applied sciences

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Method of Planning Repairs of the Installation including Building Waste

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Featured Application: The presented methodology can be the basis for making the right strategic decisions when planning refurbishment activities in buildings.

Abstract: Repairs of water supply, sewage and central heating installations in residential buildings should be carried out systematically. However, very often, renovation dates are postponed, which results in installation failures. The failures of water supply, sewage and central heating installations, due to the currently used methods of masking them and running them as under-plaster and under-floor installations, are always connected with the damage and necessity of reconstruction of the building elements. As a result, renovation work has to be carried out to a greater extent and the amount of construction waste is much greater. The analysis of different renovation strategies of water supply, sewage and central heating systems in residential buildings made in traditional technology has been carried out. The article presents the results of the research on the effects of the postponement of the renovation works on the changes in the technical condition of the building and on the scope of renovation works. The aim of the research is to develop a method for planning repairs of the installation taking into account optimization of the amount of construction waste. The aim of the research is also to answer the question: To what extent does the postponed repair of water and sewage installations influence the amount of construction waste? In the proposed method, the Prediction of Reliability according to Rayleigh Distribution (PRRD) model is used. The results of the research indicate the necessity of conducting the renovation works of the installation in a timely manner due to the increasing amount of construction waste and the introduced reduction of its amount with the increase of the recycling rate.

Keywords: refurbishment; building; plumbing; drainage; damage; construction waste

Citation: Nowogońska, B.; Nowogoński, I. Method of Planning Repairs of the Installation including Building Waste. *Appl. Sci.* **2022**, *12*, 4520. https://doi.org/10.3390/app12094520

Academic Editor: Andrea Carpinteri

Received: 26 March 2022
Accepted: 26 April 2022
Published: 29 April 2022

1. Introduction

During the lifetime of buildings, there are many problems related to the rational planning of repair works resulting from the analysis of the technical condition of the building. These problems have been previously described e.g., [1–7]. Repair works should be carried out on an ongoing basis. The consequences of wrong renovation decisions lead to damages and failures in buildings [8–10]. Refurbishment works should be carried out at preplanned times to prevent the occurrence of failures.

There is a lot of research on proper management in building operation, such as the Building Envelope Life Cycle Asset Management (BELCAM) project, which uses a stochastic decision support system to manage roofing life maintenance [11,12]. Methods for assessing repair needs are being developed, e.g., a model [13] to identify owner needs at all stages of the building life cycle, prioritization techniques that can be used to compare and rank repair projects [14], MANR building repair needs assessment method [15], APRAM architectural and psycho-environmental retrofit assessment method [16], BuildingsLife:

BdMS building management system [17], DRNB building repair needs determination [18] and a model that integrates genetic algorithm and simulation [19]. Another approach reviews general maintenance management models from the point of view of someone who believes that improvements can be made by treating maintenance as a contributor to profits rather than a necessary evil [20].

During renovation work, it is essential to pay attention to the amount of construction waste.

Globally, the volume of waste is growing rapidly, even faster than the rate of urbanization. The volume of solid waste is expected to reach 2.2 billion tons by 2025 [21]. The construction industry generates about 33% [22] to 35% [23,24] of the waste globally. For example, in the UK, of the 100% of waste generated in 2013, 44% was construction waste and the rest was generated by commercial, industrial, domestic, mining and agricultural activities. Construction waste produced during construction, renovation, repair and demolition of engineering structures such as residential and commercial buildings, roads and bridges [24]. Demolition and renovation waste consists of materials previously used in a building that are removed as a result of demolition. CDW often consists of large and heavy materials including concrete, wood (from buildings), asphalt (from asphalt shingles), gypsum, metals, bricks, glass, plastics, reclaimed building components (doors, windows and fixtures) and excess soil [25]. Much of this waste is disposed of directly to landfill, which, using the UK as an example, where construction and demolition waste (C&DW) generation in 2014 was 58 million tonnes, implies the disposal of more than half of C&DW directly to landfill. Across the European Union, construction waste accounted for 33% of total waste.

The reuse of waste materials in the construction industry is becoming extremely important for two main reasons: economic and environmental. The economic aspect is primarily the recovery of material, which means that the cost of manufacturing certain products can be reduced. However, at the moment, it is the second aspect, and the environmental impact factor assumes greater importance. For example, in Brazil, C&DW waste has been classified into the following groups [24]:

1. Class A—waste that can be reused or recycled as aggregate.
2. Class B—waste that can be recycled for other purposes, e.g., plastics, paper, metals, glass or wood.
3. Class C—waste for which economically viable technologies or applications that allow for recycling or reuse have not been developed. This class includes products derived from plastering.
4. Class D—hazardous waste from the construction process.

The use of plastics from landfills and materials recovery facilities is rare compared to the use of cleaner industrial byproducts. Consequently, research on C&DW plastics as raw materials for composites is also scarce, although it should be less problematic due to the lower residual organic parts in these materials compared to household waste. Lack of knowledge about the changes in properties and quality of recycled plastics at different stages of degradation, mixing and contamination is a major drawback of the use of recycled polymers. The construction sector uses plastics for a wide range of applications due to their durability, strength, corrosion resistance, low maintenance and aesthetic finish. Typical products include profiles, coverings, insulation materials, cable sheathing, roofing, waterproofing components, pipes and ducts [26]. Commonly used engineering plastics include polyvinyl chloride (PVC), expanded polystyrene (EPS), high-density polyethylene (HDPE), polypropylene (PP), low-density polyethylene (LDPE) and polystyrene (PS), among others [26,27]. Numerous additives and chemicals have been used in the production of plastics used in the broadly defined construction sector, over time, several of which are now considered harmful to humans and the environment (Table 1).

Table 1. Possible disadvantages of using recycled plastics [26].

No.	Plastic	Disadvantages
1	Polyethylene (LPDE, HDPE)	PE and PP have similar density, which makes mechanical separation difficult.
2	Polypropylene (PP)	Recycled PP was shown to exhibit a higher crystallization rate and higher crystallinity than virgin PP due to chain scission during reprocessing.
3	Polystyrene (PS/HIPS)	Recycled PP was shown to exhibit a higher crystallization rate and higher crystallinity than virgin PP due to chain scission during reprocessing.
4	Expanded polystyrene (EPS and XPS)	Due to the low density of EPS products, the economic benefits of recycling them are due to high transportation costs; expanded polystyrene breaks easily during demolition and mixes with other waste; the use of flame retardants creates a risk of contamination of other plastics in recycling.
5	PVC	Primary recycling is often not possible from post-consumer waste due to hazardous additives contained in PVC.

These additives contaminating products may currently be treated as harmful or be banned altogether. Recycling must necessarily consider the degradation and composition of plastics before reusing these materials.

The use of recycled materials as the main building block, filler or admixture has a significant impact and can produce materials with weaker mechanical properties compared to virgin materials [28]. Operators using construction and demolition waste should consider possible contamination and limit the spread of harmful substances.

Previously performed studies and analyses based on life cycle assessment and life cycle costs of building facilities include construction costs—both material and labor costs—and maintenance costs including material replacement, painting, etc., as well as final disposal [29]. It is typical that plumbing, electrical and air conditioning are often not included in the analysis [29–31].

Once the building is completed, the ability to repair and maintain most installations becomes unavailable, and even small failures become an impetus for significant interference with building components. The use of mounting walls and other masking elements allows the minimization of construction works. However, more and more often, it is used to hide installations under the floor and under the plaster. In this case, not only is it difficult to locate the place of failure but also the scope of construction works becomes significant. In extreme cases, the necessity to remove the failure or perform renovation of, e.g., the plumbing system becomes the main reason for the decision to carry out the renovation [32].

The analysis of predicting the need for planned rehabilitation is relatively straightforward for old, increasingly rare steel pipes. According to Cheng [32], after analyzing samples of corroded pipes, it was possible to verify the service life of piping systems in buildings. The results showed that the number of refurbishment cases increases sharply with a number of years of use of above 10 years, with a peak range in the range of 10 to 20 years. Almost 60% of the users analyzed rebuilt their piping systems before the building reaches 20 years of age. This is consistent with the life expectancy of galvanized steel pipe. If copper, plastic or multilayer pipes are used, the service life of the system increases theoretically up to 50 years. In the case of multi-family buildings, the issue becomes even more important, because the damage caused by the failure of water, sewage or water heating systems generates losses not only in the apartment where the failure occurred but also in the apartments located below. In these cases, the cause is not always significant damage, but much more difficult to locate micro-leaks [33]. The consequences of such phenomena are often noticeable in places distant from the damage location mainly of corrosive origin. Damage from micro-leaks can include collapse of walls and ceilings, and water can contribute to mold growth on wall, floor and ceiling surfaces [34]. Mold can cause allergic reactions such as eye, skin and throat irritation [34]. Additionally, most households prefer to stay with their current plumbing materials rather than install an upgrade to reduce the risk of corrosion or damage. Plumbing replacement decisions are usually made as a consequence of a significant failure. Similar risks are also generated by carelessly made connections and by improperly operated fittings [35]. Simple negligence, such as long-lasting operation of partially open ball valve, often used in indoor installations, causes their damage, accelerated corrosion [35] and, as a result, possibility of leakages. It seems crucial to ensure proper operating conditions already at the design stage [35]. One of the problems to be avoided is protection against both water hammer and vacuum occurrence and, as a result, limitation of cavitation corrosion [36].

The concept of the need for renovation caused by aging building equipment can be approached in two ways. The first is renovation caused by an aging piping system or damage, the second is renovation caused by the development of new materials or technologies that encourage people to raise standards and strive for better-functioning buildings. Consideration of technology development or the need to implement it may also be forced by changes in legislation. For example, due to the EU regulation [37], it becomes necessary to replace the heat source, and consequently, it becomes necessary to upgrade the whole central heating installation, causing the unplanned generation of demolition waste. The same situation may arise in case of pressure to modernize existing buildings in order to bring their equipment to "green" building standards. Replacement of copper pipe plumbing with PEX pipes is associated with significant reductions in CO_2 emissions, water consumption and environmental toxicity at the manufacturing stage [38]. On the other hand, overzealous forcing of retrofits before the expiration of the useful life generates the production of construction and demolition waste and triggers demand for materials and equipment. This is not an isolated contemporary phenomenon. The rapid modernization and urbanization process in China began in 1978, and one of the solutions was the implementation of an urban renewal strategy [39]. As a result of it, massive demolition and reconstruction works were undertaken. However, the large scale of demolition work led to the shortening of building life to about 30 years, much shorter than their design life. The shortened building life of buildings causes a huge waste of resources and worsens environmental pollution and contradicts the idea of an efficient approach to energy and resource conservation [39]. As a result, the average building life in China is 34 years [39], which is much shorter than the planned life.

Making decisions connected with the choice of the type, scope and date of repairs on buildings is very problematic for managers. Repair needs are a popular research topic. Methods of planning renovation works, renovation methods, methods of building modernization or methods of making decisions in renovation strategy are the subject of many studies. Shen and Spedding presented [40] a model for priority setting in planned maintenance of large building stocks, and successful validation of the model in the UK and Hong Kong has been demonstrated. Bucoń and Sobotka proposed a decision model of the choice of the scope of repairs based on three assessments of a building [41]. Jones and Sharp draw attention to the weakness inherent in the current theoretical model underpinning built asset maintenance and to propose a new performance-based model that aligns maintenance expenditure to corporate performance [42].

The correct building maintenance strategy should include a multi-annual maintenance action plan optimized for various criteria that match the owners' goals for existing restrictions.

The efficient management of a building's maintenance embraces many skills that include identifying the maintenance needs and their accurate and spot-on remedies [43]. During the operation of buildings, there are many problems related to maintenance management, use management and assessment, and forecasting of the technical condition of the building [44]. The consequences of wrong decisions concerning the renovation or neglected maintenance of buildings lead to irreversible destruction processes [45–47]. The aging process of a building is closely related to technical wear [48–50]. Absence of renovation work results in its acceleration.

As we know, the life cycle of equipment depends on the characteristics of materials and the quality of materials. Although high quality always means good condition and a long life cycle, it also means high investment cost. The designer must choose the right system for the building, striking a balance between quality and cost. Then the life cycle is a good indicator for critical evaluation when making planning decisions. Long life cycles of equipment give us the impression that they are good for buildings. However, the life cycle of piping systems will be much shorter than the life cycle of the building structure. There will be two or three cycles of piping renewal in the total building life cycle. If we include the life cycle of the piping systems in the total life cycle of the building, the corresponding life cycle is necessary to determine whether the building should be rebuilt or destroyed.

In summary, buildings are made of many complex subsystems. When we consider the concept of life cycles, we must consider the entire life of each subsystem. Otherwise, we would cause unreasonable losses and functional problems due to improper design.

From the above considerations, it is necessary to conduct a study that includes the effects of building installation failures, which cause additional damage to the building and result in additional construction waste. The authors have undertaken to develop a method of planning repairs to installations taking into account the amount of waste. The aim of the research is also to answer the question: To what extent does the postponed repair of water and sewage installations influence the amount of construction waste? A highlight innovation in the field is the development of a method for planning plant refurbishment that takes into account construction waste optimization.

2. Materials and Methods

The research was conducted in the following stages:

1. Adoption of the main assumptions of the method;
2. Analysis of the strategy S1—the refurbishment of the installation was carried out in the 30th year of operation;
3. Strategy analysis S2—the installation was refurbished in the 40th year of operation;
4. Strategy analysis S3—system failure in the 50th year of operation.

2.1. Main Principles of the Method

Every building is constructed from a variety of building materials. A building consists of many components. These elements have different functions in the building and are made of different building products. Each element has different properties and a different structure; each is individually subject to wear and tear as a result of many processes. For each building element, its technical condition changes differently during its use.

The problem of the wear of objects is an increase in damage and partial defects. To improve the representation of service life in life cycle assessments and the evaluation of environmental impacts, building service life prediction modeling was examined. The object's reliability is defined as the ability to fulfil the task resulting from the purpose it was intended for. The object is demanded to fulfill a determined function in determined time, t, in determined conditions of operation. The measure of the reliability of an object is the probability of the task being completed. Such a defined reliability measure is a function of the time of the building's reliable performance and is called the reliability function [51]. For modeling situations in survival analysis, when the probability of failure changes over time, the Weibull distribution is most often applied as the distribution of the random variable of the time a building is fit for service. This distribution has been applied for many years, as a strength distribution as well as a distribution of the time of the proper operation and durability of analyzed goods [51,52].

The proposed model [51,52] PRRD (Prediction of Reliability by Rayleigh Distribution) of the changes in the performance characteristics $R_i(t)$ of the i-th building element at time, t, based on the Rayleigh distribution, using the lifetimes of the component T_{Ri} from data found in the literature is described by the relation:

$$R_i(t) = \exp\left[-(t/T_{Ri})^2\right] \tag{1}$$

where

t—previous period of use;

T_{Ri}—period of element durability.

In determining the performance of the whole building, which is a set of m components, the intensities of the influence of the performance of the components were taken into account in the form of weights, Ai, of the individual components. Changes in the building performance, $R_B(t)$, at time, t, are defined by the relation [51,52]:

$$R_B(t) = \sum_{i=1}^{m} A_i R_{RiSR}(t) \tag{2}$$

where

$R_B(t)$—changes in performance of the whole building at time, t, according to the PRRD model;

A_i—the weight of the i-th element;

$R_{RiSR}(t)$—changes in the performance of element, i, at time, t, according to the PRRD model;

i—building element number;

m—total number of elements.

The efficient exploitation of a building should be based on maintaining an appropriate level of functional properties of the building, and this task is realized by repair processes. All types of refurbishment projects have a significant influence on the technical condition of the building during its further exploitation. Full characterization of the refurbished building must take into account its initial condition and the scope of repair works. On this basis, it is possible to determine the course of changes in functional properties over time, before and after refurbishment.

Ensuring the proper technical condition of a building over the course of its use can only be done by properly carried out refurbishment activities. The proposed PRRD model can be applied to modeling situations in the analysis of changes in the performance characteristics of a building that has not undergone refurbishment. The PRRD method of predicting changes in the performance characteristics can support activities aimed at avoiding an inadequate technical condition of a building. The accurate prediction of unfavorable changes and preventive repairs and maintenance works will make it possible to ensure the proper technical condition of the object.

The prediction of the change in performance, $R_M(t)$, of a repaired building, where t_{pi} is the date of repair, is expressed by the formula [51,52]:

$$R_M(t) = \begin{cases} \sum\limits_{i=1}^{m-r} A_i \exp\left(-\left(\frac{t}{T_{Ri}}\right)^2\right) & if\ t \in \left(0,\ t_{pi}\right) \\ \sum\limits_{i=1}^{r} A_i \exp\left(-\left(\frac{t-t_{pi}}{T_{Ri}}\right)^2\right) & if\ t \in \left(t_{pi},\ T\right) \end{cases} \tag{3}$$

where

r—the number of refurbished components in a given inter-repair cycle;

m—number of all elements;

A_i—weight of i-th element;

t_{pi}—time of carrying out refurbishment on element, i;

T_{Ri}—life cycle of i-th element.

The proposed repair works aim to maintain the building in good, satisfactory or average technical condition and rely on prophylactic action and preventing the premature emergence of unfavorable changes. Modeling various possible usage scenarios of a building according to the proposed method will allow for the optimal planning of building maintenance works' undertakings.

The material and construction solutions for the analyzed building were chosen based on traditional technology: e.g., walls and foundations are made of brick, ceilings, stairs and roof trusses are made of wood and covered with ceramic tiles. Each building material has a specific life span. Estimating the life span of both the material itself and the product made from it is not possible in a clear and universal way. An identical product may have a radically different lifetime after taking into account the location and local conditions (geological, hydrological and climatic) [53], environmental pollution, including air pollution [54], as well as the impact of climate change [55]. Depending on local conditions, even the number of building elements indicated in the literature may vary [56,57]. For example, the central heating system can be considered as a single system or divided into pipe system and radiators. The situation becomes more complicated with the spread of new techniques such as heat pumps or surface heating. Table 2 presents the division of the building into 25 elements, the material solutions of these elements and their lifetimes. The data included are based on an analysis of literature data [53–62].

Table 2. Service life of building elements with a specific material and construction system.

No.	Element Name *i*	$T_{Ri\,ŚR}$
1	brick foundations	110
2	masonry walls made of solid bricks	140
3	separating walls made of brick	100
4	wooden beam ceilings	70
5	wooden stairs	35
6	rafter framing	80
7	ceramic roofing tiles	70
8	gutters and downpipes made of galvanized steel sheet	17.5
9	internal plasters	55
10	external plasters	45
11	window joinery	50
12	door joinery	90
13	glazing	40
14	wooden floors (coniferous timber)	50
15	painting of walls and ceilings	4
16	oil paintings of woodwork	5
17	ceramic kitchen stoves	35
18	tile cookers	45
19	heating pipes (steel)	35
20	central heating boilers and radiators	50
21	water and sewerage pipes (galvanized steel)	37.5
22	water and sewerage pipes	30
23	gas pipes (galvanized steel)	37.5
24	wiring for electrical installations (flush mounted)	60
25	fittings for electrical installations	22.5

All the refurbishment strategies proposed are associated with refurbishment costs. In this paper, the main focus is on the improvement of technical condition and environmental protection, while cost is also an important topic that will be addressed in future research.

The method also neglects the problem of dwelling use during the repair work carried out. The more often a refurbishment is carried out, the more difficulties in use occur.

2.2. Analysis of the Strategy of Proceeding S1

Strategy S1 is the correct strategy to follow when using the building. It is assumed that the refurbishment of the water supply and sewerage systems was carried out in the 30th year of the building's use. The date of the planned refurbishment is due to the end of the life of the building materials used for the installations.

The developed strategy S1 is the correct strategy (Figure 1). The technical condition of the building is at least average throughout.

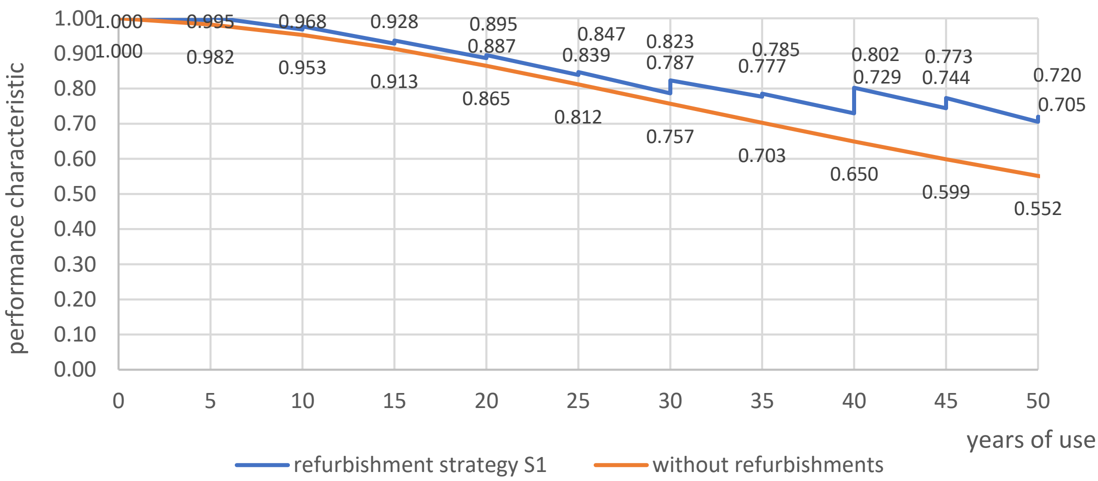

Figure 1. Prediction of changes in the technical condition of a building refurbished according to S1 strategy and a building without refurbishment.

As a result of the renovation work carried out in year 30, the technical condition of the building improved from 0.787 to 0.823, an increase of only 3.6%. The amount of construction waste is also low. Waste includes replaced plumbing and drainage systems, plumbing fixtures and waste associated with the refurbishment of these elements—fragments of floors (in 20%) and wall and ceiling plaster (in 20%), together 18.48% of the building elements.

2.3. Analysis of the Strategy of Proceeding S2

According to strategy S2, the refurbishment was carried out too late, in the 40th year of the building's use. The service life of the fittings passed 10 years ago (T_R = 30 according to Table 1), the service life of the water supply and sewer pipes passed 2.5 years ago (T_R = 37.5 according to Table 1). It was assumed that there were no system failures, but there was overt and covert damage to the building due to leaking fittings. The extent of the damage includes damage to elements: floor coverings and paint coatings of walls and ceilings.

As a result, the planned refurbishment works in year 40 have changed in scope to the replacement of elements: water supply pipes, sewerage pipes, fittings, replacement of floors, painting of walls and ceilings. There was also an increase in construction waste by these elements.

As a result of the refurbishment works carried out in year 40, the technical condition of the building improved from 0.682 to 0.754, an increase of only 7.2% (Figure 2). Compared to the previous strategy, the improvement in technical condition is small, while there is twice as much building waste, i.e., 8 elements, which represents 32% of all building elements.

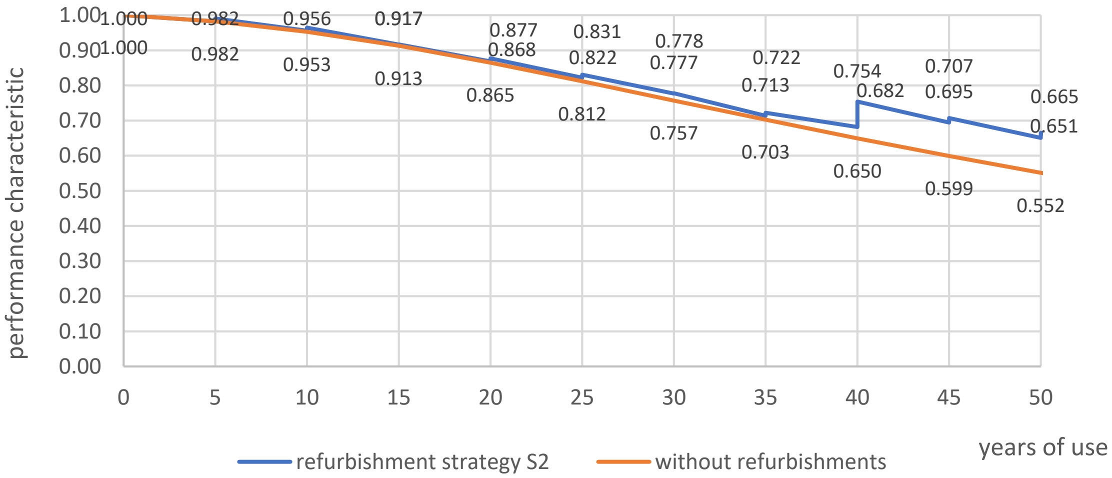

Figure 2. Prediction of changes in technical condition of a building refurbished according to S2 strategy and a building without refurbishment.

2.4. Analysis of the Strategy of Proceeding S3

According to strategy S3, the refurbishment of the installation was not carried out in a timely manner, and the installation failed in its 50th year of use. The failure caused serious damage to the ceiling structure in the building. As a result of the installation failure, a major overhaul of the building was necessary. The scope of work includes almost all parts of the building (ceilings, stairs, partition walls, internal plaster, painting of walls and ceilings, floors, all installations).

As a result of the refurbishment works carried out in the 50th year of use, the technical condition of the building improved from 0.592 to 0.744, i.e., there was a substantial increase of 15.2% in the performance (Figure 3).

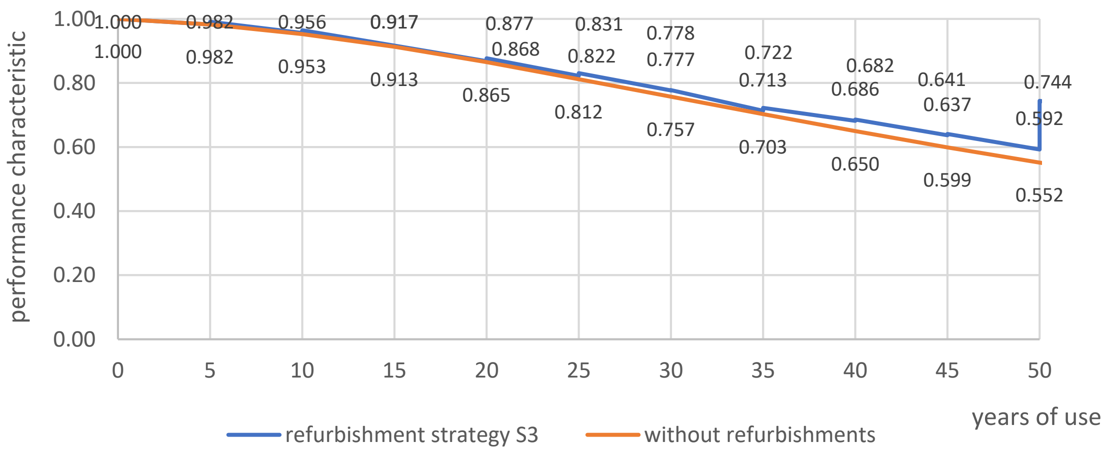

Figure 3. Prediction of changes in technical condition of a building refurbished according to S3 strategy and a building without refurbishment.

Compared to previous strategies, the improvement in technical condition is the greatest, which is due to the extensive refurbishment works. Unfortunately, the amount of construction waste is incomparably higher than in previous strategies, as many as 12 building elements are waste (48% of building elements).

3. Analysis of the Results Obtained and Discussion

The most favorable refurbishment strategy is the option with the highest sustainability factor, *Ss*. This coefficient is the result of a multi-criteria analysis in which two equivalent criteria were used:

Criterion 1—improvement of the technical condition obtained as a result of refurbishment strategy S1, S2 or S3.

Criterion 2—generation of as little construction waste as possible during refurbishment works according to strategy S1, S2 or S3.

The sustainability coefficient was determined by the formula:

$$S_S = w1k1 + w2k2 \quad (4)$$

where

$w1$, $w2$—criteria weights;

$k1$, $k2$—criteria measures.

The method adopts the two most important criteria, but other criteria, such as inconvenience of use during refurbishment, can also be used.

The results obtained are presented in the Table 3. Strategy S1 proved to be the most beneficial. In strategy S1, the increase in changes in performance may not be very impressive, but the small amount of construction waste makes this option the more beneficial than the others. The least favorable is of course variant S3, where, due to the lack of refurbishment of the installation, a failure occurred, and as a result, many additional damages increased the amount of refurbishment works and thus construction waste.

Table 3. Results of the comparative analysis.

Strategy Number	Value of Performance during the Year of Use			Improvement of Technical Condition [%] $k1$	Quantity of Construction Waste [Elements]	Quantity of Construction Waste [%] $(1 - k2)$	Factor of Sustainable Development Ss
	30	40	50				
S1	0.787	0.728	0.705	0.036	4.6	3.60	85.20
S2	0.778	0.682	0.665	0.072	8.0	7.20	75.20
S3	0.778	0.686	0.592	0.152	12.0	15.28	67.28

As a result of the repairs done in the 30th year of the building, the building condition improved from 0.787 to 0.823, an increase of only 3.6%. There is also a small amount of construction waste. Waste includes listed plumbing elements (pipes), plumbing fixtures and waste associated with the renovation of these elements—floor fragments (at 20%) and wall and ceiling plaster (at 20%), totaling 18.48% of building elements.

For refurbishment works carried out in year 40, the building condition improved from 0.682 to 0.754, there was an increase of 7.2%. Compared to the previous strategy, the technical condition improvement is small, while there is twice as much building waste, i.e., eight elements, which is 32% of all building elements.

The repair work carried out in the 50th year of operation resulted in an improvement in the technical condition of the building from 0.592 to 0.744, i.e., a significant increase in performance of 15.2%. The improvement in technical condition is the largest compared to previous strategies, which is due to the extensive renovation work. Unfortunately, the amount of building waste is incomparably higher than in previous strategies, as many as 12 building elements are waste (48% of building elements).

The most favorable strategy is strategy number S1, where there is an improvement in technical condition and there is a small amount of construction waste.

4. Conclusions

Refurbishment work in residential buildings should be carried out systematically. The quantitative analysis of construction waste associated with refurbishment works involving water supply and sewage systems also confirms this thesis.

As mentioned earlier, the impact of water supply and sewage installations as well as central heating installations have usually been neglected in previous analyses due to the relatively low cost of materials and workmanship compared to other building elements. However, this is an incorrect assumption due to the modern tendency to hide installations under plaster and floors. As a result, the possibility to quickly detect the place of failure is limited. There is also a prolongation of the duration of the phenomenon from the moment the failure occurs to the appearance of effects that are visible to the user. As a result, the failure affects more elements of the building, and its scale is larger. In addition, when a failure occurs, there is a high probability that elements of the building's equipment will be damaged or destroyed, resulting in the need to dispose of electro-waste.

As a result of the proposed repair work carried out in the 30th year of the building's use, the building's condition only improves by 3.6%. There is a small amount of construction waste—18.48% of the building elements.

For the refurbishment works carried out in the 40th year, the technical condition of the building improves by 7.2%, while there is more construction waste than before—32% of all building elements.

The renovation works carried out in the 50th year cause the technical condition of the building to improve by 15.2%. The improvement in technical condition is the largest compared to previous strategies, which is due to the extensive refurbishment work. Unfortunately, the amount of building waste is incomparably higher than in previous strategies, as much as 48% of building elements.

The systematic and planned execution of refurbishment works makes it possible to secure financial resources and correctly estimate the costs of both refurbishment works and the costs of waste disposal. It is also a good idea to synchronize such activities with refurbishment works concerning elements with a shorter lifespan or the replacement of periodically replaced elements (e.g., measurement devices). In this way, the amount of waste can be significantly reduced.

Environmental protection is an important issue in today's world. It is very important that there is as little waste as possible when doing refurbishment work. Buildings should be constructed with long-lasting building materials so that repair works are carried out as rarely as possible and the technical condition remains at an appropriate level for as long as possible.

Author Contributions: Conceptualization, B.N. and I.N.; methodology, B.N. and I.N.; formal analysis, B.N. and I.N.; resources, B.N. and I.N.; data curation, B.N. and I.N.; writing—original draft preparation B.N. and I.N.; writing—review and editing B.N. and I.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by grant number 504-B-107-00-10-21-500-00: "Strategies for refurbishment projects in the aging process of residential buildings." Small grants edition VI, 2021.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

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

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