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Developing a Waterproofing Decision-Making Model for High-Rise Building Projects in the Tropics

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Abstract: The most severe problem in high-rise structures is a failure to achieve watertightness. Since the presence of water in a structure can have a detrimental impact, adequate consideration must be taken when selecting a suitable waterproofing system based on several factors. As a result, this research aims to examine the factors that affect the selection of the best waterproofing solution in high-rise building projects in the tropics. Preliminary observations were conducted to investigate typically occurring issues with high-rise buildings which contain commercial, office, and residential facilities. Data were collected through questionnaire surveys and semi-structured interviews with professionals in the waterproofing industry. This study provides a comprehensive understanding of the issues concerning waterproofing and suggests an effective solution for the same. The assessment of the best waterproofing selection criterion was analyzed by incorporating the Best Worst Method (BWM). Based on the global ranking reached, the decision-making framework was developed, and three main specifications, technical, construction, and product, were suggested to select an ideal waterproofing solution. This study provides insightful guidance for professionals in the waterproofing industry and their clientele towards an optimal solution, facilitating informed decision-making processes.

Keywords: building defects; Best Worst Method (BWM); Multicriteria Decision-Making (MCDM); decision-making framework; waterproofing

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1. Introduction

Since the tropical environment has a distinct climate [1], including elevated temperature patterns and specific precipitation patterns, waterproofing is crucial for high-rise buildings in such a setting [2]. A monsoonal climate, which denotes high intermittent rainfall events, changing water tables, cyclical saturation level, and unsaturation with related chemical shifts and floods, is present in many tropical regions. This suggests that buildings in tropical areas have a propensity to deteriorate fast, particularly when it comes to external building materials that are exposed to factors including rain, wind, sunlight, UV radiation, and air pollution [3].

Major defects and persistent problems in high-rise buildings are caused by water [4,5]. Accessible water is carried into a building structure by a variety of mechanisms, including hydrostatic pressure, capillary forces, tension on the surface, air currents, and natural gravitation [5]. The main cause of moisture problems in buildings is leaks in structural elements such as the roof, wall, and ceiling [6]. There are several ways that water may enter a building, including through cracks, expansion joints, openings in the walls and roof, and solids that are porous in nature. Any surface area that comes into the path of water possesses the potential to let water in or potentially leads to water coming into a structure and must thus be waterproofed [4].

According to the definition of waterproofing, it is "a method to protect the structure from moisture on the surface or filtering water from groundwater, precipitation, or other aggressive environment anti-filtration waterproofing, in addition to ensuring the longevity of building components under physical or chemical forceful impacts—anti-corrosion waterproofing" [7]. Moisture is a key cause of construction problems and accounts for 75–80% of structural faults in buildings [8]. Lacking a waterproofing system, excess moisture absorption in the concrete causes the reinforcing bars to corrode, further contributing to the structure beginning to form water, which causes a leaking issue [9]. The defects will progress beginning with the leaky issue to the concrete cracking and spalling [10]. Though the cost of high-quality waterproofing design and installation may represent between 1 and 3% of the project's total cost, the cost of waterproofing system failure and repair can be between 5 and 10% of the project's total cost [11]. According to the mean evaluations of failure frequencies, water seepage brought on by waterproofing defects is the most common defect [12] and causes frequent maintainability issues [13] connected to increased maintenance cost. It is conceivable that the building will become inhabitable [14] and structurally hazardous if the obligation to maintain it as dry as possible is not satisfied [8]. Many contractors are trying to reduce the cost of waterproofing since it is so expensive. Therefore, when selecting a product, cost is their main consideration [4].

Selecting the ideal waterproofing system for a building requires careful consideration of various crucial factors such as the material type, water table, operating conditions, temperature, humidity, standards, and application purpose [7]. Therefore, during the selection of an appropriate waterproofing system for a building, it would be advantageous to assess the many aspects that may influence the decision [15]. Selecting high-quality materials and advanced technologies can enhance the durability and maintenance of a building or structure. It can also make repairs easier with hydraulic protection of the structures and ensure long-term and dependable waterproofing [16]. Neglecting any of these aspects could potentially compromise the safety and hygiene of the building [17]. As a result, the study focuses on a way to choose the best waterproofing solution for high-rise buildings in a tropical setting while considering important aspects.

Despite the existence of numerous studies on waterproofing defects [18–20], there is a notable absence of research focused on identifying the most appropriate waterproofing system based on relevant factors. The importance of design development in waterproofing is paramount, as it directly influences the long-term effectiveness, durability, and performance of waterproofing systems. At the same time, proper design development ensures that waterproofing systems are integrated seamlessly into the overall building design [21]. Therefore, the aforementioned facet might be viewed as a major contribution to the current knowledge gap and therefore, the study investigates the research problem "How to select the most suitable waterproofing solution in high-rise buildings in the tropics". As a result, this study examines the factors to be considered when selecting a waterproofing system. Since decision-making models emphasize flexibility and the consideration of various factors, aligning well with the complexities of decisions in dynamic and challenging environments [22], the Best Worst Method (BWM) was used as a means of analysis, which is a pairwise comparison-based methodology that offers a systematic approach to comparisons. The BWM is a form of Multicriteria Decision-Making (MCDM) with unique benefits that have not been previously utilized in the context of waterproofing selection. Therefore, this paper is organized to provide a complete examination of creating a waterproofing decision-making model for high-rise building projects in tropical areas. This study covers different aspects that affect the decision-making process for waterproofing and how to prioritize these factors using BWM. It provides a detailed overview of the topic and uses various data-gathering and analysis methods to understand and evaluate the different options available. By gaining a comprehensive understanding of each section, it becomes easier to address the challenges associated with making waterproofing decisions for high-rise buildings in tropical climates.

1.1. Applications of Decision-Making Models

One of the latest proposed MCDM methods is the BWM, which is commonly used to compute attribute weights. The best criterion is compared to the other criteria and all the other criteria are compared to the worst criterion in the comparison-oriented MCDM method known as BWM [23]. The comparison system has created a straightforward linear optimization model to determine the ideal weights and consistency ratio [24]. The associated issues may relate to choosing the best alternate option or rating the factors that are thought to be drivers or barriers in terms of their significance or influence. BWM, the most recent methodology introduced to the remarkable list of MCDM techniques, has drawn considerable study interest [25,26].

The BWM demonstration has been used as a suitable way for weighing criteria and alternatives in many different fields [27]. BWM has already been utilized in several real-world problems as mentioned in Table 1 below.

Table 1. Application of BWM in real world scenarios.

No.	Study Area	Source
01	Evaluated the important factors that affect how well airline baggage handling systems are evaluated.	[28]
02	Investigated the factors that affected investment choices in the conflict between battery and fuel-cell-powered electric automobiles.	[29]
03	Analyzed the performance of a Chinese power grid company's operations considering sustainability factors.	[30]
04	Given weight to the factors that are significant in the Netherlands' choice of biomass thermochemical conversion technology.	[31]
05	Industrial businesses' supplier chains' social sustainability factor has been studied.	[27]
06	Evaluation of technical and performance criteria in supply chain management.	[32]
07	Selection of the mobile phone.	[24]

In essence, the BWM has been positioned as a viable instrument for comparing criteria and alternatives due to its systematic comparison approach and applicability across several domains. This is demonstrated by the fact that it has been successfully applied in a variety of settings, giving researchers and decision-makers a flexible technique to improve their decision-making processes. The BWM continues to provide important insights to a variety of industries by aiding efficient decision-making through extensive attribute weighing and comparison studies, as evidenced by its rising popularity and broad implementation.

The simplicity and intuitiveness of BWM make it a frequently used solution. It avoids the complexity of pairwise comparisons used in other approaches by requiring decision-makers to choose the best and worst criterion from a list of alternatives [33]. For instance, it may be that since in contrast to complete pairwise comparison matrices, which indicate for $n(n-1)/2$ comparisons, the BWM only makes a demand for $2n-3$ comparisons corresponding to a linear function of n, the proponents of recent weighting methods using $(n-1)$ comparisons frequently cite the BWM as an inspiration or a reference point for their proposals [34]. Experts must thus spend less time and deal with fewer data [24]. BWM is easier for decision-makers with different levels of knowledge to use because of its simplicity. By asking decision-makers to assess both positive and negative features, BWM naturally reflects the relative relevance of criteria. BWM uses fewer pairwise comparisons than other techniques including the Full Consistency Method (FUCOM) or Defining Interrelationships Between Ranked Criteria (DIBR), which might ease the cognitive load on decision-makers. This feature is exceptionally useful when balancing multiple distinct criteria. This balanced consideration lessens potential problems with overemphasizing positive preferences and gives a truer picture of the priorities of the decision-makers [24].

1.2. The Analytical Approach for Study Context

BWM can be employed to evaluate the potential building construction industry based on criteria such as accessibility, environmental impact, and cost-effectiveness. As a representation, Ayyildiz et al. carried out a study on the evaluation of insulating materials used in the building insulation process using BWM. The basis for this inquiry derives from the critical need to account for a wide range of criteria during the evaluation of these materials [35]. The effective completion of any project is highly dependent on the selection of appropriate building materials. BWM offers a simplified approach to the material selection process by considering key factors such as cost, durability, and sustainability. This is proven by a recent study conducted by assessing pipework using BWM based on various criteria, including overall cost, security, social expenses, and environmental impact [36]. Therefore, this approach serves as a valuable tool for ensuring that projects are executed with the utmost efficiency and consideration for all pertinent factors.

Furthermore, the utilization of the BWM has proven to be highly effective in evaluating supplier performance, considering a variety of criteria including their level of expertise, experience, project management capabilities, cost, and sustainability. This has been demonstrated through several studies [37,38], which have shown the benefits of employing BWM in supplier assessment.

Comparing the above studies reveals that BWM can be proposed as a good analysis tool for the waterproofing industry. In the dynamic realm of building construction, the selection of appropriate waterproofing methods is a pivotal decision that directly impacts the durability, longevity, and overall performance of structures. With a myriad of factors to consider, ranging from effectiveness and cost to environmental impact and installation complexity, decision-makers often find themselves grappling with the complexity of these choices. In this context, BWM emerges as a valuable analytical tool that offers a systematic and structured approach to tackling the multifaceted challenges of waterproofing selection. Due to its comparative benefits over other well-known MCDM approaches, BWM was chosen for this investigation. Furthermore, the use of BWM as an MCDM for this new field of study, which was not previously covered in the literature, adds to the originality of this research.

2. Materials and Methods

To achieve the study's aims, several data gathering and data analysis approaches were used. Figure 1 below indicates the flow of data and analysis methods used throughout this study. It serves to visually convey the process by which the data were collected, analyzed, and interpreted. The approach illustrated in the figure allowed for a thorough examination of the data and ensured that the results were accurate and reliable.

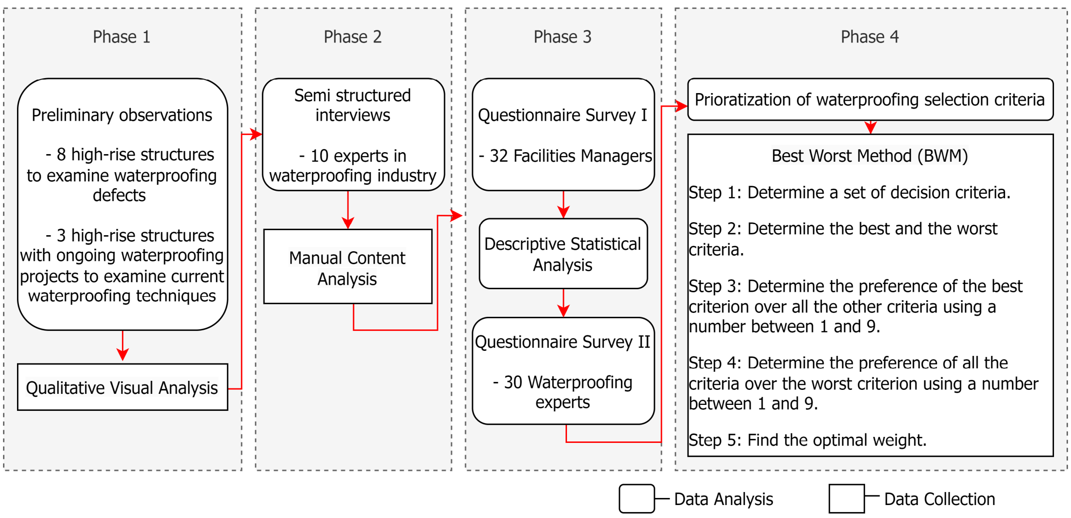


Figure 1. Phases of data collection and data analysis.

2.1. Data Collection

2.1.1. Preliminary Observations

It is possible to examine existing waterproofing defects and practices within building structures by physical observation. As a consequence, eight high-rise structures were examined to discover more about any waterproofing flaws that they may have had. To find the various waterproofing techniques currently being used in the industry, an additional three buildings with ongoing waterproofing projects were inspected. These particular high-rise building projects in the tropics were chosen at random. See Table 2 for further details of these buildings.

Table 2. Details of case buildings.

No.	Building Type	No. of Stories	Location	Age	Collected Data
B1	Residential	15	Colombo	2	Waterproofing defects
B2	Residential	14	Gampaha	5	
B3	Commercial	12	Colombo	10	
B4	Office	9	Colombo	7	
B5	Commercial	18	Gampaha	1	
B6	Residential	12	Colombo	2	
B7	Office	8	Kalutara	5	
B8	Residential	15	Colombo	8	
P1	Residential	9	Colombo	12	Initial and remedial waterproofing installation
P2	Residential	10	Colombo	10	
P3	Office	12	Colombo	New	

Note: A total of 11 high-rise buildings were examined to acquire details on waterproofing defects and initial and remedial waterproofing installation practices.

Due to their climate, which is characterized by particular tropical climatic aspects, high-rise buildings in the Western province were considered as representative case buildings for the examination in this study.

Table 3 compares the climate of the Western province with typical tropical characteristics. The information emphasizes the similarities between the two climates in terms of temperature, humidity levels, and yearly rainfall. The climate of the Western province closely resembles that of tropical regions. It has been observed that most waterproofing issues in case buildings become noticeable a few months after the construction phase. The specific circumstances and factors that contribute to the genesis of these issues need to be identified throughout the period of construction. As these defects tend to arise post-construction, it is essential to consider these factors from the design phase.

Table 3. Comparison of climate data.

Climatic Data	Western Province	Tropical Regions
Average temperature	26.5–28.5 °C (80–86 °F)	25–38 °C (77–82 °F)
Humidity levels	>80%	70–90%
Annual rainfall	1760 mm	1500–3000 mm
	Source: [39]	Source: [40]

2.1.2. Semi-Structured Interviews

To gather information from a variety of perspectives, waterproofing industry professionals were approached for semi-structured interviews. Experts were chosen through the technique of purposeful sampling, which enables the researcher to obtain data from people who share their viewpoints. Since the results seemed to be more consistent after the sixth interview, the sample size was capped at ten individuals. See Table 4 for further details of these respondents.

Table 4. Details of respondents.

Respondent	Profession	Designation	Experience in the Industry
R01	Engineering	Chief Engineer	30 years
R02	Engineering	Director	35 years
R03	MEP Engineering	MEP Manager	15 years
R04	Engineering	Project Manager	27 years
R05	Engineering	Project Manager	25 years
R06	Engineering	Site Engineer	11 years
R07	Engineering	Site Engineer	10 years
R08	Safety Engineer	Maintenance Engineer	10 years
R09	Engineering	Project Manager	25 years
R10	Engineering	Project Manager	20 years

Note: The details about the respondents who took part in the expert interviews are shown in Table 4. In terms of expertise, every participant had enough industrial experience in the waterproofing industry, plus at least ten years of construction industry experience, to contribute to the study with their technical and professional knowledge.

2.1.3. Questionnaire Survey

Two questionnaire surveys were conducted to reveal the discrepancies in decision-making on waterproofing selection. As a result, survey one was conducted with a specific focus on facilities managers who engage in managing and maintaining buildings. To acquire information on the current high-rise building scenarios and their perspectives on selecting waterproofing systems, top-level managers in high-rise buildings were approached for this survey. See Figure 2 for the years of experience breakdown for the respondents.

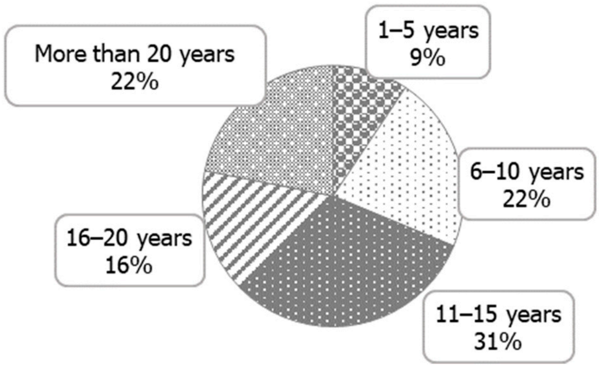


Figure 2. Questionnaire survey I—experience level of industry respondents.

Survey two targeted professionals who are knowledgeable and skilled in waterproofing. Through that, the recommended way for making waterproofing decisions was discovered while grading the selection criteria in order to determine the best and worst option for waterproofing.

Since facilities managers work as the representatives of the clients and are involved in decision-making when managing the buildings, they were selected as the respondents for this survey. The questionnaire survey was divided into three sections, the first of which was intended to gather general information about the respondents and the facility, the second was to collect information on current issues from waterproofing and practices followed, and the third of which was used to rank significant factors that are currently considered in terms of the client's perspective when deciding on the selection of waterproofing. Survey II targeted professionals who are knowledgeable and skilled in waterproofing. Through that, the recommended way for making the waterproofing decision was discovered while grading the selection criteria to determine the best and worst option for waterproofing. As illustrated in the above figure, more than half of the respondents have more than ten years of experience.

Questionnaire survey two was intended to rank significant factors during deciding on the selection of waterproofing. Professionals who have knowledge and competence in waterproofing were given 40 questionnaires designed for industry experts, and 30 of them were responded to. Figure 3 provides the details of the experience of respondents.

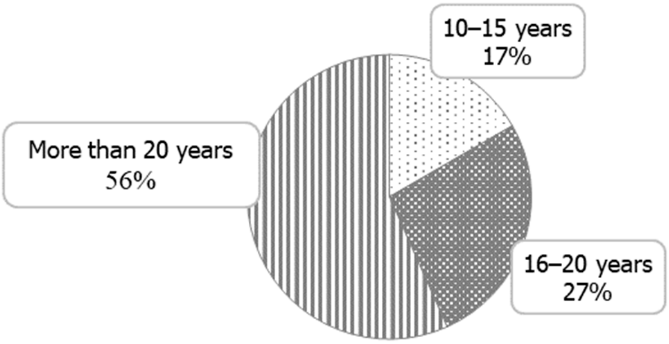


Figure 3. Questionnaire survey II—experience level of industry respondents.

More than half of the respondents had more than 20 years of experience in the industry, confirming that the data were collected with precision and reliability. A total of 32 facility managers and 30 experts in waterproofing participated in this survey.

2.2. Data Analysis

Best Worst Method (BWM)

Using the MCDM method, which allows for the consideration of many criteria with varying weights [23], the decision on waterproofing based on several aspects was studied. This study made use of a recently created MCDM method called BWM [24]. The main reason for selecting BWM in this study is that it takes fewer data than comparable existing approaches because it does not require a full pairwise comparison matrix and because its organized pairwise comparison system yields more reliable results. The decision-makers also view it as being straightforward and quite similar to how they evaluate and reason while making decisions. Accordingly, the main focus of ranking the selection criteria was analyzed using BWM. In BWM, the expert chooses the best and worst of n criteria (C_B and C_W, respectively), after which $n - 1$ pairwise comparisons are done between each of the remaining criteria and C_B and C_W, respectively, as the best and worst criteria. According to Rezaei [24], the steps of this method are:

Step 1: Determine a set of decision criteria. In this step, the criteria $\{c_1, c_2, \ldots, c_n\}$ to be utilized in the decision-making process are considered.

Step 2: Determine the best (e.g., most desirable, most important) and the worst (e.g., least desirable, least important) criteria.

Step 3: Determine the preference of the best criterion over all the other criteria using a number between 1 and 9. The resulting best-to-others vector would be $A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn})$, where a_{Bj} indicates the preference of the best criterion B over criterion j.

Step 4: Determine the preference of all the criteria over the worst criterion using a number between 1 and 9. The resulting others-to-worst vector would be $A_w = (a_{1w}, a_{2w}, \ldots, a_{nw})$ T, where a_{jW} indicates the preference of the criterion j over the worst criterion W.

Step 5: Find the optimal weight. $(w_1^*, w_2^*, \ldots, w_n^*)$. The optimal weight for the criteria is derived such that, for each pair of w_B/w_j and w_j/w_W, the conditions $w_B/w_j = a_{Bj}$ and $w_j/w_W = a_{jW}$ are satisfied [41].

To arrive at the BWM statistics, the above basic steps were used, and the aforementioned reference material (refer to [24]) can be reviewed for more clarification.

3. Results

3.1. Common Waterproofing Defects

Throughout the process of gathering data, it was discovered that neglecting waterproofing has resulted in building maintainability issues and has exposed building structures to danger, increasing maintenance costs and recovery. Based on the survey, 158 cases of waterproofing defects were reported. For the convenience of analysis, the reported defects are portrayed as a percentage from this total. Table 5 demonstrates the frequency of common defects due to poor waterproofing.

Table 5. Frequency of common defects.

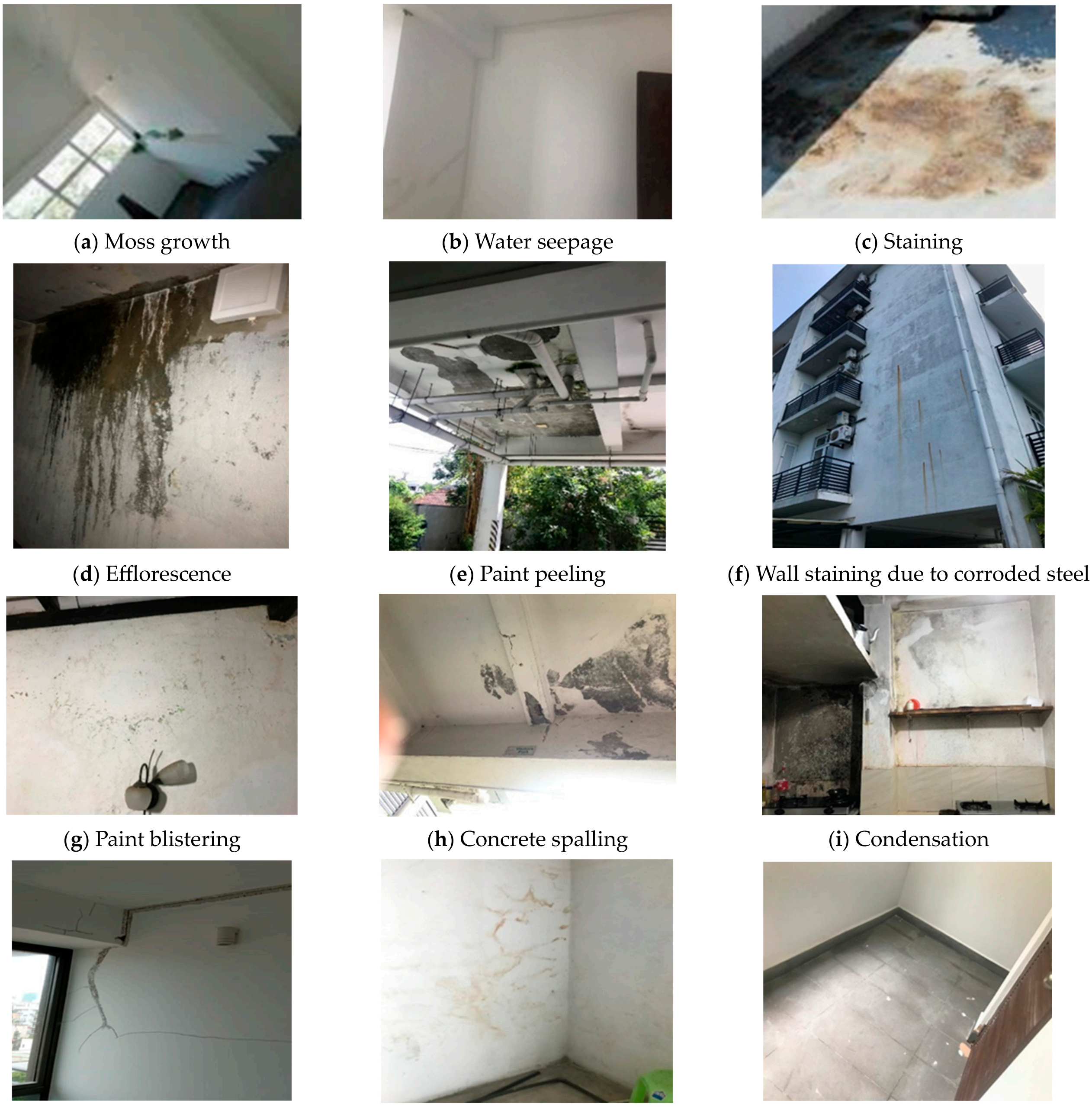
Defects	Responses (Percent)
Water penetration through cracks	21.5%
Blistering	15.3%
Dampness	11.8%
Condensation	11.8%
Staining	9.0%
Mold growth	8.3%
Concrete spalling	8.3%
Discoloration	3.5%
Wood decay	2.8%
Temperature difference	2.1%
Dirt collection on the surface	2.1%
Corrosion	2.1%
Nasty odor	1.4%
Total	100.0%

According to the findings, water penetration (21.5%) is the most prevalent defect. In most cases, water penetration was followed by cracks, joints, and porous building elements. Joints exposed to water or foundation cracks might cause more severe structural issues.

In addition, due to inadequate waterproofing, blistering (15.3%) is the second most typical problem reported. Moreover, dampness (11.8%) and condensation (11.8%) were discovered as similarly elevated defects. Prolonged dampness in a structure would lead to many deficiencies. In addition to making living conditions unpleasant and unhealthy, dampness has an impact on the building. As a result of inadequate waterproofing, frequent issues including staining (9.0%), mold growth (8.3%), concrete spalling (8.3%) discoloration (3.5%), wood decay (2.8%), corrosion (2.1%), dirt collection on the surface (2.1%), and temperature difference (2.1%) were observed. If the structure is made of wood or includes wooden furnishings, moisture from water infiltration will cause the wood to rot or delaminate. Mold and mildew are also harmful to health. This can cause allergies, asthma, rashes, and fungal infections in people who are exposed to it. If neglected, inadequate waterproofing not only compromises building safety but also poses a hygiene risk [17].

Unpleasant odor (1.4%) was rated as a rare problem in comparison to other defects. Mold and mildew are typically to blame for the foul smell. The responsible party acts to fix any defects, temporarily or permanently, as soon as the appearance of the building deteriorates. The fact that there is a lower percentage of unpleasant odors means that mold is removed as soon as it manifests itself. Further, during the preliminary observations, a number of defects due to poor waterproofing were observed. Some of which are presented in Figure 4.

As a result, it can be derived that waterproofing defects harm the building structure, aesthetics, comfort, and safety of the residents or occupants.



(**a**) Moss growth (**b**) Water seepage (**c**) Staining

(**d**) Efflorescence (**e**) Paint peeling (**f**) Wall staining due to corroded steel

(**g**) Paint blistering (**h**) Concrete spalling (**i**) Condensation

(**j**) Wall crack (**k**) Discoloration (**l**) Dampness

Figure 4. Identified common waterproofing defects.

3.2. Main Reasons for Damaged Waterproofing

Throughout the process of gathering data, it was discovered that there are many reasons behind poor waterproofing which resulted in pathological issues and exposed structures to danger. The frequency of responses for the causes of waterproofing deficiencies is shown in Table 6.

A conclusion that may be drawn from the aforementioned percentages is that noncompliance with the technologies is the primary (12.4%) reason for the damaged waterproof. The defective waterproof is most frequently caused by design mistakes and subpar construction designs, which account for 11.9% of all cases. While accidental incidents such as rodent invasion can also result in waterproofing damage (1.8% of the frequency), they are less frequent. Therefore, the most important problem linked to waterproofing faults can be referred to as technology, including technical detailing and design guidelines. Therefore, technical detailing, design guidelines, and specifications must be considered even if waterproofing technologies and demand have evolved to ensure the stability and durability of the waterproofing applied to a specific area of the structure.

Table 6. Causes of waterproofing defects.

Causes	Responses (Percent)
Noncompliance with technologies	12.4%
Poor construction design	11.9%
Design errors	11.9%
Contractor negligence	11.5%
Infrequent quality control	11.5%
Incompetent craftmanship	7.8%
Availability of maintenance practices	6.9%
Inferior materials	5.5%
Cracks due to shrinkage	4.6%
Inadequate ventilation factors	4.1%
Excessive pressure	3.7%
Weak clay surface layer	2.3%
Inadequate floor slope	2.3%
Rodent attack	1.8%
Unintentional events	1.8%
Total	100.0%

3.3. Replacement of Initial Waterproofing

This sort of question area intends to figure out the degree of deficient waterproofing in the current industry. Figure 5 depicts the percentage of replacement of initial waterproofing of high-rise buildings.

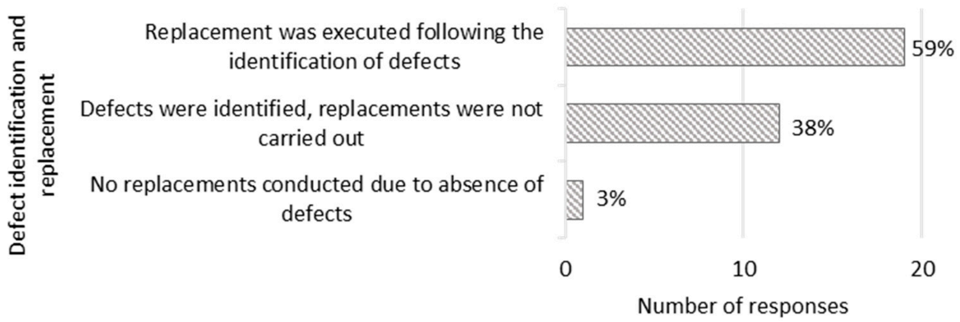


Figure 5. Percentage of initial waterproofing replacement.

According to the chart above, 3% of buildings have not had their waterproofing replaced since no issues have been discovered. Following an in-depth analysis, it was discovered that, of the 3% of buildings, the majority are between 1 and 3 years old. Nonetheless, there may still be poor waterproofing flaws that have not appeared or been detected by individuals. Regrettably, waterproofing defects were discovered in 59% of the buildings, and the original waterproofing had to be restored because of errors. Furthermore, 38% of buildings had original waterproofing that needed replacement or repair, notwithstanding the presence of defects. Due to budgetary restrictions, funds could not be reserved for a replacement. Nonetheless, it can be said that 97% of all high-rise buildings had their original waterproofing replaced as a result of errors and deficiencies.

Collectively, these data show how important it is for stakeholders to consider the inconveniences caused by remediation efforts along with effective waterproofing practices initially. In summary, the data emphasize the need for careful planning and investment in this crucial part of the construction, emphasizing the enormous influence of waterproofing on the longevity and sustainability of these structures.

3.4. Initial Waterproofing vs. Remedial Waterproofing

The most effective strategy when selecting a waterproofing solution is to be conservative. If a leak develops after completion of construction, excavation cost for repairs, even simple ones, may usually be more expensive than the waterproofing system's initial cost. The opportunity to get it properly only comes once. To guarantee that the appropriate system is specified, and all waterproofing concerns are successfully addressed, research and effort are needed. The cost details were received from the facilities managers, who are in charge of managing the maintenance budget. All the respondents agreed that the cost of replacement is higher than the initial cost, reflecting expert judgement. R02 noted that "sometimes, waterproofing systems might unexpectedly fail in a building, or some areas need to be re-waterproofed after structural alterations". Since water infiltration has the potential to seriously harm a building, it is essential to find suitable repair solutions as soon as possible to avoid further costly repairs in the future. Nevertheless, as stated by R05, "Sometimes, the waterproofing repair is not adequate, and a complete replacement needs to take place. If you are considering patching from within the structure, realize that it would not work in most circumstances".

Whilst cementitious coatings and crystalline topical treatments may temporarily alleviate small concerns, they are often merely a decorative remedy that might deflect or absorb moisture and cause additional concerns which could become severe. A proper design and implementation of waterproofing can cost 1 to 3% of the value of a construction. Conversely, damage and maintenance of waterproofing systems cost 5 to 10% of the project's worth [15]. According to R07, "it may be necessary to remove a significant quantity of top surface and replace it, or to use a jackhammer to remove the concrete protecting pads and concrete caps". Such significant upgrades can cost more than 300 times the cost of the membrane.

Thus, it can be contended that remedial waterproofing is higher than the initial cost of waterproofing. Accordingly, a waterproofing system is similar to a foundation and a structural framework in that it requires significant consideration and perseverance.

3.5. Client Inputs during Waterproofing Decision-Making

One of the initial exercises in a building's construction phase is waterproofing. Any mistake at this phase will require money to fix and occasionally will not be fixable without destruction. Water leaks often start to occur when the system is operating at maximum capacity, which is after all finishing touches have been applied. At that point, there is no way to repair the situation without completely or partially tearing down the finished work. Regardless of whether the building is being constructed from scratch or renovated, selecting the correct waterproofing system from the early design stage is the best approach to safeguarding it.

Most experts agree that customers frequently choose the least expensive alternative over the most efficacious one. According to the preliminary observations (Table 7), although the liquid cementitious waterproofing method is not recommended for rooftop areas exposed to intense UV radiation, the customer selected that approach since it is less expensive than alternative ways.

Clients choose the cheapest available option since the waterproofing layer will not be visible after installation. It is verified in Table 8, which was created based on the clients' viewpoints while choosing waterproofing. These ranking values were obtained by calculating the mode of the dataset. According to Table 8, from the perspective of clients, cost and suitability of the contractor are the jointly most considerable factors when selecting a waterproofing system. Material is the second most significant factor that clients give priority to.

There is no question that financial limitations always exist whether it comes to building, restoration, or replacement. The waterproofing system is not the place to minimize expenses, though, if a building owner or general contractor wishes to do so. In addition, even modest maintenance might cost more than the system itself [42]. In addition, contractors' appropriateness should not be the top priority, but it should still be considered for aspects such as market competition. However, subsequent sections cover the perspectives of experts evaluated using BWM. The difference between the perspectives of the client and experts is discussed in subsequent sections.

Table 7. Initial and remedial waterproofing projects—findings of preliminary observations.

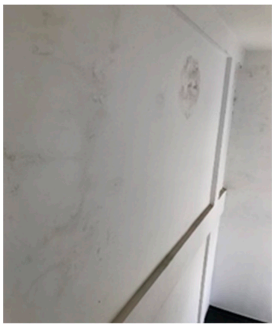
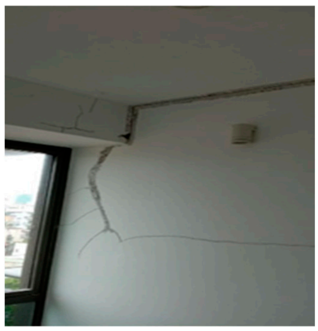
Project No		Description
	Project Details	Project: Remedial waterproofing project—Residential building Project location: Colombo Waterproofing application area: Rooftop Application method: Polyurethane liquid membrane waterproofing
		 (a) The setting before the replacement was made. The decision was made to replace the current waterproofing layer as a result of the discovery of several flaws beneath the rooftop's flooring. Adverse weather conditions and post-drilling operations after the waterproofing layer's installation pointed to its failure.
		Defects resulting from waterproofing failure
		 (b) Wall condensation When the warm, humid air in the space comes into contact with a chilled inside wall, condensation is created. When air cools down too quickly, it condenses back into water and leaves moist spots on the wall. Mold growth as well as damage to the inside walls might result from continuous condensation issues.
		   (c) Parapet wall crack (d) Internal wall crack Water that penetrates the walls may cause the walls to absorb moisture. Materials can expand and cracks contract as a result of changes in the moisture content of the walls brought on by external factors. The tension from these continuous cycles of expansion and contraction can cause cracks in the wall surfaces.

Table 7. *Cont.*

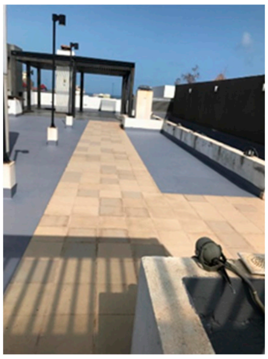
Project No		Description
Project 01	Visual Evidence	**Surface Preparation**  (e) Removing the top layer of the surface. The rooftop floor of this building was covered with artificial grass material. Therefore, the initial step in replacing the waterproofing was to remove the top layer. The above figure depicts the area of the flower bed and floor as it appeared after the top layer had been removed.  To prevent long and deep imperfections that may harm the waterproofing layer, the surface was leveled. (f) Leveling substrate using mortar **Waterproofing application—Polyurethane liquid waterproofing**  (g) Applying a waterproofing layer for floor area.  (h) Applying a waterproofing layer for flower beds.  (i) Applying a waterproofing layer for drain lines. Liquid-applied membranes made of polyurethane (PU) are quick and effective, resistant to rain, elastic, and flexible. The membrane heals immediately after application, making the process quick. It adheres to bitumen, cement, and sand surfaces because of its outstanding bonding properties. It can therefore be coated over a preexisting waterproof membrane layer. This membrane is durable and resistant to mild acids. The largest surface applications, including balconies, rooftops, pathways, and industrial applications enabling considerable foot traffic, are most suited. They are safe, flame-resistant, non-polluting, and friendly to the environment. It is a substance with a wide range of waterproofing applications.

Table 7. *Cont.*

<table>
<tr><th>Project No</th><th colspan="3">Description</th></tr>
<tr><td rowspan="6">Project 02</td><td>Project Details</td><td colspan="2">Project: Remedial waterproofing project—Residential building
Project location: Colombo
Waterproofing application area: Rooftop
Application method: Liquid cementitious waterproofing</td></tr>
<tr><td rowspan="5">Visual Evidence</td><td colspan="2">Defects resulting from waterproofing failure</td></tr>
<tr><td>
(j) Biological stains on concrete slab</td><td>Biological stains brought on by the development of algae, moss, lichens, or other organic materials may appear on concrete roof slabs. If ignored, these stains can contribute to the concrete’s degradation over time in addition to reducing the structure’s visual attractiveness.</td></tr>
<tr><td>
(k) Routing cracks</td><td>The crack sealers were used to fix the cracks. This technique enlarges the surface crack that was initially there, a process called routing, and then seals the crack with an appropriate joint sealant.</td></tr>
<tr><td>
(l) Enlarged cracks to apply seal.</td><td>
(m) Finishing wall after repairing cracks.</td></tr>
<tr><td colspan="2">Surface Preparation

(n) Pressure washing the surface
All liquid-applied applications must have excellent adherence to be successful. Therefore, proper application of the liquid solution and thorough cleaning are equally important. Pressure washing is the method used most frequently to clean the substrate surface. By employing this technique, the alleged bond violators are taken out. In addition, it will highlight issues that need care but may not be obvious at first. Therefore, the roof slab’s exterior surface was pressure washed to get rid of the dirt and debris that had accumulated there.</td></tr>
</table>

Table 7. *Cont.*

Project No	Description	
	 (o) Jackhammering the surface	Rough tiling was used to cover the opposing side of the roof space. As a result, a jackhammer was used to remove the whole tile layer.
	 (p) Softening uneven surface	The adhesiveness of the substrate and the waterproofing layer may be impacted by rough surfaces. Therefore, rough surfaces, surfaces with sharp projecting components, and surfaces with sharp exterior corners were ground.
	Waterproofing application—Cementitious liquid waterproofing  (q) Applying a waterproofing layer The waterproofing technique used was a cementitious liquid waterproofing system, which comes in a variety of forms, the most popular of which is a liquid coating mix made of cement, a waterproofing agent, and a bonding substance.	
Project Details	Project: Initial waterproofing project—Office building Project location: Gampaha Waterproofing application area: Bathroom Application method: Liquid cementitious waterproofing	

Table 7. *Cont.*

Project No		Description
		Waterproofing application—Cementitious liquid waterproofing
Project 03	Visual Evidence	 (r) Applying a waterproofing layer  (s) Waterproofed bathroom area
		Bathrooms in this structure were waterproofed using cementitious liquid. This approach is appropriate since the surface is moist and does not produce excessive heat. This is a traditional technique that involves building a thick layer of water resistance. To provide a stronger, more permanent base, the cement is therefore combined with an acrylic additive, placed in a thick layer, and allowed to dry and solidify. Under heat exposure, it does not grow or shrink. Before installing tiles in the bathroom, a simple application of cement is used to produce a sealing layer that is often used at the beginning of remodeling the space.

Table 8. Ranking of main factors based on mode—how do clients select waterproofing?

	Material	Cost	Detailing and Technology	Building Profile	Climate and Environment	Legal Requirement	Suitability of Contractor
Rank	3	1a	4	5	6	7	1a

3.6. Assessment of Suitability of Selecting the Best Waterproofing Using BWM

The final list of determinants including their global average and rank for which the experts used the BWM to rank variables is shown in Table 9. The groups were formed based on the findings of similar research articles throughout the literature review. The elements that emerged as the "Most Important" (or "Best") and the "Least Important" (or "Worst") aspects were considered in the first round of the BWM implementation. In view of the provided ranking, the subsequent global weights were computed to derive the group ranks, which were then conveyed to the final global ranking.

In terms of main factors, detailing and technology come in first, with a weighted average of 26.2%, followed by material, at 19.75%, and the third aspect (18.17%) was contractor suitability. The list of criteria is completed by four sets of problems with a lower priority level: building profile (11.39%), cost (11.04%), climate and environment (8.65%), and legal requirements and compliance (4.8%).

The global weights and ranks were also determined using the aggregated (average) weight values from both hierarchy levels. The top 11 subfactors, which together account for a weighted average of 60.2%, are, in descending order of importance: method and design principles (11.3%), testing requirements (7.3%), direct cost (6.1%), waterproofer's past performance (5.9%), the requirement of special skills (5.7%), the useful life of material (5.2%), quality of material (4.3%), weather condition (4%), location to be waterproofed (3.7%), the capability of the waterproofing contractor (3.5%), and reputation (3.1%).

Table 9. Group and global ranks of factors.

Main Factors	Group Average	Group Rank	Sub Factors	Global Average	Global Rank
Material	0.1975	2	Useful life and durability	0.052	6
			Quality	0.043	7
			Sustainability	0.016	23
			Material cost	0.021	18
			Appearance and comfort to the interior	0.009	36
			Purpose of application	0.016	22
			Location	0.023	16
			Ease of application	0.010	31
			Resistant to UV	0.009	33
Cost	0.1104	5	Direct cost (material and labor)	0.061	3
			Indirect cost (utilities)	0.030	12
			Maintenance cost	0.009	34
			Disposal cost	0.011	29
Detailing and technology	0.2620	1	Method and design principles	0.113	1
			Requirement of special skills	0.057	5
			Special equipment	0.018	20
			Testing requirements	0.073	2
Building profile	0.1139	4	Operating condition of the building	0.025	14
			Water table and soil characteristics	0.014	25
			Location to be waterproofed	0.037	9
			Size of the area to be waterproofed	0.009	32
			Composition of structural elements of the building	0.028	13
Climate and environment	0.0865	6	Changes in the temperature and humidity	0.017	21
			Chemical composition of groundwater	0.020	19
			Weather condition	0.040	8
			Seasonal changes	0.010	30
Legal requirements and compliance	0.0480	7	International codes and standards	0.023	15
			Local codes and standards	0.016	24
			Supplier recommendations	0.009	35
Suitability of contractor	0.1817	3	Reputation	0.031	11
			Ability to undertake the work	0.035	10
			Waterproofer's history (track records)	0.059	4
			Financial position	0.011	28
			Ability and confidence to warrant the product	0.022	17
			Available human resources	0.013	26
			Ability to meet all the environmental, safety, quality, statutory, and government requirements and regulations	0.011	27

4. Discussion

4.1. Detailing and Technology

The experts' rankings in BWM reveal that detailing and technology (26.2%) are valued as a critical determinant of selecting the best waterproofing system. Three of the four subfactors of the group were found in the top ten places of the global factor list, the method and design principles ranked first, testing requirements ranked second, and the requirement of special skills ranked fifth.

Over time, waterproofing problems were caused, alongside several other factors, by the absence of expertise in the methods and the use of the wrong materials. A waterproofing designer must have a fundamental understanding of waterproofing design principles and methods, even if the structural design of waterproofed building components is outside the scope of this work. Furthermore, while the problems associated with contemporary waterproofing have worsened, advances in waterproofing technology have multiplied even faster. There is now a far wider range of innovative options accessible. Therefore, having a firm understanding of the design process is essential. R03 revealed that "inadequate technical aspects will result in inadequate waterproofing, even if we employ the best waterproofing material". The responder notes that a lack of technical know-how on how different components of a waterproofing system and their application influences the performance of the overall system, more so than using better materials. Before completing the design, it is essential to explain how each envelope component will interact with nearby components as well as the requirements for testing.

4.2. Material

Material is the second most crucial aspect to consider when choosing the best waterproofing, with a weight of 19.75%, mostly reflecting the experts' concerns over the usable life of the material (ranked sixth overall) and quality (seventh place in the global factor list). The desired lifespan of a waterproofing system is the whole service life of the structure [42]. As a result, one of the most crucial waterproofing design concepts is durability. To create a waterproofing system that works well and lasts a long time, trustworthy materials are crucial.

It is a fallacy that waterproofing treatments may be applied to fresh concrete or existing treatments with a single substance. R08 stated that "there is no one material that is suitable for all structures. This misunderstanding is the main reason for waterproofing projects fail so frequently". Considering the waterproofing treatment as a system is the only approach to ensure reliable treatment. The first step in finding suppliers that have items with the same purpose but different attributes is becoming aware of them. If the customer or the applicator is not aware of this, they may apply a product in several situations in the same manner without achieving the desired results. As a result, the application's objective must be considered. Sustainable construction materials may now be chosen for waterproofing since sustainability has grown in importance in the construction industry.

Although ease of application and aesthetics are small criteria in comparison to the other issues, they should be considered because they might lead to superior craftsmanship. Although it will vary depending on the region, moreover, UV resistance is a small consideration. However, using a product with greater performance results in lower application and building maintenance cost [43].

4.3. Suitability of Contractor

The third most significant factor in choosing the best waterproofing solution is the suitability of the contractor, with a weight of 18.17%. This weight primarily reflects the experts' concerns about the waterproofer's prior experience (ranked fourth overall) and ability to complete the work (tenth place in the global factor list). For the waterproofing of a building, providing rehabilitation and maintenance, and offering a warranty of 10–20 years, there are already professional contractors with these unique skills, expertise, and technology. Yet, there are still instances where infiltrations take place, which may be attributed to a lack of skilled specialists in the region and improper implementation. The history and track record of the waterproofing contractor is further matched by their reputation.

Financial standing, the capacity to guarantee the product, the availability of human resources, and the ability to satisfy environmental, safety, quality, legal, and governmental needs and laws are also taken into consideration as minor deciding considerations when choosing waterproofing. However, they must still be considered for many reasons, including market competition. R05 stated that "certain employees appointed by the primary waterproofing contractor are unaware of the effects of factors like dampness. And precisely these factors contribute to building degradation".

Because the vast majority of the masonry foremen and other assistants lack education, only the fundamentals of many professions are known to them. Thus, laborers operate without any risks. Uneducated laborers do what they enjoy. The problem is that the site supervisor must oversee these issues.

4.4. Building Profile

The experts' assigned weights for the building profile (11.39%) indicate that it is a less significant element when compared to technology, material, and contractor compatibility. Location ranks ninth on the list of global criteria, behind the operating state of the structure, the water table and soil characteristics, the location to be waterproofed, the size of the area to be waterproofed, and the composition of the structural elements of the structure. The location of waterproofing determines the material or method to choose, making it a crucial consideration. For instance, some surfaces are more suited to crystalline waterproofing systems than to flexible membrane waterproofing systems, and vice versa. Even if the items are of the highest quality, the chances of getting the desired effects are slim. Moreover, a thorough grasp of the site's current circumstances will make it easier to decide whether a waterproofing system repair or replacement is necessary.

4.5. Cost

According to the BWM weights assigned by the experts, the cost (11.04%) is not a significant consideration. Direct cost, however, is included as a subfactor in third place. The primary factor is that the cost of materials is a significant component of waterproofing's direct cost. Without a doubt, a building, remodeling, or replacement project is always constrained by a lack of funding. Even so, if a building owner or general contractor decides to save cost, they should not attempt to do so with the waterproofing system. As said, even modest maintenance might potentially cost more than the system's purchase price [42].

According to experts, severe corrective treatment might sometimes cost more than the price of the membrane. This danger drives careful designers to forego first-cost efficiency if there is even a remote possibility of failure. Despite an increase in cost of a few cents per square foot, wise designers choose methods and materials that will last. They further advocate for strict quality assurance inspection procedures during installation and testing, if it is practical, as well as authorized applicators for installing waterproofing systems.

Considering the low significance, maintenance cost was ranked thirty-fourth. Although all industry professionals agree that maintenance is a critical component of any construction project, waterproofing is one area where it is usually ignored since it is invisible once the waterproofing membrane or layer is installed. No further maintenance could be performed after installation. However, it is important to do maintenance to fix cracks and check for flaws. The expense of upkeep, however, will not be incurred.

4.6. Climate and Environment

Climate and environment now account for an average of 8.65% of the total weight, primarily reflecting worries about the current weather (eighth place in the global factor list). Since tropical countries are exposed to dry and wet weather conditions, this should be considered while choosing a waterproofing material and method. As high-rise buildings in tropical settings are not subject to the same seasonal conditions as other nations, it is ranked thirtieth.

Nonetheless, it is important to learn how the structure has withstood different weather conditions and temperature swings over time because these elements might affect a structure's integrity and capacity to stop leaks.

4.7. Legal Requirement and Compliance

It is well acknowledged that any building must have a clear legal foundation to succeed and be free of problems. The experts' BWM weights indicate that the legal necessity and compliance (4.8%) are not a significant consideration, nevertheless. The experts' rankings of the subfactors of international codes and standards (fifteenth), local codes and standards (twenty-fourth), and supplier recommendations (thirty-fifth) show how inadequate the waterproofing-related legal measures are. There are worldwide norms and standards for waterproofing material, the expert claims. However, there are no legal guidelines or procedures that must be followed when waterproofing a structure. Furthermore, it is not sufficient to rely just on supplier suggestions since they do not have sufficient knowledge of the building profile and site circumstances.

In conclusion, a waterproofing system can be defined as a combination of materials, preparation of specifications, and application techniques designed by taking into consideration the needs of the client or owner, which would provide effective, dependable, and long-term protection to concrete structures with the least amount of upkeep [44]. Hence, it can be inferred that the ideal solution will lessen the complexity of the implementation of repair work with hydraulic protection of structures and improve the maintainability and lifespan of the operation of buildings and structures [16]. According to the authors' contention, it is essential to understand every factor influencing the reliability and operational performance of the waterproofing system that is chosen for the building.

4.8. Decision-Making Framework to Select the Best Waterproofing Solution

The top eleven subfactors were determined based on the calculated global weights in the previous section, and they are as follows: methods and design principles, testing requirements, direct cost, the waterproofer's past performance, the requirement for special skills, the useful life of the material, the quality of the material, weather condition, the location to be waterproofed, the contractor's ability to waterproof, and the reputation of the waterproofer. The weighted average of the top eleven subfactors, which together make up 60.2%, simply suggests that, by making decisions based on the top eleven criteria, 60% of the problem will be solved. Hence, as shown in Table 10, the eleven most important criteria were divided into three major categories.

Table 10. Grouping of top-ranked subfactors.

Specifications	Subfactors
Technical specifications (26.3%)	Methods and design principles (11.3%) Location to be waterproofed (3.7%) Weather condition (4%) Testing requirement (7.3%)
Construction specification (18.2%)	Waterproofer's past performance (5.9%) Requirement of special skills (5.7%) Capability of waterproofing contractor (3.5%) Reputation of waterproofer (3.1%)
Product specifications (15.6%)	Direct cost (6.1%) Useful life of material (5.2%) Quality of material (4.3%)

As a result, it is advised to consider the aforementioned three aspects when selecting a waterproofing option. Consequently, an ideal solution would be attained by promoting a long-lasting waterproofing solution. If there is insufficient knowledge in the aforementioned three areas, additional professional consultation is advised. It can be recommended that planning, controlling, and monitoring by a professional with expertise in the field, together with the waterproofing process, are crucial elements and should never be overlooked for success. Figure 6 illustrates the visual representation of the decision-making framework developed using the above findings.

According to the framework developed using the findings of this research, 60% of the waterproofing problem will be addressed by considering technical specifications, construction specifications, and product specifications. The best waterproofing solution can be obtained by considering the primary three aspects along with the other factors. As shown in the above figure, the technical specification is the most significant factor.

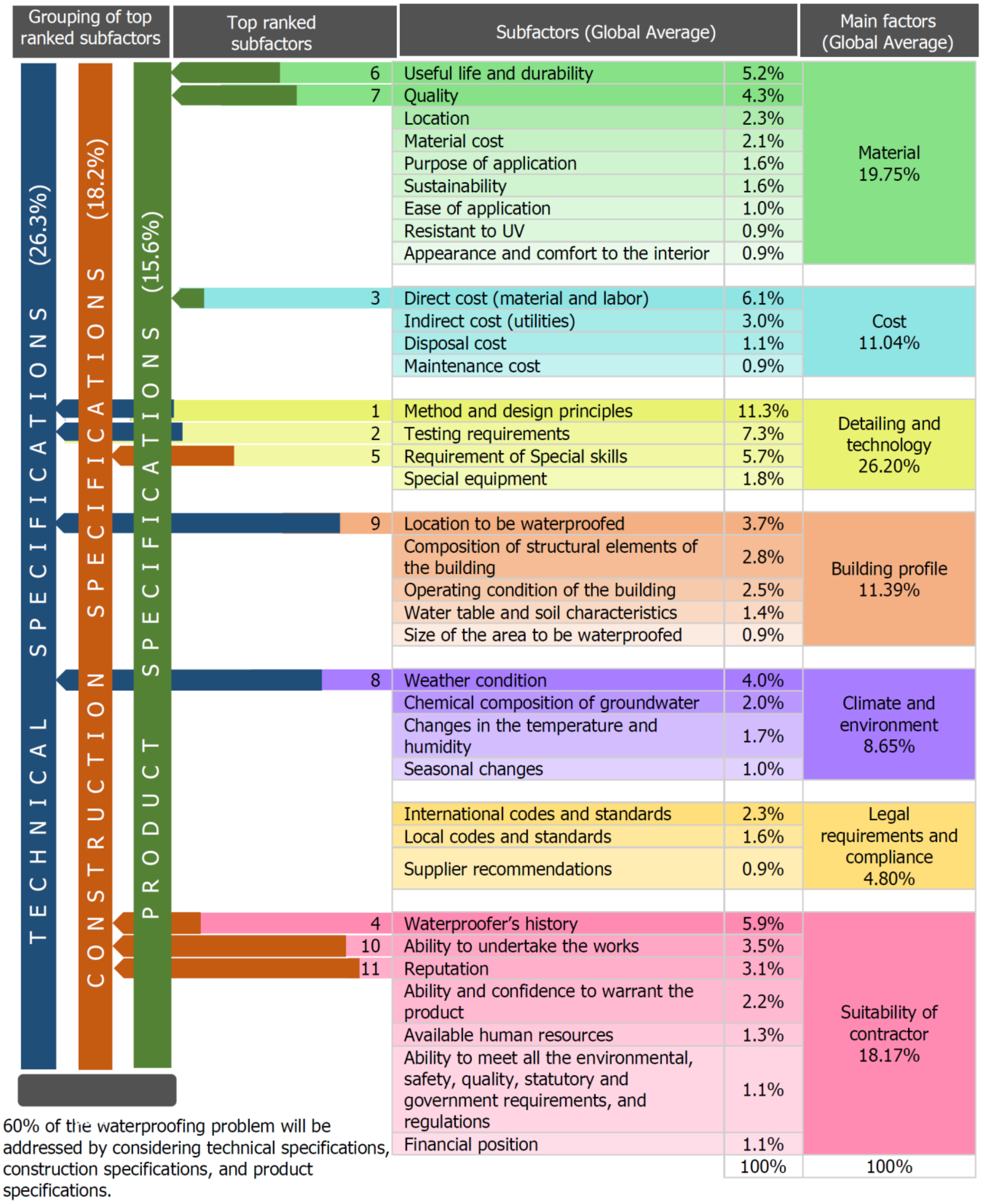


Figure 6. Visual representation of decision-making framework.

4.9. Usage of Decision-Making Framework

This study has demonstrated that the developed decision-making framework can be used to approach decision-making in waterproofing. This study includes comprehensive and useful recommendations on how to decide on waterproofing as a long-term solution in addition to outlining the problems that underlie waterproofing selection. This framework can be used as a generic model for the decision-making process. Therefore, it is possible to emphasize technical specifications, construction specifications, and product specifications as the key factors that contribute to high-quality output.

The specifications, which should be checked both before and during the development process to produce a high-quality waterproofing system that complies with the particular project requirements, should include information on each component and responsibility division.

Accordingly, during the waterproof decision-making process, according to the proposed framework, the details related to the mentioned main factors should be input along with their subfactors as inputs for the decision-making process. Then, the weights given by the experts should be considered when prioritizing the inputs. Finally, this study differs from others in that it prioritizes key aspects that must be considered to generate significant savings using a straightforward framework. Because of this, the study may be a pathfinder in terms of the factors that determine waterproofing decisions at the planning or construction stages while minimizing the cost of installation, maintenance, and replacement.

4.10. Benefits of the Decision-Making Framework

As it advances, this study could prove extremely useful in guiding waterproofers and clients on the best solutions. When making suggestions, waterproofing providers frequently have their own interests and supplies in mind. While trustworthy providers can provide insightful advice, the decision-making procedure should ideally be a joint effort that considers the client's particular demands. This framework acts as a tool to help clients engage in meaningful conversations with suppliers and waterproofing specialists. It can aid clients in critically assessing the information they get, prioritizing factors that are important for their particular circumstances, and asking the correct questions. Clients can be confident they are receiving the most appropriate and cost-effective waterproofing solution for their project in this way. Suppliers may in fact build themselves into reputable and reliable providers within the sector if they regularly deliver the best and most accurate services based on the framework. Suppliers may guarantee that they continuously provide high-quality waterproofing services, minimizing the probability of errors, by aligning their services with the framework's suggestions. Suppliers may get a competitive edge in the market by building a solid reputation and track record for offering precise and successful services.

In conclusion, suppliers that adopt and incorporate the framework into their practices not only help clients get better waterproofing results but also establish themselves as recognized and trustworthy partners in the sector. Increased customer satisfaction, recurring business, and long-term success can result from this approach.

The use of BWM as an MCDM for this new field of study, which was not previously covered in the literature, adds to the originality of this research. Moreover, the suggested decision-making framework will help professionals or consultants in the industry assist users and utilize their guidance as they operate in the market and develop into powerful competitors within it. A decrease in the amount of maintenance required, preservation of the building's structural stability and aesthetic qualities through the use of the best waterproofing solution, and assurance of the occupants' safety and comfort via the avoidance of subpar waterproofing defects are some other benefits that can be gained through the use of this framework. Additionally, by reducing the wasteful use of resources by fixing waterproofing shortcomings, value for resources may be guaranteed.

However, the presented framework has been specifically designed to solve the unique difficulties offered by the tropics and their climatic circumstances since the existence of rainy and dry seasons, high temperatures, and high humidity are all characteristics of the tropics and these elements contribute to a special set of problems for construction projects, such as greater susceptibility to water penetration, moisture-related damage, and mold development. The core ideas and tactics might act as a useful foundation even if it might not be a one-size-fits-all answer for different settings. To fit the unique climatic traits found in different regions, this method may be modified and tailored.

5. Conclusions

The intended research conclusion of this study, which was to construct a decision-making framework for selecting the most suitable waterproofing solution in high-rise buildings in tropical settings, is effectively completed and summarized. As inadequate waterproofing choices were emphasized as the major problem throughout the investigation, the ultimate result was to provide a suitable remedy for it. The best way to protect a structure is to choose the right waterproofing system early in the design process, whether the property is being built from new or restored.

To analyze the expert opinions on the factors that determine the optimum waterproofing solution, BWM was used in this study. To determine the ranks for the determinant of waterproofing choice, a pairwise comparison was also conducted to prevent waterproofing selection based on the first cost. The initial phase of the BWM implementation incorporated both the most critical and the least significant factors. As a result, detailing and technology were assigned the highest significance, and legal requirements and compliance were assigned the least significance. Based on the estimated global weights during the final ranking, the top 11 subfactors were then determined. The identified top 11 subfactors that need to be considered highly in choosing the appropriate waterproofing include methods and design principles, testing requirements, direct cost, the waterproofer's past performance, the necessity of special sills, the useful life of the material, the quality of the material, weather condition, the location to be waterproofed, contractor's ability to waterproof, and the reputation of the waterproofer. Moreover, to provide a clear method for choosing waterproofing, the weighted average of the top 11 subfactors, which collectively account for 60.2%, were separated into three primary categories. As a result, based on the suggested framework, by considering technical specifications, construction specifications, and product specifications, 60% of the waterproofing issue will be resolved. In addition, it is advised to seek expert guidance if one lacks sufficient understanding in the aforementioned three areas. The developed framework recommends:

- The reference of industry practitioners who engage in waterproofing buildings and the identification of strategies for the enhancement of the quality of the building and structural stability.
- Being incorporated during the initial design and construction stages of the buildings and post-occupancy buildings which require remedial waterproofing.

It is recommended to use the framework for choosing waterproofing that is both dependable and efficient. Consequently, by using this framework, it is possible to limit the need for waterproofing replacement and refurbishment since the optimum solution will be picked. However, the study addresses high-rise building projects in the tropics, which may restrict the applicability of the outcomes to other regions with differing climatic conditions along with construction practices. Moreover, for decision-making, the study restricts itself to the Best Worst Method. BWM does not find the global optimal solution and will provide non-unique, fluctuating weights for the criteria, which may affect the decision's result. Additionally, the process by which certain judgments are made on their relevance and significance in establishing distinct ideals might be subjected to questions. Future studies would potentially contrast these results with those from other multi-criteria decision-making techniques to confirm their validity. Different MCDM techniques have unique traits that make them appropriate for certain areas of decision-making. By using the best and worst options, BWM, for instance, is useful for expressing relative significance and preferences. However, other techniques, such as the Analytic Hierarchy Process (AHP) or the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), are superior in rating options or conducting pairwise comparisons. Combining these techniques can produce a more thorough and impartial assessment.

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