inspections.

Number	Activity Description	Total Cost (EUR)
1	inspection and testing of electrical installations	4000.00
2	inspection and testing of protection against static electricity	15,000.00
3	visual inspection of the lightning protection system on buildings	1000.00
4	testing the lightning protection system on buildings	1500.00
5	inspection and testing of emergency lighting	10,800.00
6	testing of the stable fire detection and alarm system	10,125.00
7	inspection and testing of fire switches	7950.00
8	testing of the indoor hydrant network	3000.00
9	testing of the outdoor hydrant network	2400.00
10	testing of fire extinguishers	2550.00
11	elevator inspection	1680.00
12	inspection and testing of fire dampers	2800.00
13	inspection and measurement of harmfulness in the work environment	3125.00
14	energy performance certification and energy performance certificate of the building	2500.00

Table 2. *Cont.*

Number	Activity Description	Total Cost (EUR)
15	mandatory pest control and disinfection measures	30,000.00
16	examination of the gas boiler room	880.00
17	testing the correct operation and tightness of indoor gas installations	3750.00
18	testing of gas appliances	1500.00
19	chimney testing	1800.00
20	testing of ventilation ducts	3750.00
21	testing of work equipment and machines	3750.00
22	air conditioning system inspection	48,000.00
	Total costs for 15 years	**196,993.52**
	Present value of costs in 15 years	**147,471.98**

Figure 3 shows a graphic representation of the cumulative costs of statutory periodic inspections for 15 years at the annual level, the costs reduced to the present value and the cumulative present value of the costs.

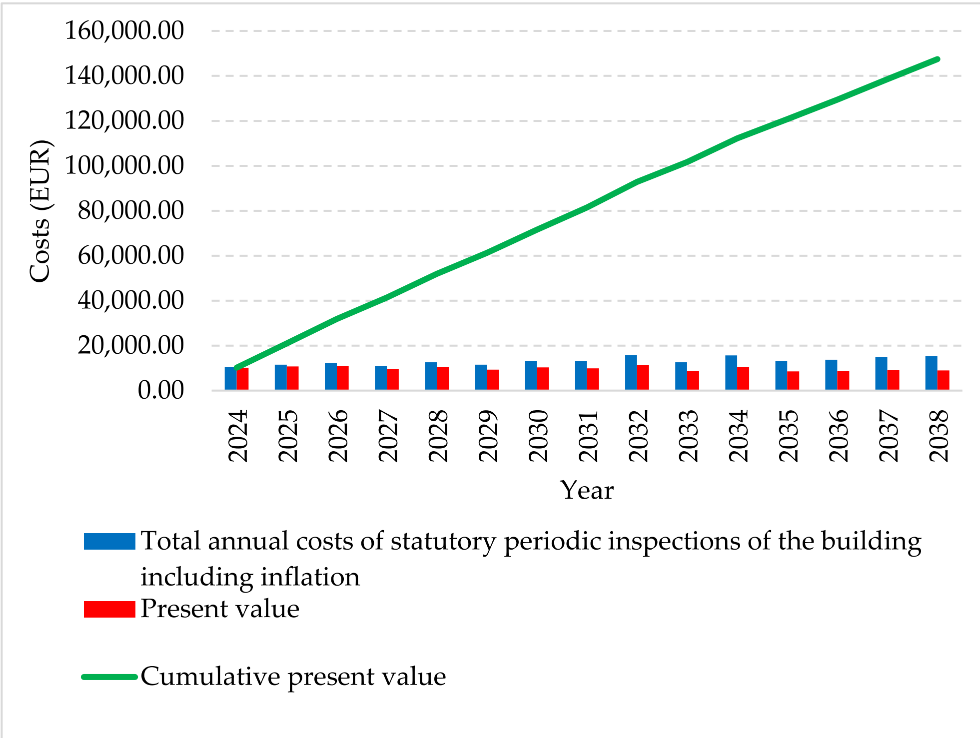

Figure 3. Graphic representation of the costs of statutory periodic inspections.

4.2. Costs of Replacement of Worn Materials and Elements

Generally speaking, the costs of replacement of worn materials and elements include the costs of activities based on the changes made to certain materials and buildings elements that have worn out. The replacement periods of worn materials and building elements were analyzed using the factor method.

A common example of replacing worn materials and elements is the replacement of floor and wall coverings. In the analyzed building, some of the most common indoor types of floors and floor coverings are as follows: gres porcelain tiles, oak parquet, and linoleum. Moreover, one of the activities of replacing worn materials and elements is the replacement of sinks and batteries for hot and cold water.

The costs of replacing worn materials and elements for the analyzed building for a period of 15 years are shown in Table 3.

Table 3. Costs of replacement of worn materials and elements.

Number	Activity Description	Total Cost (EUR)
1	replacement of horizontal rainwater drainage (gutter)	0.00
2	replacement of vertical rainwater drainage	0.00
3	replacement of tin and aluminum windowsills	0.00
4	replacement of the tin frame above the entrance wall (attic) and the frame of the canopy above the entrance	0.00
5	replacement of porcelain floor tiles in the showers	0.00
6	replacement of porcelain floor tiles in bathrooms, storerooms and changing rooms	0.00
7	replacement of wall tiles in sanitary rooms	0.00
8	replacement of wall tiles behind sinks in classrooms and specialized classrooms	0.00
9	replacement of the oak parquet floor	0.00
10	replacement of elastic linoleum floor covering	0.00
11	replacement of the sports flooring in the sports hall	0.00
12	replacement of the floor made of a thin-layer coating based on epoxy resins	0.00
13	replacement of tactile paving (warning surfaces and guidance paving)	0.00
14	replacement of indoor stone windowsills	0.00
15	replacement of granite floor covering—outdoor surfaces	0.00
16	replacement of floor covering made of terrazzo tiles (indoor stairs and landings)	0.00
17	replacement of the ventilated facade made of plastic-covered steel lamellas	0.00
18	restoration of silicate protective-decorative plaster—the facade of the inner side of the attic	0.00
19	restoration of silicate protective-decorative plaster—plinth wall	0.00
20	replacement of the outdoor mat in front of the main entrance	560.00
21	replacement of the indoor mat in the anteroom of the main entrance	520.00
22	replacement of the eight-part aluminum glazed wall of the front door	0.00
23	replacement of swing solid steel door, entrance to the boiler room	0.00
24	replacement of electric industrial sectional lift doors in workshops	0.00
25	replacement of single swing solid steel doors to classrooms	0.00
26	replacement of single swing solid steel doors	0.00
27	replacement of external glazed walls	0.00
28	replacement of electrical installation	0.00
29	replacement of the fire alarm system	0.00
30	replacement of water supply and sewage infrastructure	0.00
31	replacement of the video surveillance system	0.00
32	replacement of the ventilation and air conditioning system	0.00
33	replacement of the heating system	0.00
34	replacement of the elevator infrastructure	0.00
35	replacement of showers in changing rooms	2700.00
36	replacement of urinal with vertical flushing, complete with electronics	0.00
37	replacement of built-in ceramic sinks on the slab	0.00
38	replacement of single-handle standing battery for hot and cold water (built-in sink)	2646.00
39	replacement of ceramic sinks	0.00
40	replacement of single-handle standing battery for hot and cold water (sink)	0.00
41	replacement of a ceramic toilet bowl with a built-in cistern	0.00
42	replacement of radiators	0.00
43	replacement of locks and doorknobs	0.00
44	replacement of indoor air conditioning units	0.00
45	replacement of the vapor barrier of a flat roof	0.00
46	replacement of thermal insulation of a flat roof	0.00
47	replacement of sifted gravel on a flat roof	0.00
	Total costs for 15 years	**8758.85**
	Present value of costs in 15 years	**5426.21**

Several cost values for the replacement of worn materials and elements are zero due to the absence of replacement needs during the analyzed period. However, it is important to mention activities because they may appear after a certain time. The replacement time of worn materials and elements was obtained using the factor method, which is explained in Part 2. Methodology.

Figure 4 shows a graphic representation of the cumulative costs of replacing worn materials and elements for 15 years at the annual level, the costs reduced to the present value and the cumulative present value of the costs.

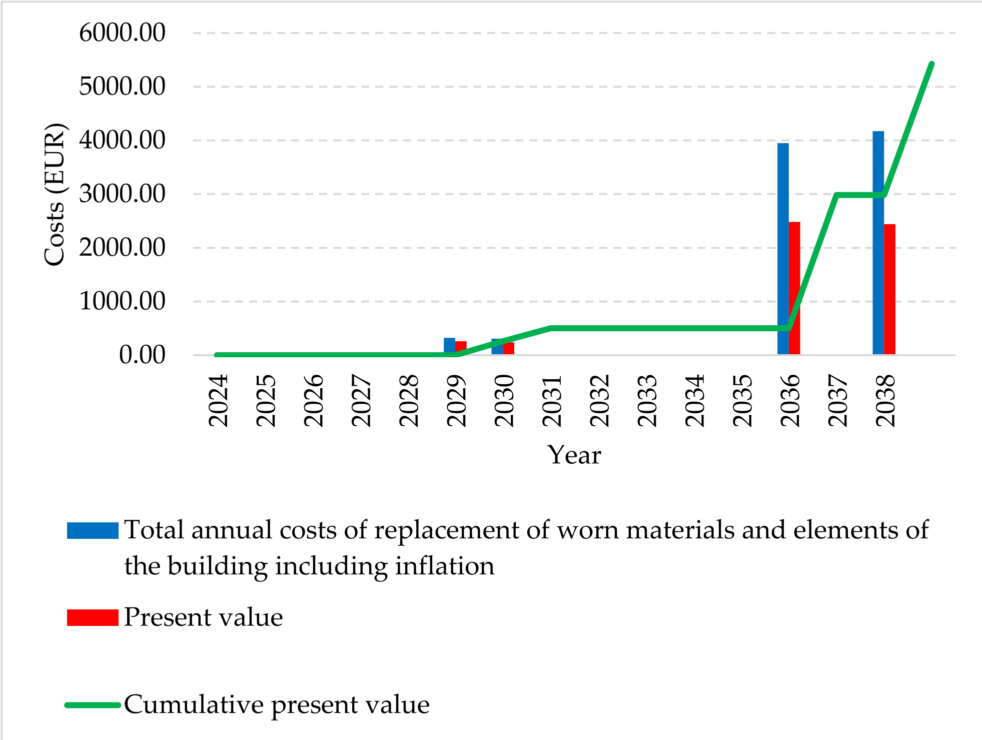

Figure 4. Graphic representation of the costs of replacing worn materials and elements.

4.3. Costs of Periodic Works and Repairs

Since there are various activities that are repeated at certain time intervals that are similar, such works are called periodic works and repairs. One of the most common examples of the above is the painting of walls and ceilings, which is usually done every five years. Of course, these works and repairs depend on the intensity of use, the manners and behavior of the users, the type of building, the work procedures per-formed in the building, external factors, etc.

The costs of periodic works and repairs for the analyzed building for a period of 15 years are shown in Table 4.

Table 4. Costs of periodic works and repairs.

Number	Activity Description	Total Cost (EUR)
1	painting the interior walls with dispersive paint	103,425.00
2	painting the ceilings with dispersive paint	48,825.00
3	painting the facade (plinth) with facade paint	2387.00
4	sanding and cleaning stone composite flooring—stairs and landings	1527.75
5	sanding and cleaning granite floor covering—outdoor surfaces	2445.00
6	sanding and varnishing the oak parquet	39,420.00
7	creating dividing lines, internal road	398.25
8	marking the parking lot with a solid white 15 cm wide line	433.50
9	painting the metal part of the fence at the border of the plot	14,178.00
10	painting the fence of a dog-legged staircase with a height of 1 m	692.00
11	painting the heating pipes with varnish resistant to increased temperature	7344.00
12	painting the radiators	10,839.50
	Total costs for 15 years	**287,899.64**
	Present value of costs in 15 years	**208,330.41**

Figure 5 shows a graphic representation of the cumulative costs of periodic works and repairs for 15 years at the annual level, the costs reduced to the present value and the cumulative present value of the costs.

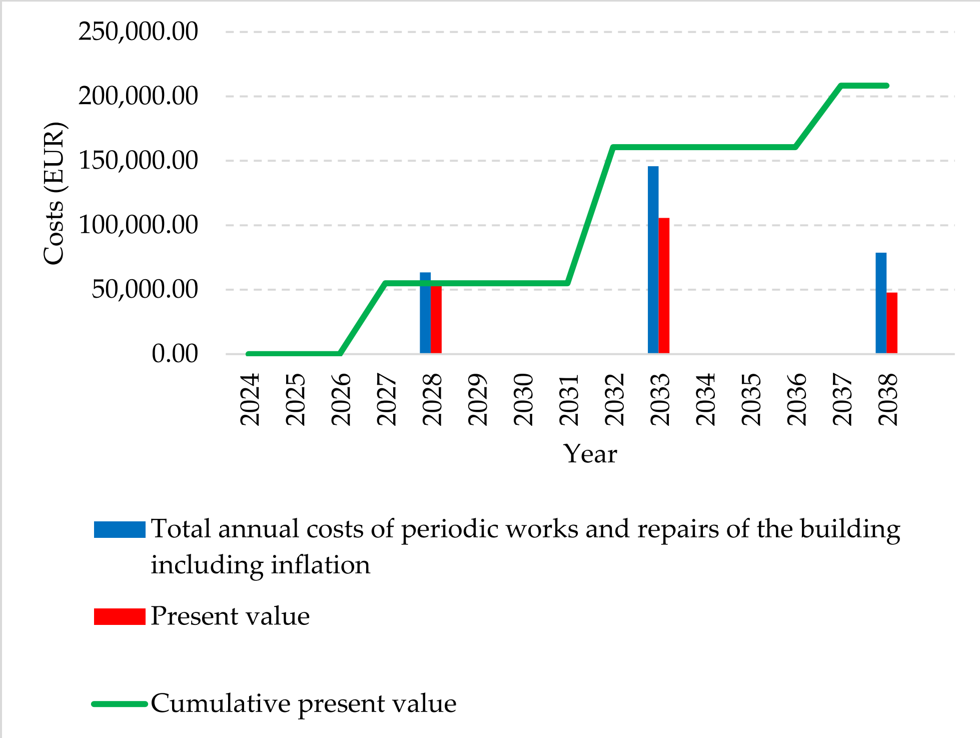

Figure 5. Graphic representation of the costs of periodic works and repairs.

4.4. Costs of Reactive Maintenance

Reactive maintenance can be seen as a method of maintenance when there is a failure or damage to an element or assembly of a building, and it includes different types of repairs and replacements. The costs of reactive maintenance are impossible or very difficult to predict because it is not possible to know when a specific failure will occur. For instance, it is not possible to know if and when someone will break a window, when a storm occurs that will damage or destroy the roof structure or the roof covering, when the water supply or sewage pipe will burst, etc. Although the costs of reactive maintenance are unpredictable, it is necessary to specify them as much as possible with respect to the observed building in order to keep them in mind if and when a failure occurs.

These costs in the building maintenance plan are foreseen in the amount of 5% of the total sum of the first three groups of costs (costs of statutory periodic inspections, costs of replacing worn materials and elements and costs of periodic works and repairs). It is not possible to calculate the specified costs precisely, so they will be calculated as mentioned above.

The costs of reactive maintenance on the building for a period of 15 years are shown in Table 5.

Figure 6 shows a graphic representation of the cumulative costs of reactive maintenance for 15 years at the annual level, the costs reduced to the present value and the cumulative present value of the costs.

4.5. Costs of Use—Operation Facility Costs

The costs of use of the building include all costs arising from the use of the building itself. The cleaning of the building and its surroundings accounts for a large share of the costs of use, as well as the inspection and minor repairs of the school. Those activities are carried out by the cleaners, the janitor and the boiler operator. In this case, the work of the janitor and the boilermaker is performed by a single employee.

Table 5. Costs of reactive maintenance.

Number	Activity Description	Total Cost (EUR)
1	replacement of broken glass surfaces	5% of costs from Sections 4.1–4.3
2	repair of the tin frame of the attic and of the canopy above the entrance	
3	repair or replacement of fittings, locks and doorknobs	
4	replacement of the toilet seat and toilet equipment	
5	repair or replacement of rainwater drainage parts	
6	repair or replacement of batteries for hot and cold water	
7	replacement of LED lighting fixtures	
8	repair of the lightning protection infrastructure	
9	repair of indoor air conditioning units and air conditioning system	
10	repair of the fire alarm	
11	repair or replacement of aluminum ribbed radiators	
12	repair of the heating system	
13	sewage network maintenance	
14	water supply network maintenance	
15	repair or replacement of oak parquet flooring	
16	repair of granite slabs paving	
17	repair of ceramic tile flooring	
18	repair of linoleum floor covering	
19	repair of the video surveillance system	
20	repair of parts of the entrance ramp	
21	repair of indoor windowsills made of stone composite	
22	replacement of electrical sockets and switches	
23	repair of indoor walls in terms of masonry and painting	
24	repair of the anti-theft system	
25	repair of the elevator	
26	repair of parts of the indoor and outdoor hydrant network	
27	repair of aluminum doors and windows	
28	replacement or repair of sinks, urinals, cisterns and toilet bowls	
29	repair of the ventilation system	
30	unplanned roof repair	
31	repair or replacement of the ventilated facade	
32	repair of the facade made of decorative plaster	
33	repair or replacement of the plot fence	
34	repair of the electric lifting partition made of different materials in the sports hall	
35	repair or replacement of waterproof walls of toilet cubicles	
	Total costs for 15 years	**24,682.60**
	Present value of costs in 15 years	**18,061.43**

The costs of using the building, i.e., electricity, drinking water, and natural gas, were calculated based on the data available to the author and can be considered actual costs. Costs per month were obtained, and their arithmetic mean was calculated. The school started operating in 2023. To be on the safe side, it was assumed that the average monthly cost for electricity, water and gas is borne by the school every month regardless of holding classes at the school because during the holidays various school cleaning jobs are carried out, certain employees work, plants and trees around the school are watered, and students' professional practice is carried out, etc.

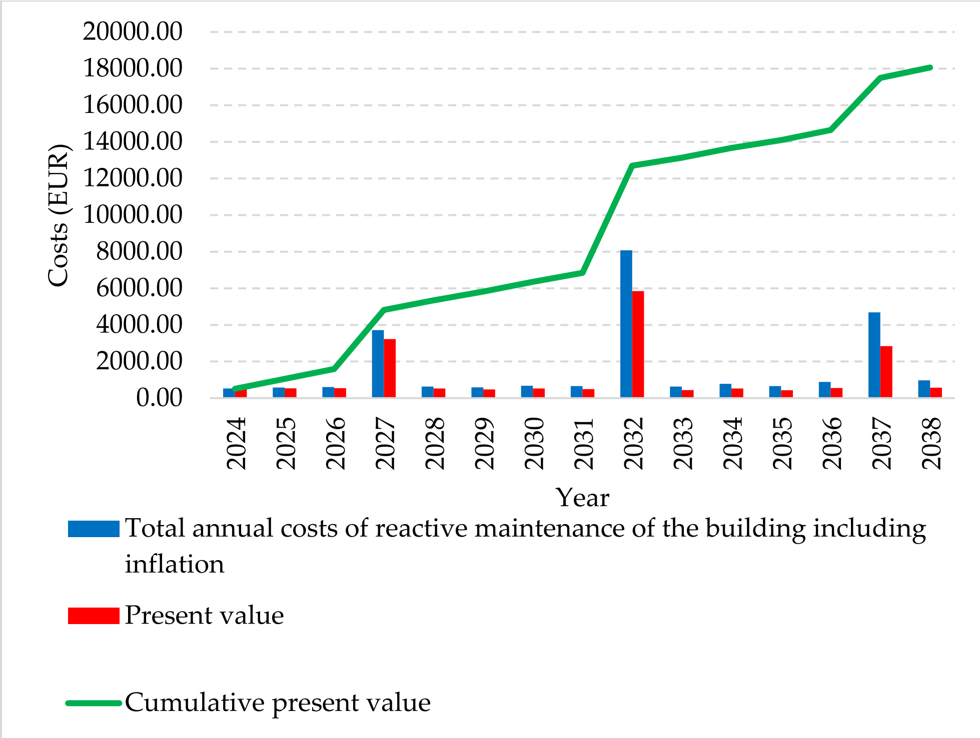

Figure 6. Graphic representation of the costs of reactive maintenance.

The costs of telephone and internet services, municipal waste collection, and water regulation fees are also obtained directly from the school's administrative documents and will be considered actual costs. The average monthly cost of consumables is assumed.

The cost of buying a new tractor lawnmower and grass trimmer, which are necessary for maintaining the school's surroundings, is determined with regard to the current type and brand that the school has or currently uses. The aforementioned tractor lawnmower and grass trimmer are considered fixed tangible assets, and such assets are subject to depreciation.

The cost of staff for six cleaners and a janitor is given in the total cost of salaries paid by the employer. The stated cost of salaries was calculated based on the data available to the author.

The operation costs of the building for a period of 15 years are shown in Table 6.

Table 6. Operation costs.

Number	Activity Description	Total Cost (EUR)
1	electricity supply	148,679.10
2	drinking water supply	13,024.80
3	natural gas supply	127,226.88
4	telephone and internet services	27,720.00
5	municipal waste collection	33,300.00
6	water regulation fee	14,279.40
7	cleaning the building and the surroundings	1,278,000.00
8	consumables (cleaning supplies and equipment)	90,000.00
9	basic means of work for the janitor (lawnmower, motor grass trimmer)	22,400.00
	Total costs for 15 years	**2,135,009.67**
	Present value of costs in 15 years	**1,599,002.18**

Figure 7 shows a graphic representation of the cumulative operation costs for 15 years at the annual level, the costs reduced to the present value and the cumulative present value of the costs.

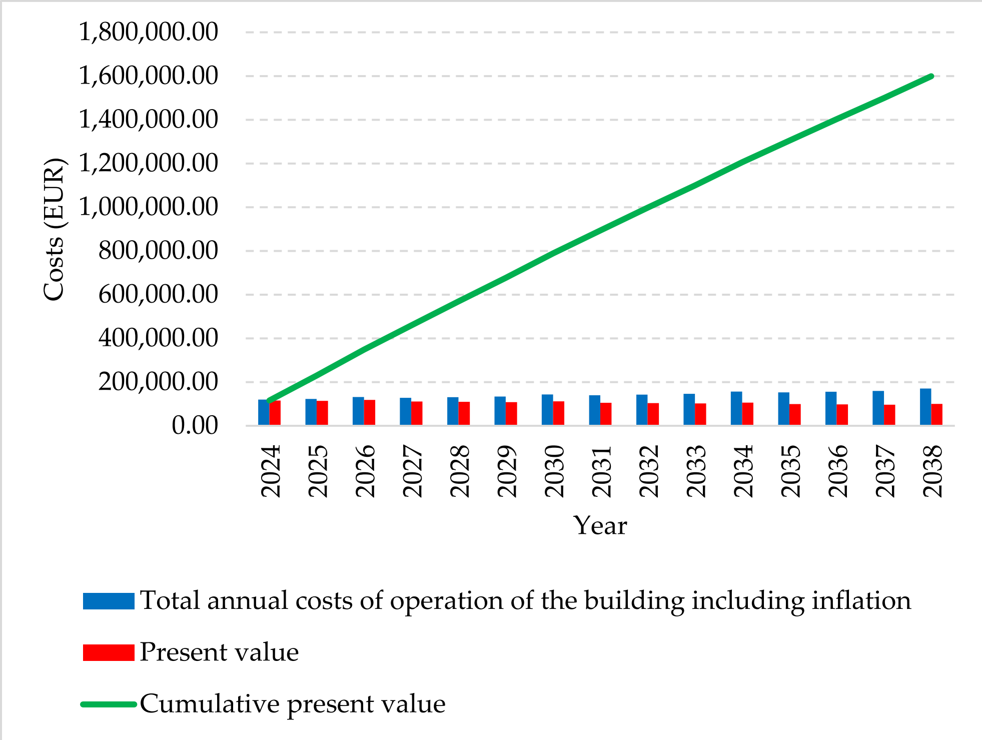

Figure 7. Graphic representation of the operation costs.

4.6. Comparison of Total Costs and Costs Reduced to Present Value

Table 7 and Figure 8 show the total costs of maintenance and operation for 15 years.

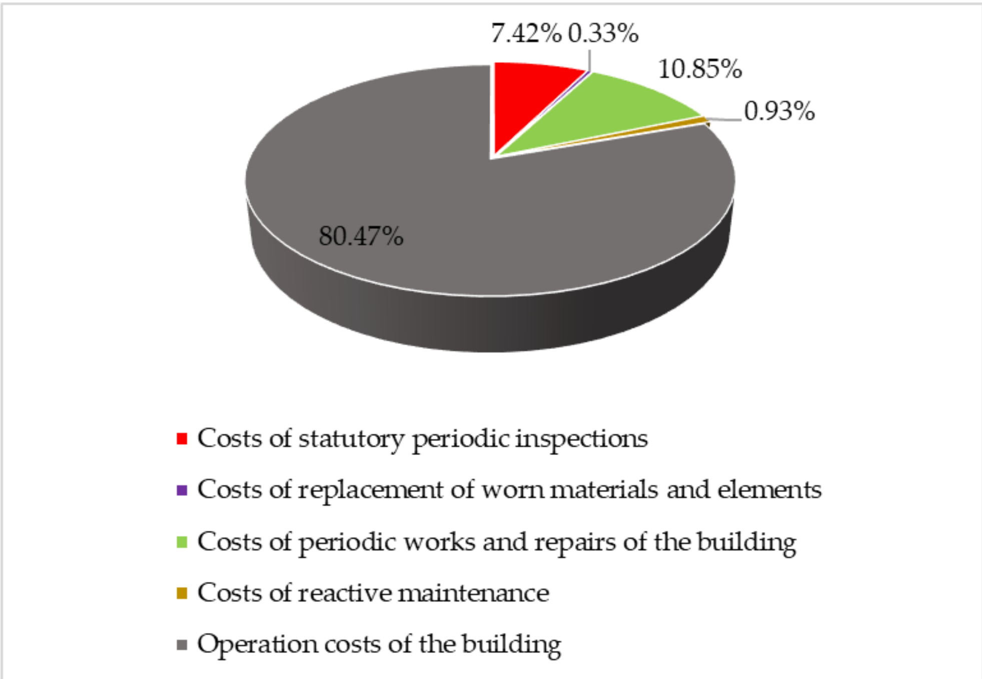

Figure 8. Representation of the share of individual groups of costs in the total cost.

Table 7. Total costs of maintenance for the building for 15 years.

Group of Costs	Total Costs (EUR)	Share in Total Cost (%)
costs of statutory periodic inspections	196,993.52	7.42%
costs of replacement of worn materials and elements	8758.85	0.33%
costs of periodic works and repairs of the building	287,899.64	10.85%
costs of reactive maintenance	24,682.60	0.93%
operation costs of the building	2,135,009.67	80.47%
Total for 15 years	**2,653,344.28**	**100.00%**

Table 8 and Figure 9 show the total present value of the maintenance and operation costs for 15 years. The discount rate used is 3.64%.

Table 8. Total present value of the maintenance costs for the building for 15 years.

Group of Costs	Total Costs (EUR)	Share in Total Cost (%)
costs of statutory periodic inspections	147,471.98	7.46%
costs of replacement of worn materials and elements	5426.21	0.27%
costs of periodic works and repairs of the building	208,330.41	10.53%
costs of reactive maintenance	18,061.43	0.91%
operation costs of the building	1,599,002.18	80.83%
Total for 15 years	**1,978,292.20**	**100.00%**

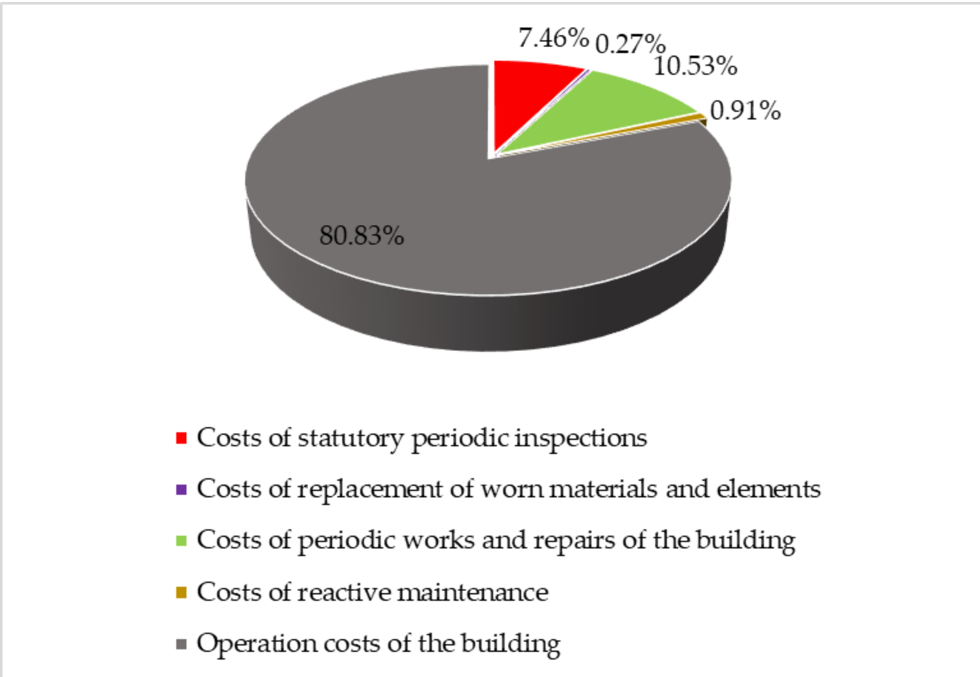

Figure 9. Representation of the share of individual groups of costs in the total present value of the cost.

4.7. Sensitivity Analysis

In carrying out the sensitivity analysis, the discount rate will first be varied by −1% and by +1% from the one used at the beginning of the analysis. This means that if the initial discount rate is equal to 3.64%, then the new two values will be 2.64% and 4.64%, respectively. Then the new total costs of maintenance and use of the building will be calculated, as well as the corresponding change in the stated costs in percentages.

Afterwards, the analysis period will be varied by −5 years and by +5 years from the period of 15 years that was set in the initial maintenance plan and program. Therefore, the newly obtained values will correspond to 10 years and 20 years. After that, the total costs of maintenance and operation of the building and changes in costs expressed in percentages will be calculated [51].

Table 9 shows the sensitivity analysis in which the discount rate was varied by ±1% compared to the initial one, while the graphic representation can be found in Figure 10.

Table 9. Sensitivity analysis—change in the discount rate by ±1%.

Discount Rate	Change in the Discount Rate	Present Value of Costs (EUR)	Change in Present Value of Costs
2.64%	−27.47%	2,137,347.09	8.04%
3.64%	0.00%	1,978,292.20	0.00%
4.64%	27.47%	1,835,506.93	−7.22%

Figure 10. Results of the sensitivity analysis—change in the discount rate by ±1%.

Table 10 shows the sensitivity analysis in which the analysis period was varied by ±5 years compared to the initial one, while the graphic representation is shown in Figure 11.

Table 10. Sensitivity analysis—change of the analysis period by ±5 years.

Analysis Period (year)	Change in the Analysis Period	Present Value of Costs (EUR)	Change in Present Value of Costs
10	−33.33%	1,354,553.02	−31.53%
15	0.00%	1,978,292.20	0.00%
20	33.33%	2,647,597.32	33.83%

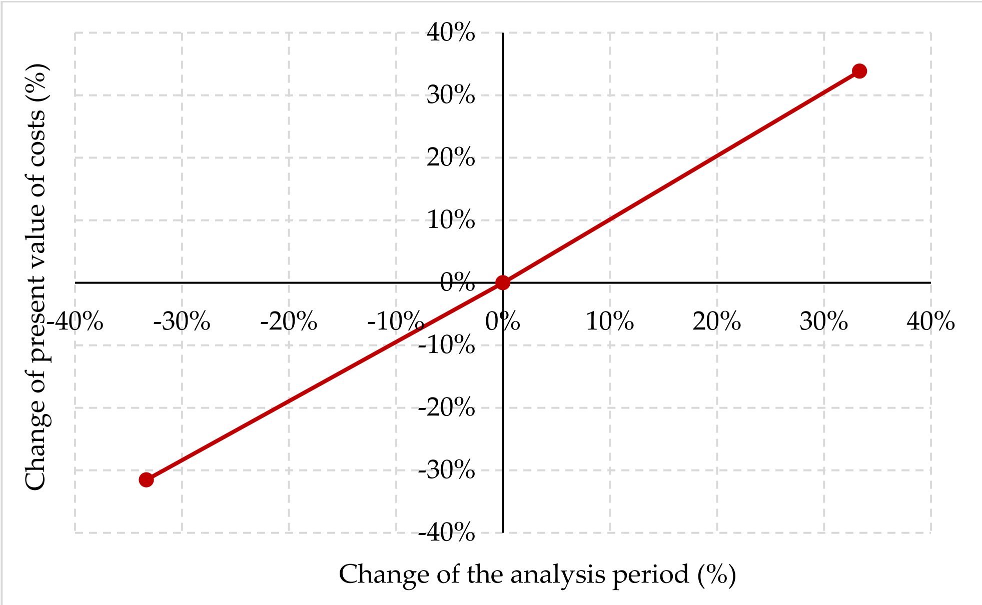

Figure 11. Results of the sensitivity analysis—change of the analysis period by ±5 years.

4.8. Correlation between Capital Costs and Costs of Operation and Maintenance for the Building

The construction cost of the building—capital cost—is about EUR 7.4 million.

Table 11 and Figure 12 shows the correlation between the costs of maintenance and operation for 10, 15 and 20 years, respectively, in relation to school building costs.

Table 11. Correlation between costs of maintenance and operation and capital costs for the three observed periods.

Analysis Period (year)	Present Value of the Costs of Maintenance and Operation (EUR)	Capital Costs (EUR)	Correlation between Costs of Maintenance and Capital Costs
10	1,354,553.02		18.30%
15	1,978,292.20	7,400,000.00	26.73%
20	2,647,597.32		35.78%

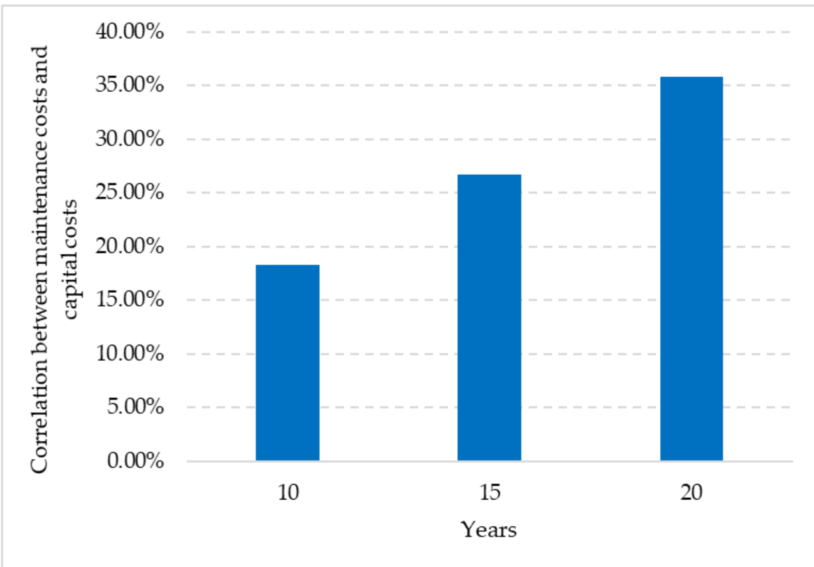

Figure 12. Correlation between the costs of maintenance and operation for 10, 15 and 20 years and capital costs.

Figure 13 shows capital costs and the costs of maintenance and operation for 15 years.

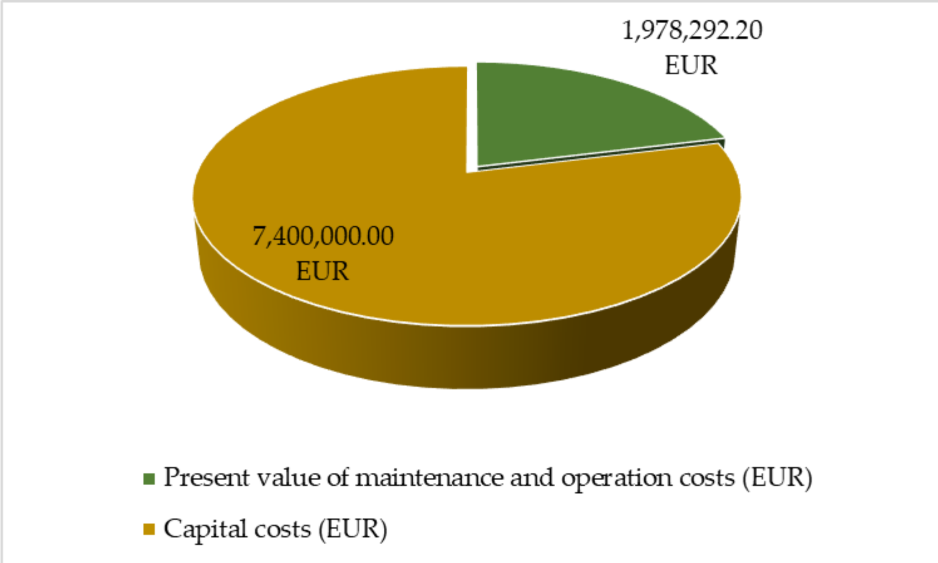

Figure 13. Costs of maintenance and operation for a period of 15 years and capital costs.

5. Discussion

In this paper, the maintenance plan and program for the building were created and presented. The maintenance plan and program for the building was created for a period of 15 years, i.e., from 2024 to 2038. The discount rate used is 3.64%. When calculating costs, inflation was also taken into account. The factor method was used to estimate the service life of an element or assembly. The above was further used to determine the replacement intervals for worn materials and elements and to calculate costs.

The present value of the costs of maintenance and operation of the building for 15 years is EUR 1,978,292.20, and the largest share of these costs is the operation cost of the building with EUR 1,599,002.18 (80.83%), followed by the costs of periodic works and repairs of the building with EUR 208,330.41 (10.53%). The third largest are the costs of statutory periodic inspections, which amount to EUR 147,471.98 (7.46%), followed by the costs of reactive maintenance with EUR 18,061.43 (0.91%), and the costs of replacing worn materials and elements with EUR 5426.21 (0.27%). It is understandable that the costs of replacing worn materials and elements are the lowest because the building has just been built and almost all installed materials and elements have a service life of more than 15 years.

A sensitivity analysis was used to vary the discount rate, and new amounts of the present value of the costs of maintenance were calculated. The selection of the discount rate was found to have a large impact on the present value of the costs of maintenance. With a discount rate of 3.64%, the present value of the costs of maintenance is EUR 1,978,292.20. By changing the value of the discount rate to 2.64%, which is a percentage change of −27.47%, the present value of the costs of maintenance and operation amounts to EUR 2,137,347.09; that is, it has increased by 8.04%.

By increasing the discount rate to 4.64%, which is a percentage change of +27.47%, the present value of the costs of maintenance and use is reduced to EUR 1,835,506.93 This is a decrease of 7.22%. From the aforementioned, it can be concluded that when the discount rate increases, the present value of the costs of maintenance decreases more slowly than the increase in the present value of costs that occurs when the discount rate decreases.

Additionally, the period of analysis was also varied. The initial period of analysis was 15 years, and the total costs amounted to EUR 1,978,292.20. For the analysis period of 10 years, the present value of the costs of maintenance is EUR 1,354,553.02; that is, the analysis period decreased by 33.33% and the costs decreased by 31.53%. When changing the analysis period to 20 years, which is a rise of 33.33%, there is an increase in the present value of the costs of maintenance of 33.83%, and in this, case the costs amount to EUR 2,647,597.32. It is observed that the increase in the analysis period generates a greater increase in costs than the decrease in costs in the case of a decrease in the analysis period. The above can be explained by the fact that with time the building begins to age significantly, certain processes of degradation of materials and elements of the building begin, an increasing number of materials and elements need to be renewed or replaced, and costs of maintenance start rising.

It is shown that the correlation between the present value of the costs of maintenance and use for a period of 15 years and capital costs amounts to 26.73%. This means that for a period of 15 years, the costs of maintenance and operation account for more than one quarter of the capital costs. When the period is reduced to 10 years, this correlation equals 18.30%, and by increasing the analysis period to 20 years, the correlation between the present value of the costs of maintenance and operation for a period of 20 years and capital costs amounts to 35.78%.

6. Conclusions

Maintenance of buildings is an important task because it extends the service life of the building, its users feel comfortable in it, and the costs of use are lower if the building is suitable for use. Maintenance requires planned budgets for each year. If budgets are not foreseen, it will not be possible to maintain the building in a proper and timely manner.

The costs of maintenance and operation are shown in the example of a building, essentially a school. The shares of individual groups of costs in the total costs of maintenance and use were calculated. Costs of maintenance very quickly reach significant percentages of the capital costs of the building. The case here is that the costs of maintenance and use for a period of 20 years amount to about 36% of capital costs. Of the observed five groups of costs, the largest costs are those generated by the operation of the building, and they amount to about 80% of the total costs of maintaining the building. Therefore, it is important to take care of the costs of operation. Only timely and proper maintenance prevents the deterioration of the building, and at the same time, the costs of operation of the building are considered in a timely manner.

Using this method of estimating the costs of maintenance opens up new possibilities for planning the necessary budget for maintenance and operation. It would be possible to estimate the necessary budget for the maintenance and operation of schools in the territory of a certain city or county. If the above were implemented for each county, the budget for school maintenance could be estimated for the entire Republic of Croatia. The advantage of the presented method of calculating costs is its very simple calculation, with changes in certain input variables such as the discount rate, inflation rate, etc. It is also possible to see the impact they have on the total costs of maintenance and operation.

Maintenance should not be left to chance, as should budget planning. Only through budget planning can one count on sufficient possibilities for proper maintenance. This paper presents how the costs of maintenance and operation of the subject building can be calculated for a certain period and the corresponding budget can be planned. It is shown how it is possible to predict the costs of the maintenance and operation of a particular building. The limitations are that a separate analysis needs to be carried out for each school, and it is difficult to obtain data on costs because they are usually considered a business secret.

Of course, it is important to emphasize that these are after all just predictions, and the costs of maintenance and operation are influenced by many factors, such as the costs of building materials, the costs of energy, the expertise and ability of the person who estimates or predicts the costs, the quality of the building elements and the quality of the building, the complexity of the building, the expertise of the person who maintains the building, the attitude of the users of the building towards it, etc.

7. Recommendations for Future Research

To achieve the most accurate results, it is essential to expand the research to include a greater number of cases, specifically by investigating additional buildings within the Republic of Croatia. Raising awareness among engineers and building maintenance managers about life cycle costs is crucial. Additionally, there is potential to extend the research to multiple European Union countries. To facilitate data collection and analysis of building maintenance costs, a comprehensive system for data aggregation across the entire Republic of Croatia should be developed. This system would allow for meaningful comparisons among buildings of the same type throughout the country. Overcoming institutional resistance to sharing cost data, especially for scientific and research purposes, is necessary. Increased availability of maintenance cost data would benefit all stakeholders, enabling better comparisons and the development of predictive models for more efficient maintenance.

Given that the research was conducted on a new building that has been operational for 2 years, it would be beneficial to track the actual maintenance and operation costs and compare them with the projected costs. Additionally, there should be more plans for building maintenance, allowing for better budget planning and monitoring of deviations.

Author Contributions: Conceptualization, D.O. and M.B.A.; methodology, D.O.; software, D.O.; validation, D.O., M.B.A. and K.Č.; formal analysis, D.O.; investigation, D.O.; resources, D.O.; writing—original draft preparation, D.O.; writing—review and editing, D.O.; visualization, D.O.; supervision, D.O., K.Č. and M.B.A.; project administration, D.O.; funding acquisition, D.O. and K.Č. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. The APC was funded by Dino Obradović (Faculty of Civil Engineering and Architecture Osijek, Josip Juraj Strossmayer University of Osijek).

Data Availability Statement: Data is contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Al-Hajj, A.; Horner, M.W. Modelling the running costs of buildings. *Constr. Manag. Econ.* **1998**, *16*, 459–470. [CrossRef]
2. Ćirović, G.; Luković, O. *Građevinska Ekonomija*, 4th ed.; Visoka Građevinsko-Geodetska Škola u Beogradu: Belgrade, Serbia, 2007.
3. Du, W.; Yu, J.; Gu, Y.; Li, Y.; Han, X.; Liu, Q. Preparation and application of microcapsules containing toluene-di-isocyanate for self-healing of concrete. *Constr. Build. Mater.* **2019**, *202*, 762–769. [CrossRef]
4. Van Belleghem, B.; Van Tittelboom, K.; De Belie, N. Efficiency of self-healing cementitious materials with encapsulated polyurethane to reduce water ingress through cracks. *Mater. Constr.* **2018**, *68*, e159. [CrossRef]
5. Wood, B. *Building Care*; Blackwell Science Ltd.: Oxford, UK, 2003.
6. Wordsworth, P. *Lee's Building Maintenance Management*; Blackwell Science Ltd.: Oxford, UK, 2001.
7. Allen, D. What Is Building Maintenance? *Facilities* **1993**, *11*, 7–12. [CrossRef]
8. Seeley, I.H. The Nature and Importance of Building Maintenance. In *Building Maintenance*; Macmillan Education: London, UK, 1976; pp. 1–21. [CrossRef]
9. Raković, R. *Kvalitet u Upravljanju Projektima*; Građevinska knjiga: Novi Sad, Serbia, 2007.
10. Designing Buildings Ltd. Maintenance. 2023. Available online: https://www.designingbuildings.co.uk/wiki/Maintenance (accessed on 21 June 2023).
11. PPP Centar. Ukupni Životni Troškovi. 2016. Available online: http://pppcentar.com/hr/usluge/ukupni-zivotni-troskovi/ (accessed on 21 June 2023).
12. *HRN ISO 15686-5:2008*; Hrvatski Zavod za Norme. Građevine—Planiranje Uporabnog Vijeka—5. Dio: Trošak Životnog Ciklusa. ISO: Geneva, Switzerland, 2009.
13. Wood, B. *Building Maintenance*; Wiley-Blackwell: Hoboken, NJ, USA, 2009.
14. Narodne Novine. *Zakon o Gradnji. Vol. 153/13, 20/17, 39/19, 125/19*; Narodne Novine, Službeni list Republike Hrvatske: Zagreb, Croatia, 2019.
15. Narodne Novine. *Pravilnik o Održavanju Građevina. Vol. 122/14, 98/19*; Narodne Novine, Službeni list Republike Hrvatske: Zagreb, Croatia, 2019.
16. Narodne Novine. *Uredba o Održavanju Zgrada. Vol. 64/97*; Narodne Novine, Službeni list Republike Hrvatske: Zagreb, Croatia, 1997.
17. Marenjak, S.; Krstić, H. *Održavanje Zgrada Javne Namjene*; Građevinski i arhitektonski fakultet Osijek: Osijek, Croatia, 2020.
18. *HRN ISO 15686-1:2011*; Buildings and Constructed Assets—Service-Life Planning—Part 1: General Principles and Framework. Hrvatski Zavod za Norme: Zagreb, Croatia, 2011.

19. *HRN ISO 15686-2:2012*; Buildings and Constructed Assets—Service Life Planning—Part 2: Service Life Prediction Procedures. Hrvatski Zavod za Norme: Zagreb, Croatia, 2013.
20. *HRN ISO 15686-3:2002*; Buildings and Constructed Assets—Service Life Planning—Part 3: Performance Audits and Reviews. Hrvatski Zavod za Norme: Zagreb, Croatia, 2004.
21. *HRN ISO 15686-8:2008*; Buildings and Constructed Assets —Service Life Planning—Part 8: Reference Service Life and Service Life Estimation. Hrvatski Zavod za Norme: Zagreb, Croatia, 2009.
22. Frković, D.; Fruk, T.; Buzov, D.; Lovrović, M.; Škrinjar, D.; Preprotić, B.; Brandt, K. *Održavanje i Gospodarenje Imovinom*; Hrvatsko Društvo Održavatelja: Zagreb, Croatia, 2016.
23. Bognar, B.; Marenjak, S.; Krstić, H. Analiza stvarnih i planiranih troškova održavanja i uporabe građevina. *Electron. J. Fac. Civ. Eng. Osijek-e-GFOS* **2011**, *2*, 85–96. [CrossRef] [PubMed]
24. Marenjak, S.; El-Haram, M.A.; Horner, R.M.W. Analysis of overall project costs for the building industry. *J. Croat. Assoc. Civ. Eng.* **2002**, *54*, 393–401.
25. Čulo, K. *Ekonomika Investicijskih Projekata*; Građevinski Fakultet Osijek: Osijek, Croatia, 2010.
26. Marenjak, S.; Krstić, H. Analysis of buildings operation and maintenance costs. *J. Croat. Assoc. Civ. Eng.* **2012**, *64*, 293–303. [CrossRef]
27. Aničić, D. *Planiranje Uporabnog Vijeka Građevina (Prijevod Norma Niza ISO 15686 s Autorskim Uvodom i Komentarima)*; Hrvatski Savez Građevinskih Inženjera: Zagreb, Croatia, 2004.
28. Nireki, T.; Inukai, T.; Motohashi, K. Toward Practical Application of Factor Method for Estimating Service Life of Building. In Proceedings of the 9th International Conference on Durability of Building Materials and Components, Brisbane, Australia, 17–20 March 2002.
29. Jardim, A.; Silva, A.; de Brito, J. Application of the factor method to the service life prediction of architectural concrete. *Can. J. Civ. Eng.* **2019**, *46*, 1054–1062. [CrossRef]
30. Bahr, C.; Lennerts, K. *Lebens- und Nutzungsdauer von Bauteilen—Endbericht*; Fraunhofer-Informationszentrum Raum und Bau IRB: Stuttgart, Germany, 2010.
31. Rodrigues, F.; Matos, R.; Alves, A.; Ribeirinho, P.; Rodrigues, H. Building life cycle applied to refurbishment of a traditional building from Oporto, Portugal. *J. Build. Eng.* **2018**, *17*, 84–95. [CrossRef]
32. Europska Komisija. *Obavijest Europske Komisije o Referentnoj, Diskontnoj i Povratnoj Stopi od 1. 6. 2023*; European Comission: Brussels, Belgium, 2023.
33. Iooss, B.; Saltelli, A. Introduction to Sensitivity Analysis. In *Handbook of Uncertainty Quantification*; Springer International Publishing: Cham, Switzerland, 2015; pp. 1103–1122. [CrossRef]
34. O'Brien, J.; Marakas, G. *Management Information Systems*, 10th ed.; McGraw-Hill, Irwin: New York, NY, USA, 2011.
35. Pichery, C. Sensitivity Analysis. In *Encyclopedia of Toxicology*; Elsevier: Amsterdam, The Netherlands, 2014; pp. 236–237. [CrossRef]
36. Obradović, D. A Contribution to Increasing the Efficiency of Sewerage Systems Maintenance by Applying a Maintenance Cost Estimation Model. Doctoral Thesis, Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering and Architecture Osijek:, Osijek, Croatia, 2022.
37. European Union, European Commision Directorate-General for Regional and Urban Policy. *Guide to Cost-Benefit Analysis of Investment Projects*; European Commision, Directorate-General for Regional and Urban Policy: Brussels, Belgium, 2014; Available online: https://ec.europa.eu/regional_policy/sources/studies/cba_guide.pdf (accessed on 2 May 2024).
38. Republika Hrvatska Državna Geodetska Uprava. Geoportal. 2023. Available online: https://geoportal.dgu.hr/ (accessed on 23 June 2023).
39. Capital ING d.o.o. *Glavni Projekt, Mapa I, Arhitektonski Projekt*; Capital ING d.o.o.: Zagreb, Croatia, 2010.
40. D.S. Consulting d.o.o. *Energetski Certifikat Zgrade*; D.S. Consulting d.o.o: Osijek, Croatia, 2022.
41. Institut IGH d.d. *Standardna Kalkulacija Radova u Visokogradnji, Bilten XII 2021 (IV Kvartal 2021)—Nadogradnja I*; Institut IGH d.d: Zagreb, Croatia, 2021.
42. Meigs, F.R.; Meigs, B.W. *Računovodstvo: Temelj Poslovnog Odlučivanja*, 9th ed.; MATE d.o.o.: Zagreb, Croatia, 1999.
43. Feldkircher, M.; Siklos, P.L. Global Inflation Dynamics and Inflation Expectations. *SSRN Electron. J.* **2018**, *64*, 217–241. [CrossRef]
44. Oikawa, K.; Ueda, K. The Optimal Inflation Rate Under Schumpeterian Growth. *SSRN Electron. J.* **2015**, *100*, 114–125. [CrossRef]
45. Alaloul, W.S.; Musarat, M.A.; Liew, M.S.; Qureshi, A.H.; Maqsoom, A. Investigating the impact of inflation on labour wages in Construction Industry of Malaysia. *Ain Shams Eng. J.* **2021**, *12*, 1575–1582. [CrossRef]
46. Gülşen, E.; Kara, H. Measuring inflation uncertainty in Turkey. *Cent. Bank Rev.* **2019**, *19*, 33–43. [CrossRef]
47. Bošnjak, I. Vujčić: Inflacija će 2025. Biti na Razini od 2 Posto. Glas Slavonije. 2023. Available online: http://www.glas-slavonije.hr/523650/1/Vujcic-Inflacija-ce-2025-biti-na-razini-od-2-posto (accessed on 7 August 2023).
48. Klepo, M. Guverner HNB-a: 'Ciljana Razina od dva Posto Inflacije Trebala bi se Vratiti 2025. Godine'. Jutarnji List. 2023. Available online: https://novac.jutarnji.hr/novac/aktualno/guverner-hnb-a-ciljana-razina-od-dva-posto-inflacije-trebala-bi-se-vratiti-2025-godine-15339992 (accessed on 7 August 2023).
49. Europska Središnja Banka. Odluke o Monetarnoj Politici. 2023. Available online: https://www.ecb.europa.eu/press/pr/date/2023/html/ecb.mp230727~da80cfcf24.hr.html (accessed on 7 August 2023).

50. European Central Bank. *Combined Monetary Policy Decisions and Statement*; European Central Bank: Frankfurt Am Main, Germany, 2023.
51. Obradović, D. *Predviđanje Troškova Održavanja Građevina*; Graduate Paper; Josip Juraj Strossmayer University of Osijek: Osijek, Croatia, 2023.