

Article

AHP as a Useful Tool in the Assessment of the Technical Condition of Hydrotechnical Constructions

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Abstract: The key challenge for sustainable water management is to carry out a proper assessment of the technical condition of hydrotechnical constructions. Maintaining them in a good state is a prerequisite for ensuring the safety of objects, as well as adjacent areas. This paper compares the results of field research obtained by three methods to assess the technical condition of structures located on the Wełna River. The main objective is to determine the differences between the methods and to indicate the most important assessment elements and criteria. Moreover, it was checked if the Analytic Hierarchy Process (AHP) can be used to carry out the correct assessment of hydrotechnical construction. An assessment that will be based on the hierarchy of factors, which is not often used in other methods. The AHP was applied for the first time to assess the technical condition of hydrotechnical constructions. Based on AHP, three variants of different weights for factors, including exploitation problems and damage to construction elements, were selected. The new variants developed by the authors allow for a more accurate, multifactor assessment. The use of scales to determine the importance of individual elements contributes to the actual representation of the technical condition of the object, which is often over- or underestimated by other assessment methods. The analysis shows that the AHP method is a useful tool to support the assessment of the technical condition of hydrotechnical construction. The use of AHP as a universal assessment method will compare the technical condition of hydrotechnical constructions located all over the world.

Keywords: AHP; technical condition assessment; hydrotechnical structures; construction safety; hierarchical tree; multicriteria decision-making



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1. Introduction

Hydrotechnical constructions play a significant role in water management within a river. The most popular of them include weirs, dams, sluices, barrage, and sills. These facilities have many different functions, which include damming water on the river, regulating the flow, increasing retention, facilitating river transport, and ensuring the safety of adjacent areas by protecting them against flooding. Weirs are also used in the construction of hydroelectric power stations, for which they constitute an effective barrier against pollution flowing down the river from the catchment area. This problem is particularly noticeable in mountain areas, where there are strong streams of mud and stones, which can damage hydromechanical equipment [1]. In such cases, Tyrolean weirs are often used [2]. However, it should be remembered that the construction of artificial river dams is also connected with several negative consequences for the natural environment, such as: Hindering the migration of fish, loss of the natural character of the river, destruction of habitats, changing environmental flows, and reduction of the diversity of the bottom and shoreline [3–7]. The construction of weirs also affects the flow rate, transport of substances, and changes in the chemical quality of water [8,9]. Currently, the aim is to reduce the negative effects of the structures by using natural materials (stones, gabions,

wood, turf) to build the weirs, making compensatory plantings, and ensuring the continuity of fish migration by creating passes with appropriate parameters [10–12]. Furthermore, mathematical models and computer programs are increasingly used to manage the weir more effectively and to determine its impact on water quality or fish migration [13–15].

The technical condition of the water structure is also a factor influencing the environment. Maintaining the structure in good condition is an extremely important aspect. It ensures the safety of the areas adjacent to the hydrotechnical facility. Keeping the structure in good condition also eliminates the risk of ecological disaster and river pollution. Many of the current hydrotechnical structures are already old and exceed the planned lifetime. Often, in cases of visible damage to the structure or its modifications, it is necessary to dimension the structure statically again and calculate the required stability [16,17]. To effectively detect damage, it is extremely important to regularly assess the technical condition of hydrotechnical objects. It is essential for the proper functioning of the structure. Methods developed by scientists to conduct technical condition assessment using visual analysis and field measurements and the latest technologies, i.e., laser scanning [18], are tools that significantly improve the work of specialists in the hydrotechnical industry [19].

Nowadays, when assessing the technical condition of hydrotechnical constructions, nobody wonders whether the selected elements and factors influencing the final assessment are correct. Many people simply adopt top-down criteria. In the long term, a lack of such considerations may result in incorrect condition assessment. Often, a final result that omits significant elements may not fully reflect the current state of construction. Scientific research has shown that there are numerous tools to facilitate the decision-making process and to give value to individual factors. Such tools include the Multi-Criteria Decision-Analysis (MCDA). The best-known MCDA methods are Analytic Hierarchy Process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), Elimination Et Choix Traduisant la Réalité (ELECTRE), and Visekriterijumska Optimizacija I Kompromisno Resenje (VIKOR) [20]. There is a wide range of different Multi-Criteria Decision Analysis applications in the literature. Despite this, researchers believe that none of them can be regarded as a ‘superior method’ suitable for all decision-making situations [21]. The AHP is one of the analytical hierarchy methods, including its generalization, the Analytic Network Process (ANP). The ANP method, like AHP, has found wide application in science [22–25]. A review article of publications on MCDA methods from 1980 to 2012 shows that AHP is the second most commonly used method. Only combined methods are used more often [26]. An analysis of publications in later years (1994–2014) demonstrated that AHP is the third most frequently-used decision-maker technique [27]. Many applications of the AHP method suggest that it is appropriate for solving problems in many different areas. Moreover, hierarchization in AHP has been identified to be consistent with that in WSM, WPM, TOPSIS [28]. This indicates the reliability of the results obtained by this method. Based on a comparative analysis of AHP, ELECTRE, TOPSIS, and MACBE methods, it was concluded that AHP is the best solution, however, under strict conditions. The research problem must meet the following assumptions: The use of a maximum of nine alternatives, the independence of the alternatives and criteria, and the availability of time for decision-making [29]. Another advantage of AHP is that it enables both qualitative and quantitative variables to be evaluated [30]. Moreover, the use of the Analytic Hierarchy Process allows for great flexibility in creating a hierarchical tree. This flexibility enables to include many factors grouped at different levels of the tree [31]. The AHP method solves complex problems more easily by analyzing pairs under problems [32]. The above arguments indicate that using AHP is the right way to solve a complex problem. Moreover, the results obtained are highly reliable because the method is based on mathematical calculations.

Moreover, the Analytic Hierarchy Process is a method used in many different areas. This applies to agricultural sciences, economics, natural sciences, engineering, and technology, as well as social sciences. This is confirmed by numerous research publications and extensive review [33–41]. AHP has also found wide applications in building con-

struction. An analysis carried out for articles from 2004–2014 with only eight selected high-quality journals showed that there are as many as 77 publications on AHP applications in construction. The most popular topics were risk management and sustainable construction [42]. Moreover, another review of construction publications showed that the most popular multicriteria decision-making method in application to buildings and structures was AHP. In terms of the amount of use in articles, AHP was significantly ahead of methods, such as ANP, COPRAS, DEA, DRSA, ELECTRE, PROMETHEE, TOPSIS, and many others [43]. The above arguments show that AHP is widely used in various construction-related problems. It has been proven, among other things, that this method can be used to determine the weighting of safety factors on construction sites with tower cranes [44]. Furthermore, it has been applied to the evaluation of double skin facades, building fire safety management, and safety risk assessment for planning and budgeting of construction projects [45–47]. Moreover, the AHP-Gray model was successfully used to evaluate the safety of construction [48]. The above review clearly shows the potential of using the AHP method to assess the technical condition of hydraulic structures.

The authors of this research paper have carried out analyses of currently used methods of visual assessment of the technical condition of hydrotechnical constructions. The main objective was to determine the differences between the methods and to indicate the most important assessment criteria. Moreover, the authors proposed a new methodology based on relevant criteria, which will assess the technical condition more precisely, while considering the damage to elements and operational problems of the object. It is hypothesized that the AHP method can be used to create a hierarchy of the importance of factors and elements in assessing the technical condition of hydrotechnical constructions. The assessment of technical conditions, using the AHP method, will be based on the hierarchy of factors, which is often overlooked in other methods. Using the AHP method, it is possible to give appropriate weights for individual construction elements. It was assumed that this could make the final result of the condition assessment more reliable and precise.

2. Materials and Methods

The field research to assess the technical condition of the hydrotechnical constructions was carried out on the section of the Wełna River from Oborniki (the mouth of the river to Warta) to Rogoźno. This is the most natural and least transformed part of that river (especially the section from Rogoźno to Jaracz). The scientists emphasize the need to maintain its good ecological condition [49]. Wełna River is classified as a lowland river and is located on the territory of Wielkopolska Voivodeship in Poland. Its sources are located on a lake area 10 km north-east of Gniezno, and the total length of this river is 118 km [50]. The area of the Wełna catchment area reaches 2621.1 km², while the average surface runoff from its area is 4.08 dm³·s⁻¹·km⁻². On the analyzed section of the river, eight constructions were evaluated: Seven weirs and one sill. The location of each object is presented on the map (Figure 1). The assessment of the technical condition was carried out using three different methods: Kaca and Interewicz, Zawadzki, and Michalec.

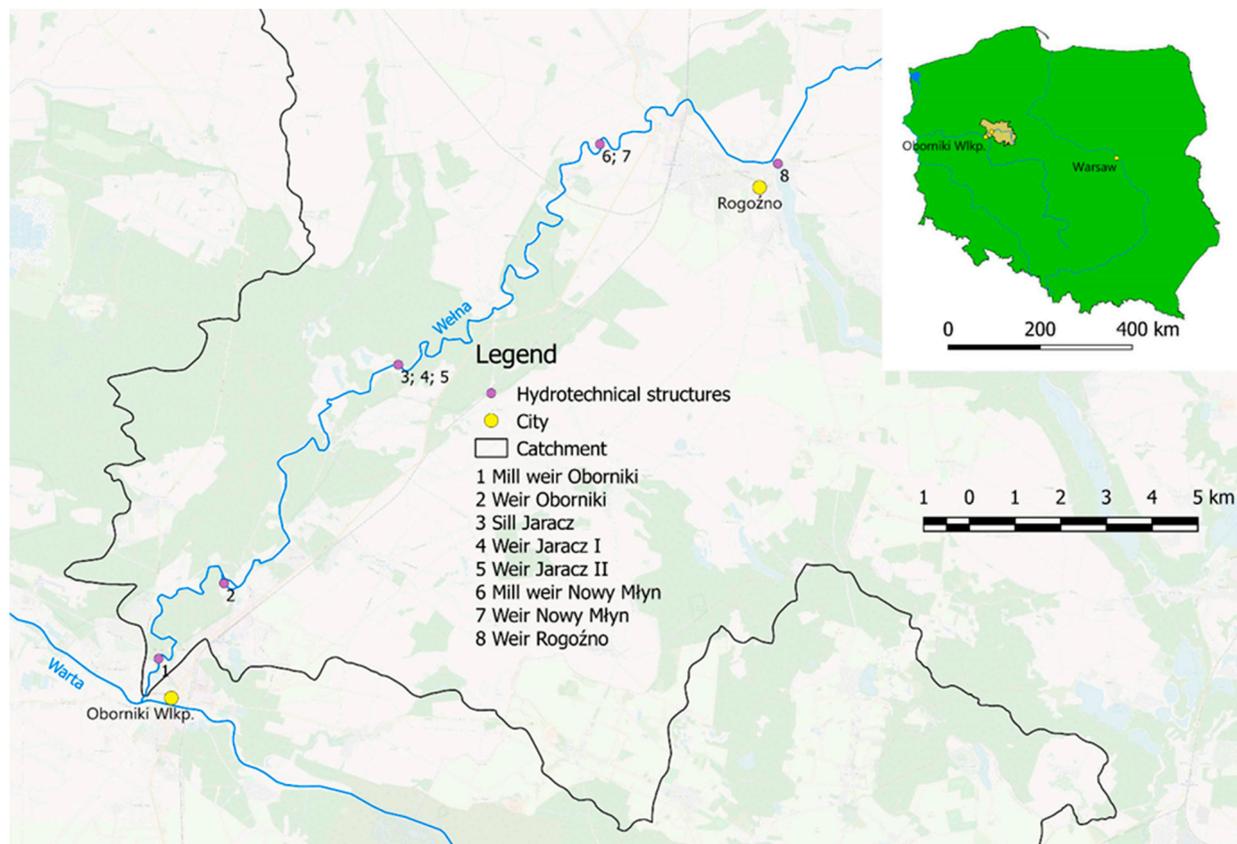


Figure 1. Location of hydropower objects on the Welna River that were assessed.

Water structures on the Welna River were evaluated using the method proposed by Zawadzki [51]. The 16 assessed elements were classified into three groups (solid elements, movable elements, monitoring, and measurement devices) presented in Table 1. Solid elements included abutments, pillars, footbridge, downstream, and upstream apron. Each element has been assessed for the intensity of the adverse processes: Losses, cracks, reinforcement exposing, dripstones and leakages, discolorations, lichens, surface (condition). After assessing the state of an element, it shall be assigned one of the following assessments: 5—very good state (no adverse processes); 4—good state, 3—satisfactory state, 2—unsatisfactory state, 1—bad state (very high intensity of adverse processes). The movable elements were evaluated: Gates, lifting mechanism, deformations, corrosion, conservation. The level of efficiency of individual elements was assessed by assigning numerical values. A rating of 5 (very good state) is given when all lifting mechanisms are operational and regularly maintained. Moreover, proper maintenance of the lifting mechanism is required. Moreover, the correct operation of the gates is carried out, and there is no corrosion on any of the components. In the case of rating 4 (very good state), the lifting mechanisms are in working order, but their appearance is not ideal. Maintenance is carried out regularly, but not thoroughly. The operation of the gates is inaccurate, and there is slight corrosion (in one place). The rating 3 (satisfactory state) is assigned when the lifting mechanisms are faulty, and maintenance is not carried out regularly. Imprecise operation of the gates together with visible corrosion cause no water damming. A rating of 2 (unsatisfactory state) is awarded when the lifting mechanisms are severely damaged, and maintenance is carried out episodically and carelessly. Improper care of the gates has led to their severe damage. This, together with the strong corrosion of the steel elements, makes it completely impossible for water damming. The lowest grade 1 (bad state) is given when there is a lack of lifting mechanisms and maintenance has been completely abandoned. The exploitation of gates has been stopped due to their absence. The flow and damming of water are completely out of control. Corrosion is strongly developed on steel elements. The

third group of monitoring and measurement devices includes benchmarks, piezometers, water-level gauges, information boards. The rating 5 (very good state) is awarded when the object is equipped with a set of devices: Benchmarks, piezometers, water-level gauges, information boards. Moreover, all these elements are efficient, well maintained, legible, and well visible. A rating of 4 (good state) is given when the equipment is not regularly checked and maintained. A rating of 3 (satisfactory state) is assigned for equipment with minor damage, due to improper maintenance. The rating 2 (unsatisfactory state) is given for heavily damaged equipment. The lowest rating of 1 (bad state) is assigned in the absence of an element. The total score of the structure was the arithmetic mean of all 16 components. Such an evaluation is relatively easy and quick to perform and does not require specialized equipment, and is not invasive to the object.

The second method that was used to assess the technical condition was the Michalec method [52]. Michalec noticed that even new water structures without repetitions, piezometers, or information boards have a much lower rating than the actual technical condition indicates. The author proposed to introduce modifications in the form of scales for individual elements to be assessed. For solid and movable elements, he assigned a weight equal to 1.0; for benchmarks, piezometers, water-level gauges in control, and measuring devices, he assigned a weight of 0.25 and removed information boards from the assessment by giving a weight of 0.0. The score in Michalec method is calculated based on the weighted average considering the above-mentioned weights and all the elements assessed using the Zawadzki method [51].

Table 1. The assessment of the technical state of the weirs.

Elements of Construction	Weight Value	
	Zawadzki Method	Michalec Method
A. Solid elements: (abutments, pillars, footbridge, downstream, and upstream apron)		
Surface		
Cracks	1.0	1.0
Losses		
Reinforcement exposing		
Dripstones and leakages		
Discolorations		
Lichens		
B. Movable elements:		
Gates		
Lifting mechanism		
Deformations	1.0	1.0
Corrosion		
Conservation		
C. Monitoring and measurement devices:		
Benchmarks	1.0	0.25
Piezometers		
Water-level gauges		
Information boards	1.0	0.0

The hydrotechnical construction on the Wełna River was also evaluated using the Kaca and Interewicz method [53]. It is commonly used on drainage objects, such as subirrigation and drainage systems, where it is used mainly to assess the parameters of ditches, valves, and culverts [54]. It has also been shown that it can be successfully used to assess the technical condition of small structures on watercourses and little retention facilities in forest districts [55,56]. The authors of this publication have attempted to implement this method on larger constructions of the Wełna River (weirs and sills). To be able to compare the results obtained by this method with other studies conducted by the authors, the paper

uses a modification of the Kaca and Interewicz method [53]. A two-stage classification of the suitability and efficiency of individual construction elements was abandoned in favor of assessing their condition using a description: good, satisfactory, unsatisfactory. The modification of this method has already been used before studying the technical condition of hydrotechnical objects [55,56]. To compare the results with the Zawadzki method, the descriptions were given the following points: good condition = 5, satisfactory condition = 3, unsatisfactory condition = 1 [51]. The following elements of individual objects were evaluated: Building abutments, abutment backfill, lifting mechanism, sluice, sluice guide, impervious apron, downstream and upstream apron, building signposting, anti-corrosion protection, start-up protection, footbridge on the valve, and sealing. Detailed assessment criteria are presented in Table 2. Based on assessments of individual elements, the average value corresponding to the state of the entire construction was calculated.

Table 2. Criteria for assessment of technical condition in the modified the Kaca and Interewicz method.

Elements of Assessment	The Condition of the Element and Its Value		
	Good Condition (5)	Satisfactory Condition (3)	Unsatisfactory Condition (1)
Abutments	No cracks	Slight cracks	Deep cracks
Abutment backfill	Vertical position correct	Vertical arrangement with lowering of the terrain behind the abutments, 10–20 cm	Clearly tilted with a lowering of the ground behind the abutments >20 cm
Lifting mechanism	Complete, functional	Incomplete, faulty	Damaged or missing
Sluice	Complete, operational	Start-up difficult, corroded	Blocked, holes, or missing
Sluice guide	Functional, tight	Uneven at the contact with the valve	Damaged or missing
Impervious apron	Equal	On contact with sluice uneven, stamped	Damaged, loss of concrete >10 dm ³
Upstream apron	Damaged < 10% of the area	Damaged 10–20% of the surface	Damaged >20% of the surface
Downstream apron	Damaged <10% of the area	Damaged 10–20% of the surface	Damaged >20% of the surface
Building signposting	Full, clear	Incomplete (e.g., no building number)	Missing
Corrosion protection	Full	Incomplete	Missing
Start-up protection	Sufficient	Insufficient	Missing
Footbridge	Efficient	Damaged	Missing
Sealing	Good	Broken	Missing

To present the methodology in a clearer and more precise way, a diagram of the individual research stages is included (Figure 2). After field measurements were carried out, analyses of the obtained results were performed. Advantages and disadvantages of particular methods were determined, and then an attempt was made to apply the AHP method to determine the technical condition of the construction. The AHP (Hierarchy Process Analysis) was also used to determine the importance of individual elements of the hydrotechnical construction. This method enables the analysis of many factors (parameters) describing the technical condition of hydrotechnical structures.

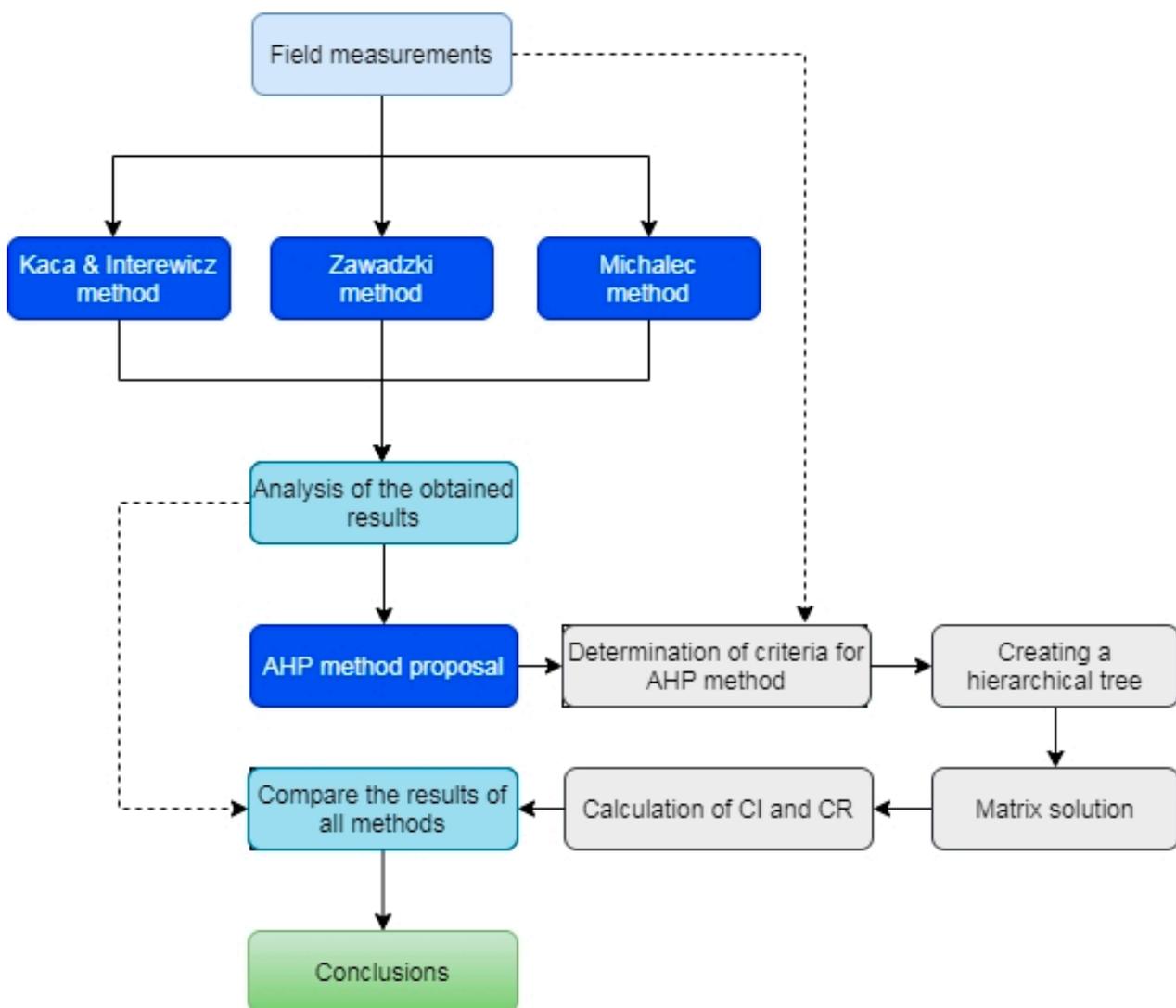


Figure 2. Research work scheme.

The analyses with the use of the multicriteria decision-making support method started with the formulation of the problem and the creation of a hierarchical tree on which the factors describing the examined problem are located at levels II and III. On the last level, there are individual elements of water structures, which, according to the authors of the article, are the most important for safety reasons. The parameters describing the technical condition are divided into two groups. The first of them was exploitation parameters, and the second one damage to construction elements (level II). A detailed description of individual factors is presented in Level III (Figure 3). The following factors are highlighted: Maintaining the water damming level, erosion under the foundation, hydraulic fracturing, lichens, corrosion, losses and cracks, deformations, dripstone and discolorations, erosion material. The main task of weirs and dams is to safely and reliably maintain the water damming level. This main criterion is one of the most important for the efficiency of the weir. Moreover, the ability to regulate the water level properly is extremely important for flood safety [57]. Therefore, the maintaining of the water damming level was considered to be an important factor that should be placed on the third level of the hierarchical tree. Furthermore, the element directly affecting the stability of the structure is the erosion under the foundations, which was also placed on the hierarchical tree. Excessive erosion can lead to foundation failure and construction disaster. It has also been shown that foundation failure is one of the basic errors in designing weirs [58]. Another unstable factor is lichen.

Recent studies indicate that the impact of biogenic deterioration on the structure of concrete structures should also be taken into account when assessing the condition of hydrotechnical constructions [59]. Concrete is also associated with two further factors—corrosion, losses, and cracks. Their existence is an unavoidable effect of concrete carbonation. When the concrete comes into contact with the atmosphere and water, undesirable chemical reactions occur, leading to concrete weakening. These reactions result in losses and cracks. Large losses and cracks can lead to a weir disaster [60]. Erosion material and hydraulic fracturing were chosen as the next two factors of the third level of the hierarchical tree. It is well known that the prevention of erosion material below the weir is extremely important in terms of reducing the risk of damage to the structure. Neglecting this aspect can lead to a loss of soil stability. Moreover, it facilitates and accelerates hydraulic fracturing. This can cause damage or even destruction of the construction [61]. Deformations are included as another factor in the hierarchical tree. Scientific research indicates the need to monitor the geometry of weirs with emphasis on deformations. This is very important for its proper functioning [62]. The last factor considered at level III is dripstone and discoloration, which are usually closely related to the emergence of efflorescence. The efflorescence is the visual result of the concrete's reaction to moisture, and consequently, salt build-up. Their occurrence may be due to the migration of water through the concrete structure [63]. In the case of dams and other hydrotechnical structures, the migration of water in the wrong place is not a desirable phenomenon. On the other hand, level IV describes individual elements of the structure, which were analyzed in terms of the importance of their assessment. Elements, such as abutments, gates, downstream apron, pillars, and lifting mechanism, have been selected. These are the main components of the hydrotechnical constructions.

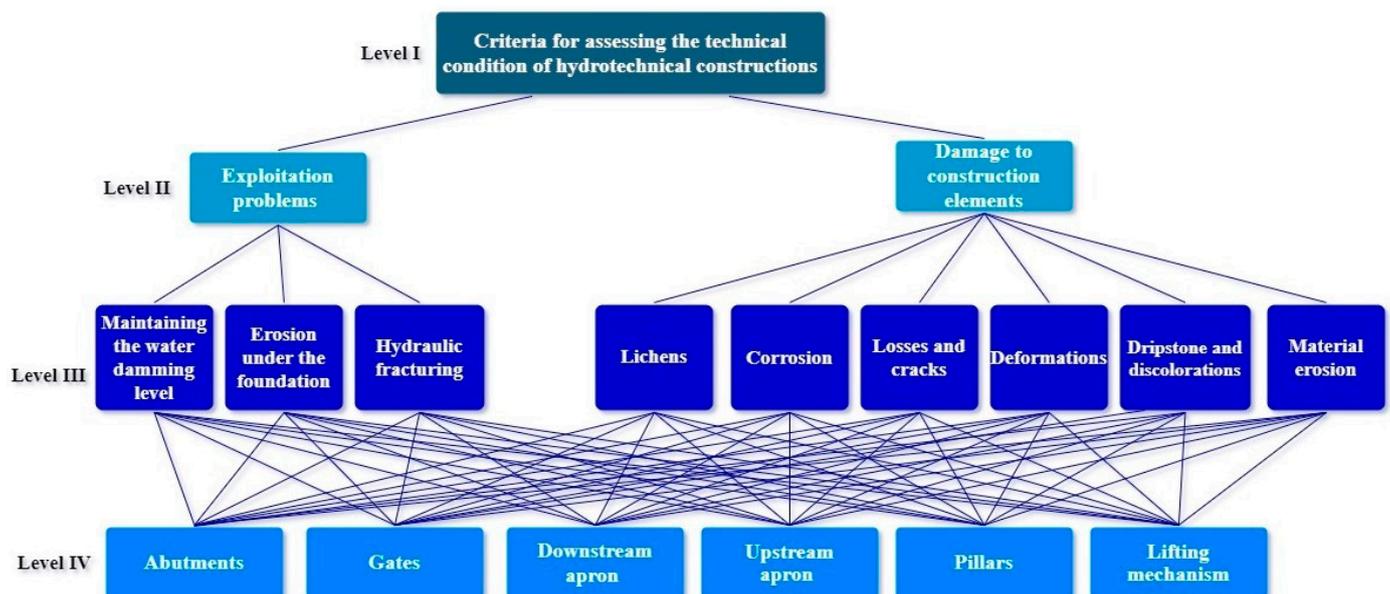


Figure 3. The hierarchical tree of factors that influence the assessment of the technical condition of the most important elements of a water structure.

Based on the hierarchical tree, matrices were created, which were complemented by the obtained results of comparisons of the importance pairs of individual factors and particular elements of the hydrotechnical construction according to the Saaty scale (Figure 4) [64,65]. The scale values equal to 1 indicate equal importance, 3 a slight advantage of one factor over another, 5 a clear advantage between factors, 7 a very clear advantage, and 9 an absolute advantage [66,67].

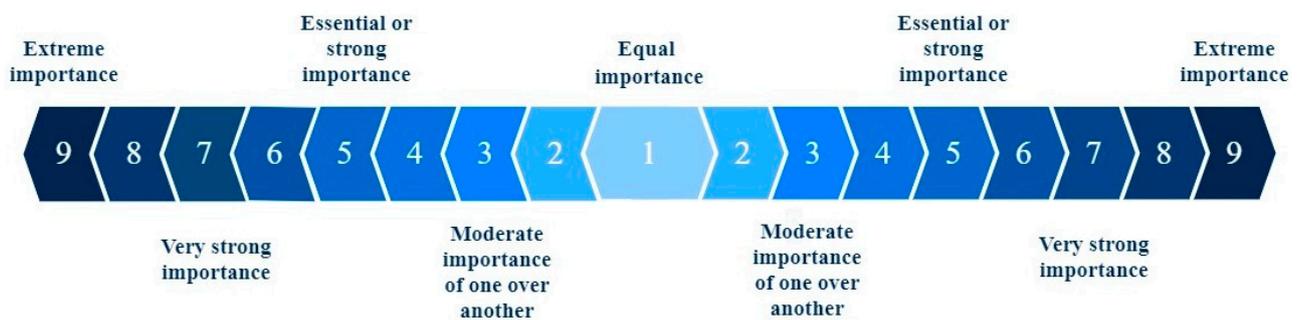


Figure 4. The Saaty weighting scale is used to compare different factors and solutions.

Comparison by pairs of all assessment criteria, and sub-criteria, made it possible to create an $A = [a_{ij}]$ matrix, with $n \times n$ dimensions, in which $n(n - 1)/2$ comparisons were made (Equation (1)) [68].

$$A = \begin{bmatrix} 1 & a_{1,2} & \dots & a_{1,n} \\ 1/a_{1,2} & 1 & \dots & a_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1,n} & 1/a_{2,n} & \dots & 1 \end{bmatrix} \quad (1)$$

where:

a —weight of argument (factor);

n —dimension of the matrix.

The next step in the AHP method is to solve the matrices, which are based on a hierarchical tree. For level two, one matrix is solved. For level three, as many matrices are solved as there are factors in level two. Then, at level four, a single matrix is solved in which the solutions are compared as many times as there are factors at level three. To check the correctness of the matrix computation following the commonly used methodology, the value of the maximum eigen value (λ_{\max}), and the Consistency Index (CI), Random Index (RI), Consistency Ratio (CR) were used [69–71]. The more an average deviates from the dimension of the n -weighted matrix, the greater the error is made. The logical consequence principle is used to calculate the CI. The natural measure of inconsistency or deviation from consistency, called consistency index (CI), is defined as Equation (2).

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (2)$$

where:

λ_{\max} —maximum eigen value

n —dimension of the matrix

To calculate the CR, the value obtained by dividing the value of CI by RI was used. Random Index is dependent on the matrix dimension [28]. The appropriate Random Index values determined by Saaty are shown in Table 3. The obtained indicator (CR) checks the strength of the relationship between the elements being compared. The calculated CR values should not be greater than 0.1 [30]. The solutions of the matrices are local vectors, based on which global vectors have been calculated at individual hierarchical tree levels. Using solutions of individual matrices from the fourth level, weights of individual elements of the hydrotechnical structure were determined.

Table 3. Random Index values depending on matrix size [65].

Matrix Size	1	2	3	4	5	6	7	8	9	10
Random Index (RI)	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

The calculation of the global weights for the entire hierarchical tree was performed three times, resulting in three variants to consider. In variant I, according to the experts, the damage to construction elements is more important than the exploitation problems. However, to check the influence of changes in the importance of level II factors of the tree on the obtained weights of building elements (level IV), other variants were analyzed. In variant I, it was assumed that the weight for exploitation parameters was 0.11, and the damage of construction elements was 0.89. The obtained weights in variant I result directly from the expert evaluation of the matrix calculations made by the authors of the AHP method. In variant II, the assumed weights were taken in the opposite way (construction damage of 0.11, exploitation parameters 0.89). In variant III, on the second level, equal importance (0.50) of both analyzed factors was assumed.

3. Results

Field research was conducted on eight objects. The analyses made it possible to determine the technical condition of individual hydrotechnical constructions. First, the analysis of the technical condition of the object was presented using various methods, then the weights were determined for selected elements of the object, which were considered the most important by the authors of the article. The assessment of the technical condition was carried out using the methods of Zawadzki, Michalec, Kaca and Interewicz [51–53]. Based on the field research, the technical condition of eight objects was assessed. The methodology of the assessment was presented on the example of one object in Jaracz. The field tests for the remaining buildings were carried out similarly. For detailed analysis, weir II in Jaracz (Figure 5a,b) was chosen.



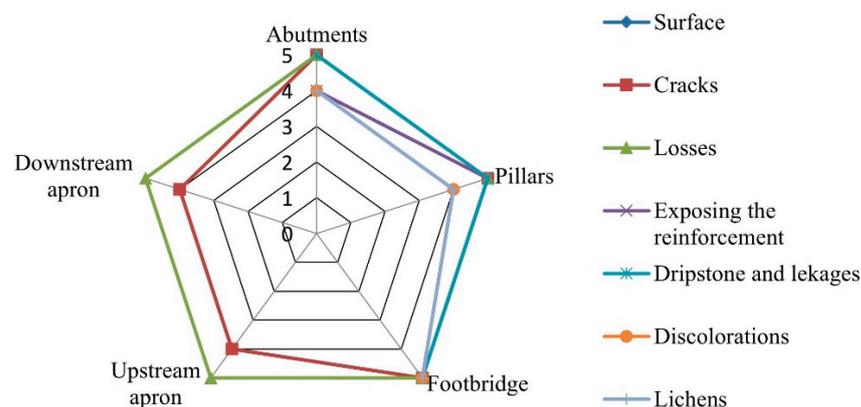
Figure 5. Photos of Weir II Jaracz (a) upstream view; (b) downstream view.

As part of the field research, a large difference in levels was observed between the end of the impervious apron and the bottom reinforcement. The visible footbridge is in very good technical condition, as is the upstream apron. Table 4 summarizes the ratings obtained based on the Zawadzki method.

Table 4. Evaluation of the solid elements of the weir II Jaracz obtained using the Zawadzki method.

Elements of Assessment	Assessment				
	Abutments	Pillars	Footbridge	Upstream Apron	Downstream Apron
Surface	4	3	4	3	4
Cracks	4	4	5	4	5
Losses	3	2	4	5	3
Uncover of reinforced rods	3	5	5	5	
Dripstone and leakages	5	5		5	
Discolorations	4	4		4	
Lichens	4	3	4	4	1

The obtained ratings for the pillars are caused by surface damage that occurred during the exploitation of the construction. In Figure 5, it is possible to observe losses on the weir pillars visible above the water table. Minor cracks and discoloration of the concrete of the pillar walls were also noticed. This resulted in a relatively low assessment of the element. (Table 4). Based on a local inspection, the reinforcement exposing of the abutments of the weir was also found in several places. Figure 6 presents graphically assessing the technical condition of the solid elements (abutments, pillars, footbridge, upstream, and downstream aprons) of the discussed weir. Each of the elements was evaluated in terms of seven factors: surface, losses, cracks, reinforcement exposing, dripstones and discolorations, lichens.

**Figure 6.** Values of technical condition assessment of each element of the weir Jaracz II according to the Zawadzki method.

The radar chart indicated that the pillars are in the worst technical condition because the surface, losses, and discolorations received low marks according to the scale proposed by Zawadzki. Analyzing individual construction elements, the lowest ratings were obtained for factors, such as losses and lichens. In addition to solid elements on weirs, moving elements and control and measuring devices can be distinguished. The values of the technical condition of the other elements received from the Zawadzki method are presented in Table 5.

Table 5. Summary of the marks of movable elements and control and measuring devices of weir Jaracz II obtained using the Zawadzki method.

Movable Elements:	Assessment	Control-Measuring Devices	Assessment
Gates	5	Benchmarks	1
Lifting mechanism	2	Piezometers	1
Deformations	5	Water-level gauges	5
Corrosion	5	Information boards	5
Conservation	3		

No piezometers or benchmarks have been installed in the weir II, which makes it impossible to check the displacement of the hydrotechnical structure and the levels of the water table in the dam. The movable elements were in a very good technical condition, but the lifting devices and railings require a little maintenance.

After the Zawadzki method of assessment, the authors of this research study analyzed the condition of the building using the assumptions of Kaca and Interewicz. The obtained results are presented in Table 6.

Table 6. Ratings of movable elements and control and measuring devices of the weir Jaracz II obtained using the Kaca and Interewicz method.

Assessment Elements	Assessment	Assessment Value
Abutments	No cracks	5
Abutment backfill	Vertical position correct	5
Lifting mechanism	Damaged or missing	1
Sluice	Complete, operational	5
Sluice guide	Functional, tight	5
Impervious apron	Equal	5
Upstream apron	Destroyed 10–20%	3
Downstream apron	Destroyed <10%	5
Building signposting	Full, clear	5
Corrosion protection	Full, clear	5
Start-up protection	Sufficient	5
Footbridge	Efficient	5
Sealing	Good	5

This method indicates that the hoisting equipment was in the worst condition, and the upstream apron was rated low. They are buckling and heavily cracked. The technical condition of the other elements of the water level was described as very good.

Table 7 presents the technical condition assessments obtained by various methods for the key elements of weir Jaracz II. The comparison made it possible to determine the difference between the methods. The key elements were selected for the compilation, which was then used in multicriteria decision-making (AHP) analyses.

Table 7. Summary of technical condition assessments determined by various methods for key elements of weir Jaracz II.

Elements	Zawadzki Method	Kaca and Interewicz Method	Michalec Method
Abutments	3.86	5.00	3.86
Pillars	3.71	5.00	3.71
Lifting mechanism	3.75	3.67	3.75
Gates	5.00	5.00	5.00
Downstream apron	3.25	5.00	3.25
Upstream apron	4.29	3.00	4.29
Control-measuring devices	3.00	5.00	1.75
Footbridge	4.40	5.00	4.40

The analysis of the results shows that according to the Zawadzki and Michalec method, the control and measurement equipment and the downstream apron are in the worst condition. According to the Kaca and Interewicz method, the upstream apron is in the worst condition.

The summarized results of the technical condition assessment received by the method of Kaca and Interewicz, Zawadzki, and Michalec [51–53] for all analyzed constructions are presented in Table 8. The differences in the final assessment of the structure between the method of Zawadzki and Michalec are small and usually do not differ more than

0.2 from each other. The biggest differences between the two methods were observed during the evaluation of weir II in Jaracz. The significant difference in ratings is due to the lack of grades for the upstream apron and the footbridge. The final grade, which is an average of a much smaller number of components, is more susceptible to change the weight of individual elements. The change of sign of the assessment of control and measuring devices strongly alters the resultant assessment. A similar situation can be observed in the example of sill in Jaracz. This structure stands out strongly from the other objects. Due to its purpose and the way of working, it has no pillars or footbridges, or movable elements connected with the gates. The set of control and measuring devices, excluding piezometers, significantly improves the final rating understated by the fatal state of the upstream apron. Lowering the weighting in the Michalec method for control and measuring devices, in this case, results in the opposite situation than on other structures, which is decreasing the final grade. A frequent lack of control and measuring devices in almost all cases results in a decrease in Zawadzki grade concerning the Michalec method.

Table 8. Summary of the results of technical condition assessments carried out using the methods of Kaca and Interewicz, Zawadzki, and Michalec.

Object Number	Object Name	Object Coordinates in EPSG2180	The Results of the Assessment of the Technical Condition of the Individual Methods		
			Kaca and Interewicz	Zawadzki	Michalec
1	Mill weir Oborniki	351,882.80; 534,109.60	4.85	4.56	4.66
2	Weir Oborniki	353,313.79; 535,766.27	2.85	2.98	3.15
3	Sill Jaracz	357,134.33; 540,598.95	3.00	2.87	2.77
4	Weir Jaracz I	357,109.00; 540,648.80	4.54	3.85	3.91
5	Weir Jaracz II	357,030.00; 540,674.00	3.38	3.51	3.77
6	Mill weir Nowy Młyn	361,492.90; 545,388.70	1.62	2.64	2.86
7	Weir Nowy Młyn	361,534.79; 545,439.10	1.62	2.14	2.22
8	Weir Rogoźno	365,436.60; 545,025.10	4.69	4.42	4.68

The final marks from the Kaca and Interewicz method differ strongly from the other marks. In an extreme case, they reach even 1.24 compared to Michalec grade for Mill Weir in Nowy Młyn. This is due to the characteristics of the way of evaluating individual elements. In the Zawadzki method and its modification by Michalec, a deliberate lack of elements, due to the design and character of the object results in a lack of assessment value and a change in the number of elements taken to determine the overall technical condition of the structure. Kaca and Interewicz clearly state that the lack of a given element causes the lowest rating to be assigned. Table 8 presents the final results of the technical condition assessment for each hydrotechnical construction. There are three results for each object (one of the Kaca and Interewicz method, one of the Zawadzki method, and one of the Michalec method).

The constructions which were awarded the highest marks are mill weir in Oborniki and weir Rogoźno. The biggest influence on this was the recent renovations in Rogoźno and the reconstruction in Oborniki. The object which has the lowest score in all three methods is weir Nowy Młyn. The impervious apron of the construction is heavily damaged (halved). Moreover, the lack of a downstream apron caused washing out of the building, threatening the stability and safety of its functioning.

The obtained results prompted the authors to re-examine the assessments of structures and to try to propose a different way of assessing, which will take into account the elements directly evidencing the safety of the object. For this purpose, the analysis was carried out using the AHP method, which included three variants of accepted weights for level II of the hierarchical tree. Based on the calculations, the weights for separate elements of water structures were obtained. In variant I, a higher weight was given to damage to construction elements (0.89) than to exploitation problems (0.11). Variant II received reverse weights. On the other hand, in variant III, it was assumed that the exploitation and damage factors

have equal weights. Table 9 summarises the eigenvector and CR values for level III of the hierarchical tree.

Table 9. Eigenvector and CR values for level III of the hierarchical tree.

	Maintaining the Water Damming Level	Erosion under the Foundation	Hydraulic Fracturing	Lichens	Corrosion	Losses and Cracks	Deformations	Dripstone and Discolorations	Erosion Material
Local vector	0.082	0.368	0.550	0.030	0.142	0.267	0.225	0.047	0.289
CR value		0.074				0.028			

The analysis of the Consistency Ratio values indicates that the weights comparing the individual factors in level three were correctly chosen. The values did not exceed the specified maximum CR of 0.10. Table 10 shows the matrix solutions for level IV of the hierarchical tree.

Table 10. Eigenvector and CR values for level IV of the hierarchical tree.

		Abutments	Gates	Downstream Apron	Upstream Apron	Pillars	Lifting Mechanism
Maintaining the water damming level	Local weight CR	0.0303	0.3133	0.0399 0.0387	0.1142	0.2932	0.2092
Erosion under the foundation	Local weight CR	0.0716	0.1213	0.4572 0.0717	0.0421	0.2467	0.0611
Hydraulic fracturing	Local weight CR	0.0453	0.1296	0.2707 0.0694	0.4212	0.0718	0.0614
Lichens	Local weight CR	0.1565	0.2298	0.0549 0.0752	0.0474	0.1795	0.3320
Corrosion	Local weight CR	0.1101	0.3127	0.0498 0.0798	0.0434	0.1272	0.3568
Losses and cracks	Local weight CR	0.1324	0.3184	0.0747 0.0492	0.0585	0.1369	0.2792
Deformations	Local weight CR	0.1282	0.3531	0.0545 0.0667	0.0529	0.1554	0.2560
Dripstone and discolorations	Local weight CR	0.1010	0.3135	0.0660 0.0733	0.0680	0.2612	0.1902
Erosion material	Local weight CR	0.1578	0.0461	0.3596 0.0534	0.2762	0.1172	0.0431

Figure 7 presents the values of the global vector for level III, considering different weight variants adopted for level II of the hierarchical tree. Level III of the hierarchical tree described the factors describing damage to construction elements and exploitation problems.

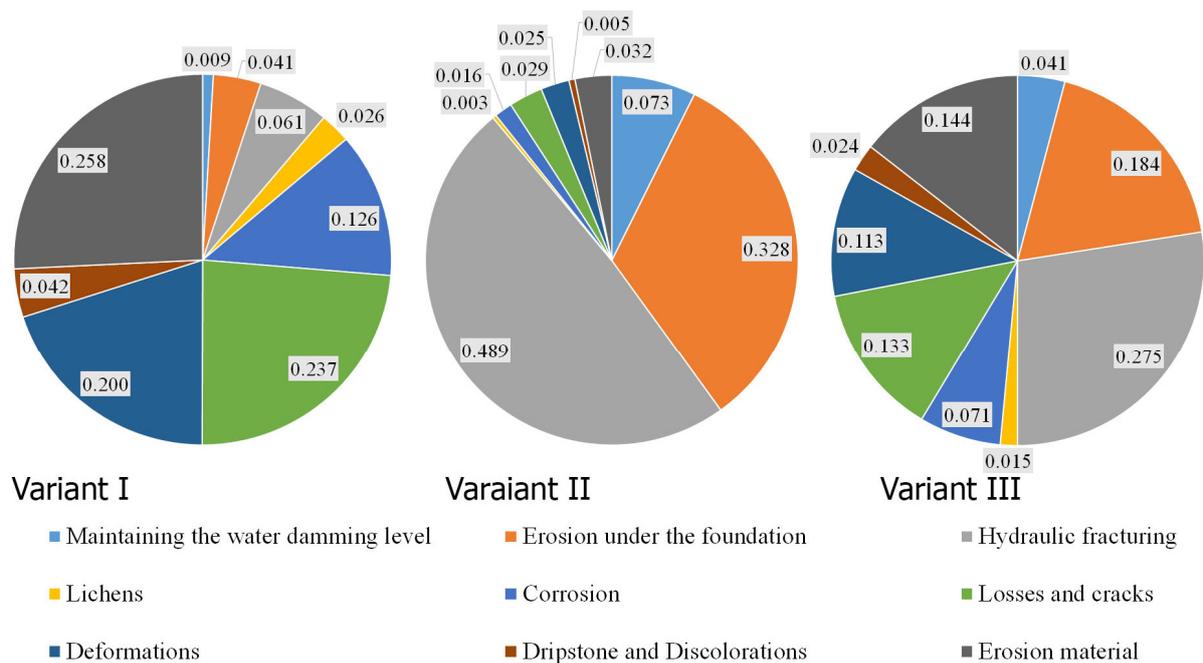


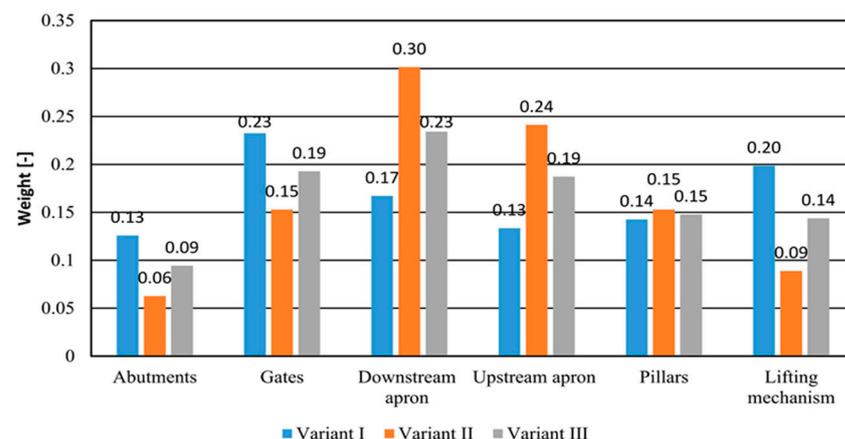
Figure 7. Distribution of the weights of level III factors in different variants of the AHP method.

Changes in the global vector values for level II caused significant differences in the results obtained at level III. For variant I (the predominance of damage factors (0.89) over exploitation (0.11)), the most important elements were material erosion (0.26) and losses and cracks (0.24). A slightly lower value was achieved for deformation (0.20). The smallest values of weights were obtained for the maintenance of the water damming level (0.01) and lichens (0.03). For variant II, in which the exploitation (0.89) had the advantage at level II of the hierarchical tree, the most important factor was the hydraulic fracturing, whose weight almost doubled to the previous variant (0.49). The second place was the erosion under the foundation, whose value also increased (0.33). For variant III, the most important factors were also hydraulic fracturing (0.27) and erosion under the foundation (0.18), and the least relevant were dripstone and discoloration (0.02) and lichens (0.01). The highest weight for hydraulic fracturing in variants II and III is due to the importance of individual factors on level III and their number on a given branch of the hierarchical tree. Using the values of weights for level III (Figure 7), the values of global weights for level IV were calculated (Table 11). Based on the analysis carried out, it can be concluded that there are large differences in the hierarchy of hydrotechnical structure elements (abutments, gates, downstream apron, upstream apron, pillars, lifting mechanism) depending on the variant.

Figure 8 presents the results of the matrix solution for the fourth level, on which there were elements of the structure considered by the authors of the article as the most important because of its safety. The figure below shows the weights by which the evaluations of individual elements of water structures were multiplied.

Table 11. Summary of global weights for level IV of the hierarchical tree.

		Maintaining the Water Damming Level	Erosion under the Foundation	Hydraulic Fracturing	Lichens	Corrosion	Losses and Cracks	Deformations	Dripstone and Discolorations	Erosion Material	Sum
Variant I	Abutments	0.0012	0.0132	0.0125	0.0023	0.0078	0.0177	0.0144	0.0024	0.0228	0.0943
	Gates	0.0129	0.0223	0.0356	0.0034	0.0222	0.0425	0.0397	0.0074	0.0066	0.1927
	Downstream apron	0.0016	0.0841	0.0744	0.0008	0.0035	0.0100	0.0061	0.0016	0.0519	0.2341
	Upstream apron	0.0047	0.0077	0.1158	0.0007	0.0031	0.0078	0.0060	0.0016	0.0399	0.1873
	Pillars	0.0120	0.0454	0.0197	0.0027	0.0090	0.0183	0.0175	0.0062	0.0169	0.1478
	Lifting mechanism	0.0086	0.0112	0.0169	0.0049	0.0253	0.0373	0.0288	0.0045	0.0062	0.1438
	Sum										1.0000
Variant II	Abutments	0.0022	0.0235	0.0222	0.0005	0.0017	0.0039	0.0032	0.0005	0.0050	0.0627
	Gates	0.0229	0.0397	0.0634	0.0008	0.0049	0.0093	0.0087	0.0016	0.0015	0.1529
	Downstream apron	0.0029	0.1498	0.1325	0.0002	0.0008	0.0022	0.0013	0.0003	0.0114	0.3014
	Upstream apron	0.0083	0.0138	0.2061	0.0002	0.0007	0.0017	0.0013	0.0004	0.0088	0.2412
	Pillars	0.0214	0.0808	0.0351	0.0006	0.0020	0.0040	0.0038	0.0014	0.0037	0.1529
	Lifting mechanism	0.0153	0.0200	0.0300	0.0011	0.0056	0.0082	0.0063	0.0010	0.0014	0.0889
	Sum										1.0000
Variant III	Abutments	0.0003	0.0029	0.0028	0.0041	0.0139	0.0314	0.0256	0.0043	0.0405	0.1258
	Gates	0.0029	0.0050	0.0079	0.0061	0.0395	0.0756	0.0706	0.0132	0.0118	0.2325
	Downstream apron	0.0004	0.0187	0.0165	0.0015	0.0063	0.0177	0.0109	0.0028	0.0923	0.1670
	Upstream apron	0.0010	0.0017	0.0257	0.0013	0.0055	0.0139	0.0106	0.0029	0.0709	0.1334
	Pillars	0.0027	0.0101	0.0044	0.0047	0.0161	0.0325	0.0311	0.0110	0.0301	0.1426
	Lifting mechanism	0.0019	0.0025	0.0037	0.0088	0.0450	0.0663	0.0512	0.0080	0.0111	0.1985
	Sum										1.0000

**Figure 8.** Values of the global vector obtained at level IV of the hierarchical tree for three different variants of the AHP method.

In variant I, the most important elements were gates (0.23), and the least important were abutments (0.13). Gates are the most significant elements of the building in the context of maintaining a damming level. In case of their damage, the structure ceases to fulfill its basic function—regulation of water table level. Sudden damage to the gates may cause significant financial losses in the areas below the tank. The most important elements in terms of evaluating the technical condition of water structures for variant II and III were downstream apron (0.3, 0.23). These reinforcements are necessary to keep the bottom below the damming construction stable. Increasing bottom lowering below the damming object

leads to erosion under the foundation of the structure, which may result in the loss of stability. The abutments (0.09, 0.06) were the least significant elements, which, according to experts, are not very important concerning other factors. Table 12 presents technical condition assessments of the analyzed structures calculated using the scales obtained from the AHP method, presented in Figure 8.

Table 12. Summary of values of technical condition assessments of individual structures converted with the weights obtained from the AHP method.

Object Number	Object Name	AHP		
		Variant I	Variant II	Variant III
1	Mill weir Oborniki	4.66	4.55	4.60
2	Weir Oborniki	2.63	2.77	2.70
3	Sill Jaracz	3.50	3.08	3.27
4	Weir Jaracz I	4.04	3.92	3.98
5	Weir Jaracz II	3.13	3.18	3.16
6	Mill weir Nowy Młyn	1.84	2.18	1.98
7	Weir Nowy Młyn	2.08	2.38	2.20
8	Weir Rogoźno	4.75	4.83	4.79

The assessment of the water structure using three calculation variants of the AHP method showed that weir Rogoźno is in the best technical condition. The second place was classified as mill weir in Oborniki. On the border of a good technical condition (4.0) is weir I in Jaracz, while other buildings were in a bad technical state. The lowest marks were given to the weir Nowy Młyn. This is mainly due to the very poor condition of the upstream apron, which affects the final rating of the structure (variant I—1.84, variant II—2.18). Moreover, a strong impact was also observed in the case of lifting mechanisms, where the weight for variant I is 0.20 and for variant II is 0.08. In the assessment of the water sill in Jaracz, the greatest difference between variant I and II was obtained. This is mainly due to the destroyed upstream and downstream apron; whose weight is high in variant I 0.13 and 0.17 and in variant II 0.24 and 0.30.

The results obtained with three variants of the AHP method indicated that for most of the analyzed objects, variant I (damage to construction elements) gave a lower rating for a given structure than variant II (exploitation problems). This is because of the fact that in variant II, it was the most crucial to strengthen the downstream apron 0.30, which in variant I was 0.17. The use of three variants of weights made it possible to check the impact of changes in the values of the level II hierarchical tree factors on the diversity of obtained technical condition assessments.

4. Discussion

The results obtained from assessing the technical condition by the Kaca and Interewicz, Zawadzki, Michalec methods [51–53] for different elements from each evaluated structure are presented in the diagrams below (Figure 9a,b). The charts show the differences in the received ratings for the elements, due to the various course of proceedings in a given method of the technical state assessment.

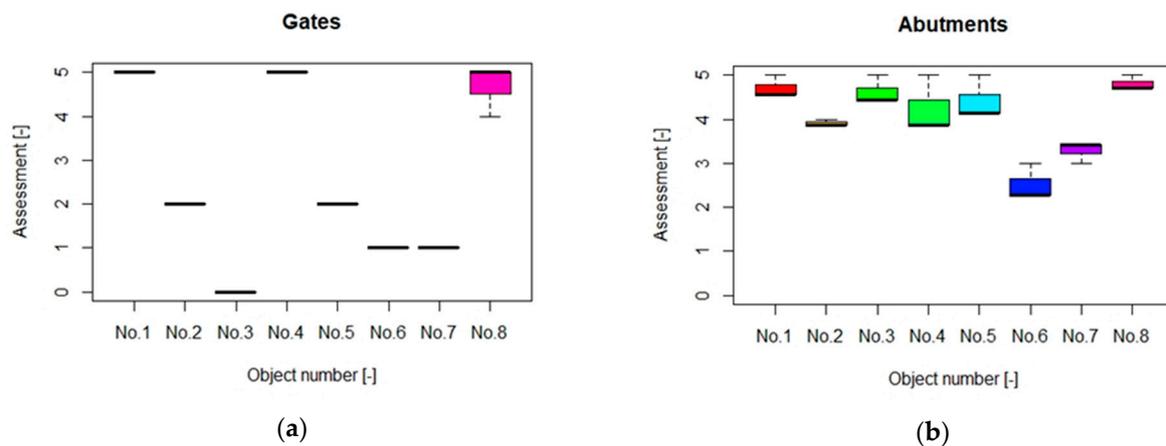


Figure 9. Analysis of the variability of assessing the technical condition of selected elements depending on the method used (a) gates; (b) abutments.

In the case of gates, the results of the three methods do not differ too much from each other. This is because in both the Zawadzki and the Kaca and Interewicz methods this element is rated with only one variable. The expert can use one number to describe the condition and does not take into account many factors, e.g., the Kaca and Interewicz method focuses only on the efficiency and completeness of the gates. There are no precise parameters (e.g., degree of bending of the elements, percentage of corrosion, tightness), whose separate evaluation would obtain a more accurate result. Each of these methods focuses on only one overall visual evaluation (Figure 9a).

Differences in results obtained by different methods in the case of abutments result mainly from the details of a given methodology (Figure 9b). In the Zawadzki method, as many as seven parameters were taken into account, which makes up the final result of the abutments. They include surface, losses, cracks, reinforcement exposing, dripstones and leakages, discolorations, lichens. The final assessment of abutments is a result of the above-mentioned grades. In the Michalec method in this particular case (abutments), no scales were used—which would account for more and less significant parameters. Thus, the grades obtained in this method are equal to those obtained using the Zawadzki method. The Kaca and Interewicz method is much less complex and includes only two parameters, such as cracks, and maintaining the correct position of the structure. Based on the analysis of the results obtained for individual constructions, it was found that the Kaca and Interewicz method overestimates the values of assessments to the Zawadzki method (Figure 10).

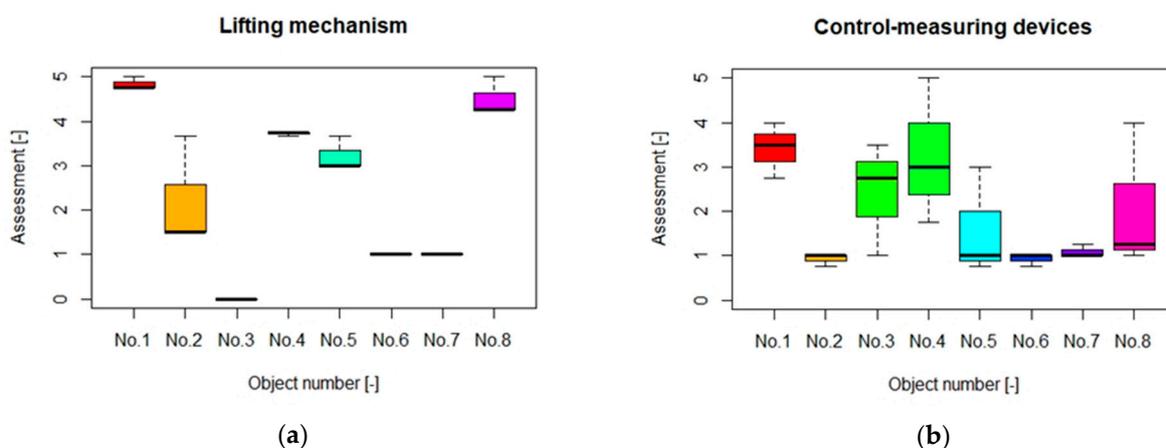


Figure 10. Analysis of the variability of selected elements evaluation depending on the method used (a) lifting mechanisms; (b) control and measurement devices.

The analysis of the ratings obtained for the lifting mechanism is presented in the chart above (Figure 10a). In the case of this element, four parameters were taken into account for the Zawadzki method, such as deformation, corrosion, maintenance, and the general condition of the lifting mechanism. The Kaca and Interewicz method included three parameters: Efficiency of the sluice guides, sealing, and general condition of the lifting mechanism. The differences in the results of individual assessments are much smaller than in the case of abutments. It results from the fact that both methods included a similar number of parameters, 3 and 4, respectively, in the analysis, and one parameter was common for both methods (general state of the mechanism). The biggest difference was obtained in object no. 2 because the sluice guides and seals evaluated in the Kaca and Interewicz method were in a very good technical condition, which gave the element a relatively high score of 3.67. The Zawadzki method did not include these parameters directly, but it emphasized the corrosion and deformation, which were underrated on this object. Thus, the whole structure obtained the final result of 1.5. The same score was achieved using the Michalec method because no scales are used to evaluate the lifting mechanism.

The biggest differences between the obtained assessments in different methods were observed in the case of control and measuring devices (Figure 10b). This is due to several factors. Only two parameters were taken into account in the Kaca and Interewicz method (construction signposting and protection of the object against unauthorized start-up). Therefore, the results obtained are quite general concerning the others. The Zawadzki method, on the other hand, takes into account equipping the object with many elements, such as information boards, piezometers, benchmarks, and water-level gauges, but it does not assess their condition. In his methodology, Michalec states that the information boards do not affect the technical condition of the object, which gives them a weight equal to zero. Thus, when evaluating control and measuring devices, he takes into account the existence of piezometers, repers, and water-level gauges. He suggests that these elements also have a small impact on the condition of the building, so their weight is 0.25. The example of control and measuring devices perfectly shows the discrepancy between the analyzed methods. The highest score was obtained with the Kaca and Interewicz method (5.0), due to the visible signposting of the structure and good protection against start-up. The last-mentioned aspect was taken into account only in this method, which resulted in lower scores in subsequent methods. Moreover, the fact that the construction does not have either benchmarks or piezometers had a high impact on the low rating of the Zawadzki method (3.0). The worst score obtained with the Michalec method (1.75) was achieved mainly by using scales suggested by the author. Thus, the information boards, which were in good condition and positively influenced the result of the previous assessments in this method, were not included. The example of control and measuring devices perfectly shows the contrasts between the individual methods. Unfortunately, in other cases, the distribution of marks obtained by different methods does not show too much variability, due to the absence of the weights used in the Michalec method.

Figure 11 presents the results of assessing the technical condition by Zawadzki, Kaca and Interewicz, Michalec, and three variants of the applied AHP analysis for all the structures under consideration.

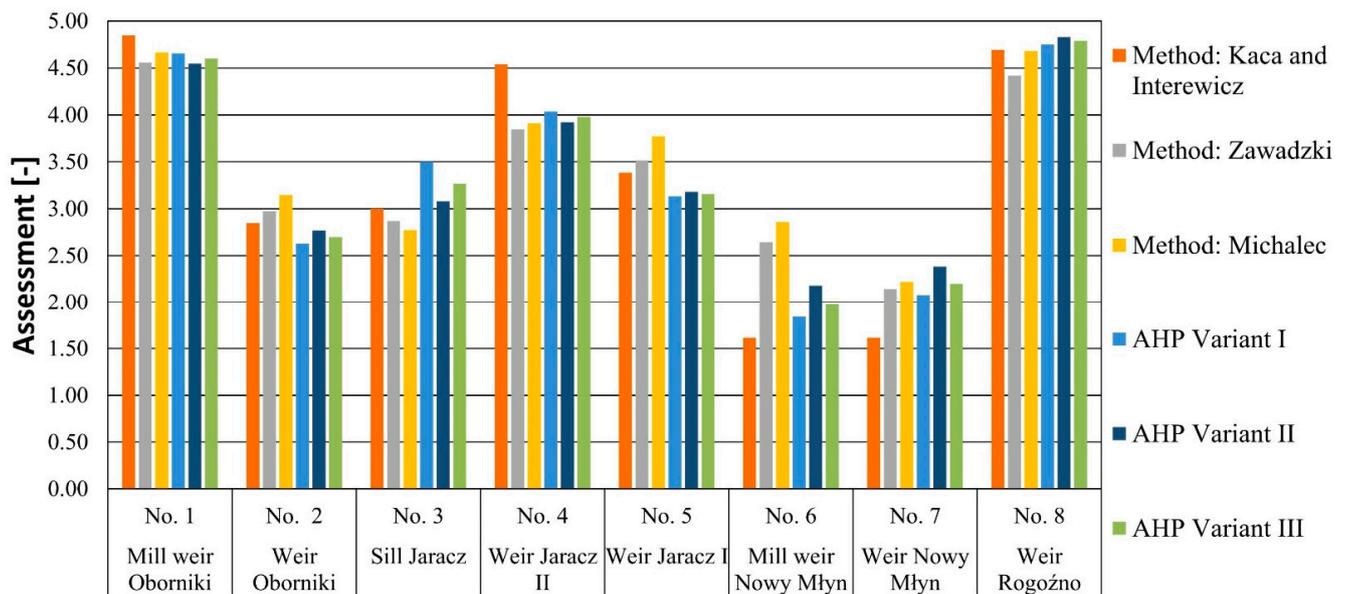


Figure 11. Comparison of technical condition assessments made using the Zawadzki, Michalec, Kaca and Interewicz methods, and three variants of the AHP method for structures located on the Wełna river.

Analyzing the obtained values of the technical condition assessment, it can be stated that regardless of the method used for structures no. 1 and 8, the results differ less than 0.5 marks. It was noted that in the case of structures that are renovated and regularly maintained, the achieved assessments are similar. A comparable tendency was observed in the case of building no. 4, where apart from the assessment obtained from the Kaca and Interewicz methods, the other results did not differ significantly. The high value for the Kaca and Interewicz method is because the detailed aspects of the downstream apron and control and measurement devices were included in the Zawadzki method. Detailed consideration of individual elements resulted in lowering the final score, as opposed to the Kaca and Interewicz method, in which the general grade of individual elements overestimates.

The method of multicriteria decision-making (AHP) most underestimated the obtained technical condition assessments for structures 2 and 5. Decreased values of the marks result from the poor condition of the gates and downstream apron. The weights of the listed elements in the AHP method are relatively high and directly influence the low final grade.

In the case of hydrotechnical structure no. 3, the field measurements included the evaluation of such elements as control and measuring devices, downstream apron, and abutments. Control and measuring devices in methods using AHP are not taken into account because the authors of the method considered them insignificant in the context of technical condition assessment of the construction. Thus, building no. 3, which does not have information boards and is generally insufficient technical condition, received higher final marks in AHP methods. This example shows that the lack of control and measuring equipment contributes to lowering the final grade in the Zawadzki method by as much as 0.5 of the grade (concerning AHP variant I).

Lack of apron in construction no. 6 causes the omission of elements of high importance in AHP methods (high weights), which changes the distribution of ratings for the remaining elements. Thus, the most important are the components that are in a bad technical condition (lifting mechanisms and gates), which strongly understate the final grade. High results obtained in the Zawadzki and Michalec method are the effect of including pillars as an element of assessment. In the case of structure no. 6, this element received very high marks (4.0). The Kaca and Interewicz method completely omits the pillars, so the final grade obtained by the discussed one is the lowest. This is also because this method is the only one that takes into account the condition of the impervious apron, which in this case was

rated 1.0. Object no. 7 received the lowest marks by all methods. Individual results differed slightly except for the Kaca and Interewicz method, whose mark was the lowest. A similar tendency (about Kaca and Interewicz) was also observed in the case of construction no. 6. This was influenced by the general nature of the ratings and the factors described above.

The AHP method is commonly used to carry out analyses and assist in selecting the appropriate variant. It is a tool that supports the decision-making process. The AHP application in the world of science is very broad [72–74]. Furthermore, with regard to aspects related to rivers and their water management, several attempts have been made to implement this method to choose the right solution to the problem. AHP was used to determine the frequency of river water quality sampling [75], and to planning and carrying out regulatory work on the river [76]. AHP was also applied in combination with a membership degree in fuzzy mathematics theory (Fuzzy AHP), which assesses the safety of the water reservoir [77], and the efficiency of polder modernization located in the floodplain of the river [78]. Furthermore, taking into account many natural factors (e.g., speed of water flow, distance from one river bank to another, and river bed material), it has also been used to select the locations for river crossing by tanks with a deep wading technique [79]. Moreover, AHP has been used for aesthetic qualities, such as assessing landscape aesthetics for watershed stream regulation works [80], and the evaluation of scenic beauty of dams [81]. Taking into account water structures, AHP was also applied to determine the most environmentally beneficial variants of barrages [82]. Furthermore, it has been shown that multicriteria decision support methods can be successfully used to select the best project for a small run-of-river hydropower plant. The AHP method has selected the key criteria to determine the impact on the environment and made it possible to choose the most balanced investment options [83,84]. Research has also attempted to integrate the Geographic Information System (GIS) and Analytical Hierarchical Process (AHP) to find a suitable site for a dam [85]. The analysis of geographical factors, such as slope, geological factors, soil type, catchment size, land cover, proximity to roads, and giving them weights, has selected the most favorable areas and terrain completely unsuitable for this type of construction [86]. The integration of GIS and AHP has also been used on several occasions in flood risk analyses in the catchment area [87–91]. Attention was also paid to the potential of these combined tools in assessing river pollution [92], and the location of water reservoirs [93].

This review of research shows that AHP can be used effectively in problems involving river water management. The research conducted in this article was aimed at the innovative application of AHP in assessing the technical condition of hydrotechnical constructions. It has been proven that AHP is a tool to facilitate and improve the assessment process. The widespread use of this method will contribute to systematizing the methodology for assessing structures all over the world. It should also be noted that the estimated number of barriers in Europe is over 1 million, which confirms the importance of the problem we are considering [94]. Moreover, the presented implementation of the AHP method fills a gap in science concerning the application of the multicriteria methods in assessing the technical condition of hydrotechnical constructions.

5. Conclusions

The assessment of the technical condition of hydrotechnical constructions is very important for their safety. In the literature, you can find various methods to facilitate the assessment. They include many elements that are not always significant for the safety of structures. That is why the authors have chosen elements in their work that they believe are essential for evaluating the safety of constructions. To determine their importance, they used multicriteria decision-making methods (AHP). Analyzing the prepared hierarchical tree, they distinguished three variants and checked the impact of changes in the importance of factors related to exploitation problems and damage to construction elements on the weights taken into account in the assessment. Based on the conducted research, the authors came to the following conclusions:

1. The Zawadzki and Michalec methods consider many parameters—not all of which directly affect the safety of the construction, e.g., information boards, benchmarks. The inclusion of these elements in the Zawadzki method results in an excessive overestimation or underestimation of the entire hydrotechnical structure depending on the condition of control and measuring devices.
2. The scales used in the Michalec method include elements that are less important for the safety of the hydrotechnical construction. However, this method does not specify the elements of greater importance.
3. The Kaca and Interewicz method is recommended for small objects, such as drainage valves and small structures on watercourses, but it is not best suited for assessing large hydrotechnical objects, such as weirs or other elements of the barrage to its too large generality. Moreover, this method does not take into account many significant elements, such as pillars.
4. The selection of an appropriate method of technical condition assessment should depend on the size and character of the construction. Moreover, it is important to remember that the main purpose of the assessment is to determine whether the current technical condition does not adversely affect the safety of the object and adjacent areas [95]. The conducted analysis indicates the necessity to develop a new method that takes into account the different importance of particular elements during the assessment of the structure, with particular emphasis on the elements directly affecting safety. Therefore, the analysis uses the multicriteria decision-making method (AHP).
5. The highest weight for variant I of the AHP method was given to the gates (0.23), and the smallest abutment (0.13). The obtained results confirm the previously conducted research—that gates are an important element of the construction in the context of safety, and their damage is a huge threat to the areas located below the structure. The most important elements for variant II and III were the downstream apron (weights: 0.3, 0.23), which are an important factor affecting both the damage and parameters of the hydrotechnical construction. Progressive lowering of the bottom below the damming may lead to loss of stability.
6. The analysis of the results of technical condition assessment of the construction obtained with three variants of the AHP method indicated that for most of the objects in variant I a lower assessment of a given construction was obtained than in variant II. The values achieved with the proposed variant I of the weights showed correct tendencies of the received assessments concerning the actual technical condition of the structure.

Upon analysis of the results of technical condition assessments obtained with the use of AHP methods, it was concluded that the change of weights of level II factors did not significantly affect the final score. A comparison was made of the final grades obtained with the use of Zawadzki, Michalec, Kaca and Interewicz methods [51–53], and three variants of the AHP method. It showed that the results achieved based on the first three methods known in the literature differ from each other more than the results obtained with three variants of the AHP method.

The methods of assessing the technical condition of hydrotechnical constructions, developed by the authors with the use of AHP, is more accurate and considers many factors of evaluation. The use of scales to determine the importance of individual elements (both more and less significant) contributes to a more realistic representation of the technical condition of the object. This has been proven by conducting several analyses covering methods and factors influencing the assessment of technical conditions. These analyses indicate that the non-use of weights contributes to over- or underestimating the actual technical condition of the hydrotechnical construction. The analyses carried out in the paper showed that the application of AHP facilitates the assessment of the technical condition of hydrotechnical constructions. The use of AHP as a universal assessment method will allow for a comparison of the technical condition of hydrotechnical constructions located all over

the world. This is an important proposal, since there are currently more than one million barriers in Europe [94].

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