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Assessment of the Recreational Potential of Flooded Quarries in Slovakia

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Abstract: This article focuses the assessment of the recreational potential of selected water-filled quarries in Slovakia, specifically the Škrabské, Beňatina, and Kraľovany quarries. Water-filled quarries represent a significant untapped resource that can contribute to the development of various leisure activities while simultaneously supporting local communities and environmental conservation. The main challenge of the study is finding a balance between the recreational use of these sites and the need to maintain ecological sustainability, which requires a detailed evaluation of the natural conditions, infrastructure, and accessibility of the individual quarries. The study focuses on a comprehensive assessment of the recreational potential of selected water-filled quarries in Slovakia, specifically the Škrabské, Beňatina, and Kraľovany quarries, using a methodology based on point evaluation according to criteria such as natural beauty, accessibility, existing infrastructure, and ecological status. The results of this study provide an important foundation for further research and decision-making processes in the transformation of water-filled quarries, aiming to maximize their recreational potential while ensuring long-term environmental sustainability.

Keywords: recreational potential; quarry assessment; flooded quarries; natural resources; sustainable tourism

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Citation: Iannaccone, B.; Domaracká, L.; Tometzová, D.; Gabániová, Ľ. Assessment of the Recreational Potential of Flooded Quarries in Slovakia. *Sustainability* **2024**, *16*, 9602. https://doi.org/10.3390/su16219602

Academic Editor: Harry Coccossis

Received: 30 September 2024
Revised: 25 October 2024
Accepted: 31 October 2024
Published: 4 November 2024

1. Introduction

For many years, countries worldwide have engaged in the restoration of abandoned and flooded quarry sites. In many regions, especially urban areas, local authorities have employed diverse rehabilitation strategies to address the basic needs of their communities [1,2]. Flooded quarries, in particular, present unique challenges and opportunities, as they can evolve into aquatic ecosystems or recreational water bodies [2]. These sites, if properly managed, may serve as reservoirs for water storage, aquaculture, or be transformed into leisure destinations like swimming lakes, diving spots, and fishing areas [3]. Abandoned and unrehabilitated quarries often become suboptimal land use assets, fraught with environmental risks and diminished in value [4]. In contrast, open and accessible spaces typically hold significant economic, environmental, and social worth. Without proper maintenance, these abandoned pits, whether dry or flooded, become sources of geological and environmental risks [5].

There are various historical examples of repurposing abandoned quarries. During the Roman era, they were frequently used for burials and other religious rituals [6]. The funeral complex along the Appian Way in Rome, Italy, is situated within an ancient stone quarry. In the Renaissance era, the old Pietraforte sandstone quarry in Florence was recultivated into the Boboli Garden [7]. Underground quarries were extensively utilized during World War I and World War II. In regions like the German Empire, England, Bohemia, Austria, and Poland, quarries were converted into factories, warehouses, or shelters to protect people from Nazi threats [8]. Additionally, some quarries, such as the old granite quarry Wiener-Graben in Austria, were used to detain war prisoners or even as death camps. During this period, the limestone quarry in Litoměřice was expanded, becoming the largest underground factory in the Czech Republic [9].

At present, there are numerous examples of abandoned quarries being repurposed for secondary use. The former China clay quarry in Great Britain, now famously known as the Eden Project, functions as a hub for environmental education. Another notable example is the transformation of an old quarry into the five-star hotel "Shimao Wonderland InterContinental" in China [10]. Some quarries have been converted into mining museums (Wieliczka, Poland), amusement parks (Salina Turda, Romania), wineries (Milestii Mici, Moldova), mushroom farms (Paris Catacombs, France), or galleries (Val d'Enfer, France).

Corrective measures for mining quarries include renovation and the creation of new ecosystems beyond their original functions [11]. These activities should align with the surrounding environment, promote biodiversity, enhance the aesthetic value of the landscape, and contribute to improving the social and economic conditions in the region. Additionally, they should address environmental issues such as air, water, and soil contamination [12]. When planning land restoration, it is crucial to consider ecological, economic, and aesthetic aspects. Some analysis suggest that underutilized sites have the potential to become recreational destinations [13]. Recreational service options should be evaluated according to land use planning and management principles. Restoration efforts in mining quarries can protect against land degradation and offer new uses for affected areas [14]. Revitalizing and repurposing quarries for tourism development involves unique characteristics. Consequently, this process attracts traditional stakeholders such as investors, developers, Destination Tourism Organizations, scientists, and the public [15].

The approach to recultivating and transforming brownfields and quarries varies across Europe. In post-socialist countries, the primary challenge is the lack of funding. Consequently, various regional non-profit organizations strive to repurpose mining brownfields for secondary uses in tourism, focusing on minimal adjustments and low financial costs [16]. Scandinavian countries (Norway, Sweden, Denmark, and Finland) with low population density focus on mitigating environmental pressures and potential health risks while recultivating old quarries, especially in urban areas [17]. In contrast, densely populated Western European countries with strong economic potential, including Belgium, the Netherlands, Luxembourg, France, Germany, Austria, and the United Kingdom, prioritize redeveloping abandoned areas, buildings, or brownfield sites for economically beneficial secondary uses, despite ecological challenges [18].

The utilization rate of abandoned quarries varies significantly around the world. In the United States, approximately 70% of abandoned mines have been restored since 1970. In Australia, integrating ecological restoration of pits into mining technology is common practice. Conversely, the reuse rate in China is under 10%. According to Hronček [19], the number of abandoned quarries in Slovakia is estimated to exceed 10,000, making them potential targets for tourism and recreation. However, most of these quarries are unsuitable for secondary use due to various reasons, such as difficult terrain, poor accessibility, an inability to ensure sufficient safety, and a lack of tourist attractiveness [20].

Former quarries can be recultivated for various purposes, including secondary applications in industry and energy, residential construction, agriculture, forestry, water management, transportation, and more [20,21]. Interesting examples described by Lintukangas et al. [21] or Otchere et al. [22] involve using flooded open pits for fish and crab farming. However, in cases where flooded quarries are used for farming, sports, or recreation, water quality is critical [23]. Another potential use of these cultural landscapes is recreation. Converting quarries into recreational zones after mining operations cease, especially near residential areas, can be seen as a sensible approach to land restoration. Particularly, the redevelopment of quarries close to inhabited areas can positively impact the community's social, physical, and mental well-being [24].

Abandoned quarries in Slovakia are significant geographic and ecological features with substantial potential for recreational use. Once characterized by intense industrial activity, these former mining sites are now of interest for revitalization and regional diversification. Current societal trends highlight the need for new forms of recreation and relaxation in natural settings, and abandoned quarries offer unique opportunities for developing such recreational potential [25]. Although mining can threaten the sustainable use of natural resources, post-mining areas can be rehabilitated and transformed into recreational zones. These sites feature attractive surface formations and underground galleries that can be intriguing and beneficial to the public [26].

Recreational activity is currently one of the most frequently used terms, encompassing all leisure-time pursuits. The modern surge in recreational interests and individual needs is a global phenomenon driven by rapid urbanization, the industrialization of agriculture, and the expansion of extensive transportation networks. In this context, planning green infrastructure requires more than mere environmental protection or creating recreational zones; it demands a comprehensive approach that leverages green spaces to fulfill people's needs [27]. Recreation can be categorized into three primary components: home, indoor, and outdoor activities. Outdoor recreation has been extensively researched and is regarded as one of the most significant cultural activities. It includes protecting, preserving, developing, and enjoying natural scenery, water, and cultural landscapes, including archeological and historical sites. Recent studies on the suitability of recreational activities examine the relationship between landscape characteristics and individual preferences gathered through surveys, photo series, and interviews [28].

While various authors [29–34] have individually evaluated different aspects of the secondary use of quarries, there is a gap in the literature, as few have comprehensively addressed the collective recreational potential of former mining locations. This paper seeks to bridge that gap by providing a holistic perspective on these abandoned quarries' diverse recreational opportunities and potential. By exploring the concept of recreational potential and activities, we aim to underscore the multifaceted benefits these sites can offer, fostering a broader understanding of their value in post-mining landscapes.

2. Literature Review

2.1. Methods for Assessing Recreational Potential

Evaluating recreational potential is essential for determining the value of natural and cultural resources within a given area. This process entails a thorough analysis of the site's attractiveness, accessibility, and suitability for various recreational activities. Key considerations include environmental conditions, biodiversity, climate, infrastructure, and cultural heritage. A holistic evaluation of recreational potential not only fosters sustainable tourism but also enhances economic prospects while safeguarding the environment. This method enables regions to optimize their natural and cultural assets, offering visitors distinctive and enriching experiences.

Extensive research has been conducted assessing recreational potential across different landscape types, utilizing diverse methodologies [28,29,35–38]. For instance, Lu et al. [30] introduced the Integrated Nature-Based Recreation Potential Index (INRPI), a comprehensive tool for evaluating nature-based recreation in expansive areas such as the Qinghai–Tibet Plateau. This index integrates factors such as landscape appeal, visitor comfort, and the land's carrying capacity, employing the Analytic Hierarchy Process (AHP) in conjunction with entropy evaluation. Before applying this method to assess nature-based recreational potential, it is crucial to assign appropriate weights to each indicator. These weights are derived using AHP and the entropy evaluation method (EEM).

Various authors have also explored methodologies that leverage programs integrating multi-criteria decision-making (MCDM) and geographic information systems (GIS). One notable example is the Fuzzy Analytic Hierarchy Process (FAHP), which has been employed to delineate ecotourism zones. This technique, when combined with GIS, allows for the evaluation of criteria such as topography, vegetation, and accessibility, ultimately identifying areas most suitable for recreational activities [39].

Another approach incorporates Multi-Attribute Decision-Making (MADM) with GIS to assess ecosystem services and recreational potential within forested landscapes. This method evaluates a range of criteria, including landscape metrics, ecological characteristics, and user preferences, offering a robust framework for such assessments [31].

The Weighted Sum Method (WSM) is frequently adopted for tourism potential evaluation due to its simplicity and reliability. For instance, Mamun and Mitra [40] applied this methodology in an Indian case study to assess recreational potential. The process involves five distinct steps, beginning with the assignment of weights to key physical, social, and environmental attributes.

At Level 1, these attributes include the quality of services and the socio-economic and cultural context. Level 2 breaks down these attributes into more specific variables:

- Physical (Wp): geographic terrain, connectivity, accommodation, and recreational facilities.
- Social (Ws): tourist influx, festivals, safety, and the conduct of service providers.
- Environmental (We): natural disasters, pollution, and land use.

The weighting of these attributes is determined through expert consultation, tourist surveys, and interviews with service providers. The model is designed to be adaptable, allowing for the exclusion of attributes that may be irrelevant or uniform across the region.

Dirin and Madry [41] devised a standardized scoring system for evaluating various bodies of water. This system identifies key indicators based on both physical characteristics and aquatic ecosystems. International experts selected 27 criteria, and priorities were established through hierarchical analysis using Expert Choice software. Water bodies are then scored on a scale from 0 to 2 points, reflecting their appropriateness for recreational activities. In their publication on geotourism potential, Beranová et al. [42] employed a combination of GIS and multitemporal data analysis to assess the geotourism value of abandoned quarries. This approach allows for a detailed examination of both the historical changes and the present condition of quarries, providing critical insights for sustainable tourism development and heritage conservation.

The publication "Research on the Landscape Attractiveness of the Selected Abandoned Quarries" [43] employs three primary methodologies for assessing landscape appeal. The first method, a semantic differential survey, gauges public perception of quarries through questionnaires, measuring both positive and negative associations. The second approach, point-based evaluation, assigns scores based on features such as vertical differentiation, natural succession, conservation status, boundary contrasts, the presence of water, and accessibility. Lastly, the entropy method evaluates the diversity of sensory stimuli a landscape offers, classifying landscapes according to the variety and richness of these stimuli. Together, these methods deliver a comprehensive analysis of quarry attractiveness.

Tsolaki-Fiaka et al. [44] utilize the PROMETHEE method, a multi-criteria decision analysis tool, to rank alternative restoration scenarios for abandoned quarries. This approach considers financial, environmental, and socio-economic factors. Talento et al. [6] further investigates the post-mining transformation of quarries, highlighting that rehabilitating degraded sites often necessitates a variety of interventions, from minimal modifications to substantial reconstruction, such as backfilling, afforestation, or new infrastructure. Key factors influencing this process include quarry typology, morphology, safety, and ecological concerns. Effective rehabilitation strategies are informed by case comparisons and contextual analysis of each site, considering geometric characteristics and boundary compactness. Restoration can be achieved through natural methods (e.g., vegetation regeneration), recreational uses (e.g., tourism and leisure facilities), cultural and educational purposes (e.g., museums and galleries), or productive applications (e.g., agriculture and tourism improvements). Each strategy aims to restore and repurpose the site, thereby enhancing its ecological and social value [6].

A scientific assessment of recreational potential synthesizes various methodologies and approaches, facilitating the effective and sustainable use of natural and cultural resources. These strategies support the development of sustainable tourism while ensuring environmental preservation and the protection of cultural heritage, contributing to the broader regional development goals.

2.2. Definition of Recreational Potential and Activities

Recreational potential refers to the capacity of a specific area, location, or facility to offer opportunities for leisure activities, relaxation, and a wide range of experiences that enhance the overall well-being and satisfaction of individuals. This concept encompasses various factors that contribute to the attractiveness and suitability of a place for recreation [41]. Recreational potential is influenced by both natural and anthropogenic factors. Natural elements, such as beauty, water bodies, mountainous terrain, and other unique features, can significantly enhance the attractiveness of a location for recreational purposes [45,46]. Human interventions, including the construction of recreational zones, parks, cycling paths, hiking trails, and other infrastructure, play a crucial role in transforming an area into a suitable place for both active and passive recreation [40,47]. An effective use of recreational potential can positively impact the local economy, support tourism development and improve the overall quality of life for residents. Assessing recreational potential involves evaluating various aspects, such as accessibility, safety, the range of available activities and experiences, and how well the area integrates into the broader social and cultural context [48]. Recreation, as an active form of leisure, emphasizes rest, relaxation, energy renewal, and the improvement of both physical and mental well-being. It involves intentional activities that positively influence mental and physical health, tailored to diverse preferences and needs.

Recreational activities can encompass a wide range of pursuits, from sports and exercise to cultural and artistic activities, travel, relaxation in nature, or simply resting [49]. The primary goal of recreation is to alleviate stress, tension, and fatigue, while simultaneously improving physical fitness and mental health, ultimately enhancing the overall quality of life. A critical characteristic of recreation is its voluntary nature, allowing individuals to choose activities that bring them pleasure and relaxation [50,51]. Recreation can be pursued individually or in groups, and it can be either organized or spontaneous. As an integral part of daily life, regular participation in recreational activities significantly contributes to overall well-being and health [33,52].

An objective evaluation of recreational resources is an essential part of tourism development. This assessment influences the structure of the tourism economy, the creation and specialization of recreational destinations, and the efficiency of service provision. In the current economic climate, the competitiveness of these resources among countries with transitional economies is a key issue in international tourism [34].

3. Materials and Methods

This chapter outlines not only the Study Areas, but also the selected methodologies used to calculate the tourism potential of specific locations. The combination of these approaches enables a more comprehensive and accurate assessment. Method 1, based on a weighted average, provides a systematic framework for evaluating key criteria such as access safety, water quality, and service availability. Each criterion is assigned a score and a weight, which allows for the calculation of the overall potential. Method 2, which employs the Analytic Hierarchy Process (AHP), expands the concept of the weighted average by offering a deeper evaluation of the relative importance of each criterion through pairwise comparisons. This process facilitates a more precise determination of the weights of individual criteria based on their relative significance within the context of the area being assessed.

There is a strong interconnection between Method 1 and Method 2 in the context of evaluating tourism potential, as both methods consider key factors influencing the attractiveness of sites, though they approach them in different ways. The decision to apply both methods was driven by the goal of ensuring a comprehensive and multi-level approach to the assessment of tourism potential. Method 1 offers an efficient framework for the rapid evaluation of locations, while Method 2 allows for a more in-depth analysis and a more objective assignment of weights, thereby enhancing the accuracy of the results. The combination of these two methods provides a reliable foundation for strategic decision-making in the development of tourism sites, ensuring that all relevant aspects of tourism attractiveness and development are considered. This approach not only allows for an evaluation of status but also facilitates future development planning with an emphasis on sustainability and the efficient use of natural and cultural resources.

3.1. Method 1—The Calculation of Tourism Potential Using the Weighted Average

In this section, we present the methodology for assessing tourism potential, which is based on evaluating selected criteria using a scoring scale ranging from 1 to 5. This approach allows for the quantification of the attractiveness of tourist sites, focusing primarily on flooded mining quarries, based on key factors essential for tourism development. Each criterion is rated according to this scale, where a value of 1 indicates the lowest level and a value of 5 indicates the highest level of tourism attractiveness. Table 1 lists the individual criteria, along with the justification for their inclusion in the evaluation framework. Each criterion is assigned a weight that reflects the priority of the given aspect in the tourism sector [53,54].

The calculation of tourism potential (TP) based on the weighted average is carried out using the following formula:

$$\text{TP} = \left(\sum (\text{criterion value} \times \text{factor weight})\right) / \sum (\text{weight}) \quad (1)$$

Table 1. Criteria with point ratings and justification for inclusion in the evaluation table for calculating tourism potential.

Criterion	Point Scale (1–5)
Accessibility Safety	1 (dangerous access)–5 (very safe access with protection and railings)
Infrastructure Accessibility	1 (no infrastructure)–5 (excellent infrastructure with parking and toilets)
Water Quality	1 (very poor)–5 (excellent quality, clean water)
Presence of Vegetation	1 (very dense, unmaintained)–5 (balanced, suitable vegetation)
Ecological Value of the Site	1 (low biodiversity)–5 (high biodiversity, presence of endangered species)
Water Visibility	1 (very poor visibility, below 1 m)–5 (excellent visibility, above 8 m)
Size and Depth of the Water Body	1 (small/shallow quarry)–5 (large and deep, suitable for various activities)
Tourist and Cycling Paths	1 (no paths)–5 (developed network of marked paths)
Aesthetic Value of the Site	1 (unsightly, polluted surroundings)–5 (naturally beautiful with scenic views)
Availability of Nearby Services	1 (no services)–5 (multiple services, e.g., dining, accommodation)
Sports Activity Options	1 (no options)–5 (multi-purpose options including diving, swimming, canoeing)

(Modified by the authors).

This method for assessing tourism potential is based on a series of factors that influence the attractiveness and safety of sites. The first factor considered is accessibility safety, which evaluates the degree of security provided by access routes to the site. This aspect is crucial to ensuring the safety of visitors, including vulnerable groups such as children and the elderly [55]. Infrastructure accessibility assesses the availability of parking, restrooms, shelters, and other services. Accessible infrastructure significantly enhances visitor comfort and overall site attractiveness, as supported by research on sustainable tourism destination development [56,57]. Water quality directly affects visitor safety and recreational experience. Scientific studies have demonstrated that water quality has a substantial impact on the popularity of water-based sites, particularly for activities such as swimming and diving [58]. The presence of vegetation around the site influences its aesthetic and visual appeal. Vegetation can contribute to a positive visual experience, but dense, unmanaged vegetation may decrease safety and hinder visitor movement, as evidenced by research on the impact of natural environments on the tourist experience [59]. The ecological value of the site, which considers biodiversity and the presence of endangered species, is essential for development in line with nature conservation [60]. Sites with higher biodiversity are often more attractive to tourists interested in ecotourism, as documented by Samal and Dash [61]. Water visibility is particularly important for swimmers and divers, with higher visibility improving safety and aesthetic appeal, as highlighted in the study by Barnett et al. [62]. The size and depth of the water body influence the range of recreational activities; larger and deeper water bodies allow for a wider variety of sports, which is supported by research on tourist preferences for water sports [63,64]. Tourist and cycling paths assess the connectivity of the site with surrounding trails, increasing accessibility and attractiveness to a broader visitor group, as demonstrated by studies on infrastructure linkages and their impact on tourism [65]. The aesthetic value of the site focuses on visual appeal and environmental cleanliness, with natural beauty contributing significantly to a positive experience, aligning with findings on the influence of aesthetics on tourist behavior [66].

The availability of nearby services, such as restaurants and accommodation, directly increases the site's attractiveness, particularly for visitors planning extended stays, as evidenced by studies on the role of services in tourism destination development [67,68]. Sports activity options are another crucial factor that enhances the site's appeal to a wider range of visitors, supported by research in the field of sports tourism [69]. These criteria were selected based on literature sources that emphasize their importance for evaluating and developing tourism destinations.

3.2. Method 2—Calculation of Tourism Potential Using the Weighting Method of the Analytic Hierarchy Process (AHP)

The second method for calculating tourism potential is based on the assignment of weights using the Analytic Hierarchy Process (AHP). The formula for calculating tourism potential is chosen for its ability to integrate key factors that directly influence the attractiveness of specific tourist sites. This formula systematically evaluates and aggregates the impact of factors such as tourist attractiveness (Ta), access infrastructure (Ai), natural values (Ni), accessibility (Di), and social infrastructure (Si), providing a comprehensive picture of tourism potential. It is essential to assign weights to these factors (W), as not all have equal importance for a given location. For instance, in remote ecological sites, natural values (Ni) may be the most critical factor, while in urban destinations, social infrastructure (Si) may take precedence.

Therefore, it is recommended to assign appropriate weights to each factor based on the site's characteristics:

$$TP = W_{Ta} \times Ta + W_{Ai} \times Ai + W_{Ni} \times Ni + W_{Di} \times Di + W_{Si} \times Si \quad (2)$$

where

- W_{Ta}, W_{Ai}, W_{Ni}, W_{Di} and W_{Si} are weights assigned to individual factors (typically values ranging from 0 to 1) that reflect the importance of these factors in relation to the overall tourism potential.
- Ta (tourist attractiveness) represents the value that expresses the aesthetic and cultural appeal of the location, considering factors such as natural beauty, cultural heritage, or historical significance (scored from 1 to 10, based on the total number of attractions).
- Ai (access infrastructure) focuses on the accessibility of the location, including the quality and density of road infrastructure, availability of public transportation, and proximity to major transport hubs (scored from 1 to 5, where 1 indicates low attractiveness and 5 indicates high attractiveness).
- Ni (natural values) evaluates ecological and environmental aspects such as biodiversity, water bodies, forests, and nature reserves, which enhance the attractiveness for tourists preferring ecotourism (scored from 1 to 5, where 1 indicates low quality and 5 indicates high quality).
- Di (accessibility) refers to the geographic location and distance from major residential areas and tourist centers, which significantly impact visitation (scored from 1 to 5, where 1 indicates a large distance and 5 indicates a short distance).
- Si (social infrastructure) includes the availability of services for tourists, such as accommodation, dining facilities, healthcare, and other visitor support services (scored from 1 to 5, where 1 indicates low quality and 5 indicates high quality).

When assigning weights, methods such as expert estimation or the Analytic Hierarchy Process (AHP) can be used to obtain more accurate and objective weights based on the complexity of individual factors. In AHP, a pairwise comparison matrix needs to be created. To compare the importance of each pair of criteria, we chose to use Saaty's scale, which includes the following values:

- 1: The criteria are equally important.
- 3: One criterion is moderately more important than the other.
- 5: One criterion is significantly more important than the other.
- 7: One criterion is much more important compared to the other.
- 9: One criterion is extremely important compared to the other.

If one criterion is less important, reciprocal values (e.g., 1/3 or 1/5) can be applied [70].

Each criterion in the pairwise comparison matrix is compared with every other one in an $n \times n$ matrix, where n is the number of criteria. Values are inserted based on pairwise comparisons. Once all cells are filled, a complete comparison matrix is obtained. Constructing the pairwise comparison matrix is a key step in AHP, as it incorporates the subjective evaluation of the importance of criteria and allows for the systematic calculation of weights. This process facilitates assigning weights to individual criteria based on their relative importance, leading to more efficient decision-making. To ensure the consistency of our pairwise comparisons, we use the Consistency Index (CI) and the Consistency Ratio (CR). If the CR value is less than 0.1, it indicates that the comparisons are sufficiently consistent. The CI expresses the degree of inconsistency in the pairwise comparisons [54].

The CI calculation is:

$$CI = \frac{(\lambda max - n)}{(n - 1)} \tag{3}$$

where

- λmax is the largest eigenvalue of the matrix.
- N is the number of criteria.

The value of λmax (the largest eigenvalue of the matrix) should be close to the number of criteria evaluated. The calculation of λmax is equal to the average of all results. The Consistency Ratio (CR) is an important indicator that tells us whether the comparisons are sufficiently consistent for the AHP results to be reliable. CR compares the Consistency Index (CI) to the Random Index (RI), which depends on the number of criteria.

Calculation CR is:

$$CR = \frac{CI}{RI} \tag{4}$$

The critical threshold for CR is 0.1. If the CR value is ≤0.1, the comparisons are considered sufficiently consistent, and the weights assigned to the individual criteria are reliable. If the CR value is ≥0.1, it is recommended to reassess the pairwise comparisons, as they are too inconsistent [54].

3.3. Study Areas

Figure 1 shows the geographical locations of three major quarries in Slovakia: Kral'ovany Quarry, Škrabské Quarry, and Beňatina Quarry. These quarries are indicated by red markers and are spread across different regions of the country, with Kral'ovany located in the northern part, Škrabské in the east, and Beňatina near the eastern border with Ukraine.

Figure 1. Map depicting the quarries Kral'ovany, Skrabské, and Beňatina, marked with red squares [71] modified by the authors.

3.3.1. Beňatina Quarry

The former quarry is situated in the cadastral area of Beňatina village in the Sobrance district, between Beňatina and Inovce, near the Ukrainian border. Located within the flysch zone, a designated natural monument, Beňatina Quarry (Figure 2) was originally established for andesite extraction in 1959, with systematic mining beginning in 1974. Operations were halted due to the depletion of the highest-quality deposits, challenges posed by spontaneous landslides, and safety concerns [72]. The quarry lies within the East Slovak Lowland and Podvihorlatská Upland, areas known for their unique geological features, including the Beňatina Travertine. Today, the flooded quarry has become a popular tourist destination, attracting visitors who enjoy swimming in the "lake" and are captivated by the turquoise water and the so-called "Beňatina Whale". This whale-like image on the quarry wall was created by reddish-brown sections of limestone emerging through a pale limestone layer. Combining recreational use with nature conservation could ensure the sustainable management of this site.

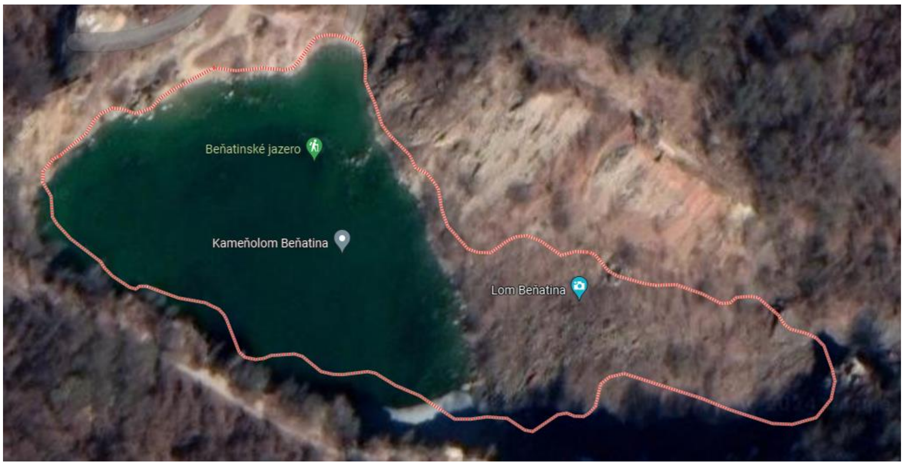

Figure 2. Satellite map of the Beňatina quarry [73] modified by the authors.

3.3.2. Skrabske Quarry

The Skrabské quarry (Figure 3) is situated in the village of Skrabské in the Vranov nad Topľou district, within the Alpine-Himalayan system, specifically in the Beskydské Foothills and Ondavská Highlands. Mining operations for marl limestone began at this site in 1956, but ceased in 1997 due to a shift in focus to another quarry. In 2006, groundwater gradually infiltrated the quarry, resulting in its eventual flooding [74]. Currently, the water in the flooded quarry reaches a depth of 10 m. The geological composition of the area is relatively straightforward, primarily consisting of sedimentary rocks with some volcanic formations. The bedrock of the Skrabské quarry is mainly limestone, a sedimentary rock formed during the Mesozoic era, particularly in the Jurassic and Cretaceous periods. In addition to limestone, other sedimentary rocks like dolomites and clay shales can be found in the area. The Ondavská Highlands are characterized by Paleogene flysch rocks, primarily composed of claystone, sandstone, shale, and marl [75]. The Skrabské quarry offers considerable potential for recreational development, which could boost tourism and the local economy. Converting the quarry into a recreational area would create new opportunities for both residents and visitors, ensuring the site's continued value even after the end of its mining operations.

Figure 3. Satellite map of the Skrabske quarry [76] modified by the authors.

3.3.3. Kral'ovany Quarry

The Kral'ovany quarry (Figure 4), located in northern Slovakia in the Žilina region near the village of Kral'ovany, lies on the edge of the Vel'ká Fatra National Park, providing it with a distinctive natural environment. With convenient car and public transport access, the quarry is an appealing destination for visitors [77]. The site holds significant geological value as it was once used to extract limestone and dolomite, materials crucial for the local construction and industrial sectors. Mining activities spanned several decades, leaving a notable imprint on the landscape. Following the end of mining operations, expansive water bodies formed in the quarry, which is now its most prominent feature. The quarry's location and specific microclimatic conditions have fostered unique habitats for various plant and animal species. Surrounded by the forests of the Vel'ká Fatra range, the quarry's ecological value is further elevated [78].

Figure 4. Satellite map of the Kral'ovany quarry [79] modified by the authors.

In addition to its natural appeal, the quarry is also cultural and educationally important. It regularly hosts educational excursions and environmental workshops on geology, ecology, and mining history. The Kral'ovany quarry offers a rare blend of natural beauty, geological significance, and recreational potential, making it a popular destination for visitors and a notable landmark among Slovakia's natural attractions.

4. Results and Discussion

4.1. Evaluation of the Method 1

The point values assigned to the criteria in Table 2 were assigned based on objective indicators and observations in relation to individual quarries. Each criterion assesses a particular aspect that contributes to the tourism potential of the site. Safety of access and accessibility of infrastructure were assessed based on visual inspection of access routes into the site. For infrastructure, parking areas, toilets, rest areas and information boards were evaluated. To determine water quality, the municipalities and communities under which the selected quarries fall were contacted. Furthermore, market surveys were carried out to gather information about the availability of services in the area, information about the possibility of sports activities or about hiking and cycling routes. Aesthetics were assessed using available photo documentation. Water visibility, size, and depth of the water body were assessed based on information obtained from internet sources.

Table 2. Evaluation of Selected Quarries.

Criterion	Beňatina Quarry	Kraľovany Quarry	Škrabske Quarry
Accessibility Safety	4—good access, few hazardous areas	4—good access, terraces	2—more difficult access, walking required
Infrastructure Accessibility	2—basic infrastructure, few parking spaces	4—good infrastructure, access to parking	1—almost no infrastructure
Water Quality	4—clear turquoise water	5—clean water, suitable for swimming	3—good, but impurities present
Presence of Vegetation	4—balanced vegetation	5—balanced vegetation with terraced areas	3—some dense stands
Ecological Value of the Site	4—significant biodiversity	3—moderate biodiversity, natural environment	3—moderate biodiversity
Water Visibility	5—visibility over 8 m, beautiful turquoise color	5—good visibility	3—good visibility but not at full depth
Size and Depth of the Water Body	3—medium depth, smaller size	5—larger quarry with sufficient depth	3—medium-sized quarry
Tourist and Cycling Paths	3—several hiking trails in the area	4—several hiking and cycling routes in the area	2—limited access to cycling routes
Aesthetic Value of the Site	5—natural beauty, comparable to Plitvice Lakes	5—interesting landscape with terraced slopes	3—beautiful but less maintained
Availability of Nearby Services	2—limited services, few restaurants	4—several restaurants and accommodation options	1—almost no services
Sports Activity Options	5—swimming, diving, zipline	4—swimming, some water sports	3—swimming, relaxation

For each of the criteria listed in the table, we assigned a weight that reflects its relative importance in the overall evaluation of the tourism potential of the sites. These weights were determined based on expert knowledge as follows (Table 3):

Table 3. Allocation of Weights to Individual Criteria.

Criteria	Weights	Criteria	Weights	Criteria	Weights
Accessibility Safety	0.15	Ecological Value of the Site	0.1	Aesthetic Value of the Site	0.1
Infrastructure Accessibility	0.1	Water Visibility	0.1	Availability of Nearby Services	0.05
Water Quality	0.2	Size and Depth of the Water Body	0.05	Sports Activity Options	0.1
Presence of Vegetation	0.05	Tourist and Cycling Paths	0.1		

In determining the weights for each criterion, we focused on analyzing the development of nature-based tourism in the selected areas, placing greater emphasis on the natural attributes of the sites, such as water quality, ecological value, and the presence of vegetation. Criteria related to infrastructure and service availability were assigned lower weights, as nature-based tourism prioritizes authenticity and sustainability.

The overall tourism potential for each location was calculated using the weighted average method, which takes into account the assigned scores for individual criteria and their respective weights.

The following formula was used to calculate the tourism potential (TP):

$$TP = \left(\sum (\text{criterion value} \times \text{factor weight})\right) / \sum (\text{weight})$$

- $TP_{\text{Beňatina}} = (0.15 \times 4) + (0.1 \times 2) + (0.2 \times 4) + (0.05 \times 4) + (0.1 \times 4) + (0.1 \times 5) + (0.05 \times 3) + (0.1 \times 3) + (0.1 \times 5) + (0.05 \times 2) + (0.1 \times 5)$

$$TP_{\text{Beňatina}} = 4.25$$

- $TP_{\text{Kraľovany}} = (0.15 \times 4) + (0.1 \times 4) + (0.2 \times 5) + (0.05 \times 5) + (0.1 \times 3) + (0.1 \times 5) + (0.05 \times 5) + (0.1 \times 4) + (0.1 \times 5) + (0.05 \times 4) + (0.1 \times 4)$

$$TP_{\text{Kraľovany}} = 4.8$$

- $TP_{\text{Škrabske}} = (0.15 \times 2) + (0.1 \times 1) + (0.2 \times 3) + (0.05 \times 3) + (0.1 \times 3) + (0.1 \times 3) + (0.05 \times 3) + (0.1 \times 2) + (0.1 \times 3) + (0.05 \times 1) + (0.1 \times 3)$

$$TP_{\text{Škrabske}} = 2.75$$

The results of the tourism potential analysis for the individual quarries, within the context of nature tourism development, highlight significant variations in the attractiveness of these sites. Based on the scoring of each criterion and the subsequent weighted average calculation, the highest rating was achieved by the Kraľovany Quarry, with a score of 4.8, indicating its strong potential for nature-based tourism. This quarry excels particularly in water quality, ecological value, and the presence of balanced vegetation, making it highly appealing to visitors focused on nature-related activities. Additionally, it benefits from adequate infrastructure, which enhances its accessibility and overall visitor comfort. Ranked second is the Beňatina Quarry, with a score of 4.25. Although it also possesses high water quality and natural value, slightly lower scores in infrastructure and service availability position it in second place. Beňatina holds substantial development potential, particularly if investments are made to improve infrastructure accessibility. The Škrabské Quarry, with a score of 2.75, demonstrates the lowest tourism potential. Despite some ecological value and natural features, the lack of infrastructure, lower water quality, and more challenging access limit its suitability for nature tourism. Future development plans for this site should prioritize improvements in accessibility and infrastructure to enhance its overall appeal.

The findings of this research offer valuable insights into the priorities for the development of abandoned quarries for recreational purposes, providing a foundation for effective investment planning and infrastructure enhancement in specific locations. The proposed method of assessing tourism potential, based on a weighted average of various factors, is applicable even in regions with low current tourist interest but potential for future development. The primary advantages of this approach lie in the identification of priority investments, which enable the strategic allocation of financial resources towards areas with the greatest potential impact, such as infrastructure accessibility and safety. In the context of abandoned quarries that possess natural or aesthetic value, this method facilitates the identification of opportunities for revitalization for recreational purposes. It also promotes the efficient use of financial resources and supports decision-making based on objective data. A crucial aspect of this approach is its emphasis on sustainable development, assessing factors such as ecological value and vegetation presence to ensure that development is aligned with environmental conservation. Furthermore, it enables the expansion of recreational opportunities, which can attract diverse groups of tourists. This systematic method, therefore, equips local authorities with a tool to revitalize abandoned areas and strengthen their tourism potential.

4.2. Evaluation of the Method 2

For the calculation of tourism potential for the selected quarries, we used the following formula:

$$TP = W_{Ta} \times Ta + W_{Ai} \times Ai + W_{Ni} \times Ni + W_{Di} \times Di + W_{Si} \times Si$$

To conduct this calculation, it was necessary to determine the values for each criterion, followed by the assignment of weights. In our case, prioritization was given to natural values, considering the characteristics of the selected sites and their significance in the context of nature-based tourism. The chosen sites—Beňatina Quarry, Kral'ovany Quarry, and Škrabske Quarry—are primarily recognized for their natural environments. These quarries offer unique and distinctive natural features, such as rock formations and rich ecosystems. Such attributes enhance their appeal to tourists seeking destinations closely connected with nature.

In Table 4, the criterion values for Beňatina Quarry, Kral'ovany Quarry, and Škrabske Quarry are presented.

Table 4. Criterion Values for Individual Quarries.

	Criterion Values		
	Beňatina Quarry	**Kral'ovany Quarry**	**Škrabske Quarry**
Ta	4	4	3
Ai	2	3	1
Ni	4	4	3
Di	4	3	2
Si	2	3	1

The weights for the individual criteria were calculated using the Analytic Hierarchy Process (AHP) method, based on pairwise comparisons. Table 5 presents the values for the pairwise comparison matrix, a critical step in the AHP method, where the relative importance of each criterion is assessed in pairs. This matrix serves as the foundation for calculating the criterion weights, which are subsequently applied in the calculation of tourism potential.

Table 5. Pairwise Comparison Matrix for Weight Calculation Using AHP.

	Ta	**Ai**	**Ni**	**Di**	**Si**
Ta	1	3	5	7	5
Ai	1/3	1	3	5	3
Ni	1/5	1/3	1	5	3
Di	1/7	1/5	1/5	1	1/3
Si	1/5	1/3	1/3	3	1

Calculation of Normalized Values for Individual Criteria in Table 6 (for example):

- Tourist Attractiveness (Ta):

  Column Sum = 1 + 1/3 + 1/5 + 1/7 + 1/5 = 1.88
  First Normalized Element for Ta = (1/1.88) = 0.533

Table 6. Normalized Values for Individual Criteria.

Normalized Values for Individual Criteria					
	Ta	**Ai**	**Ni**	**Di**	**Si**
Ta	0.533	0.616	0.524	0.333	0.406
Ai	0.177	0.205	0.314	0.238	0.243
Ni	0.106	0.068	0.104	0.238	0.243
Di	0.076	0.041	0.021	0.047	0.027
Si	0.106	0.068	0.035	0.143	0.081

Determination of Weights for Each Criterion Using AHP:

Following the normalization of the matrix, the average value for each row was calculated. This average represents the weight of the corresponding criterion. Thus, for each row, the mean of the normalized values was computed to determine the weight of the criterion.

The final weights for the criteria are as follows:

- tourist attractiveness (W_{Ta}) = 0.483
- access infrastructure (W_{Ai}) = 0.236
- natural values (W_{Ni}) = 0.152
- availability (W_{Di}) = 0.043
- social infrastructure (W_{Si}) = 0.087

Table 7 displays the calculation of the tourism potential for individual quarries after substituting the values into the formula.

Table 7. Calculation of Tourism Potential.

Calculation of Tourism Potential After Substituting Individual Values		
Beňatina Quarry	Calculation	TP = (0.483 × 4) × (0.236 × 2) × (0.152 × 4) × (0.043 × 4) × (0.087 × 2)
	Result	TP = 3.358
Kraľovany Quarry	Calculation	TP = (0.483 × 4) × (0.236 × 3) × (0.152 × 4) × (0.043 × 3) × (0.087 × 3)
	Result	TP = 3.638
Škrabske Quarry	Calculation	TP = (0.483 × 3) × (0.236 × 1) × (0.152 × 3) × (0.043 × 2) × (0.087 × 1)
	Result	TP = 2.314

To verify the accuracy of the criteria determination for the selected quarries (Beňatina Quarry, Kraľovany Quarry, and Škrabske Quarry), we opted to calculate the Consistency Ratio (CR). Table 8 presents the weight values of the individual criteria along with the weighted product values, which are necessary for calculating λmax.

Table 8. Display of Weighted Product and Weights of Individual Criteria.

	Weighted Product	**Weight of Individual Criteria**
Ta	2.6836	0.4824
Ai	1.3269	0.2354
Ni	0.8008	0.1518
Di	0.2181	0.0424
Si	0.4405	0.0866

Based on these values, we can substitute the individual values into the formula as follows:

$$\lambda max = (2.6836/0.4824) + (1.3269/0.2354) + (0.8008/0.1518) + (0.2181/0.0424) + (0.4405/0.0866)$$

The average of these values yields a result of λmax = 5.33

Calculation of the Consistency Index (CI):

To calculate the Consistency Index, we used the following formula, where n represents the number of criteria (in our case 5) and the value of λmax is 5.33, as follows:

$$CI = (5.33 - 5)/(5 - 1) = 0.0821$$

Calculation of the Consistency Ratio (CR):

The Consistency Ratio is calculated as the ratio of the Consistency Index (CI) to the Random Index (RI), where the value of RI depends on the number of criteria, and for n = 5, RI = 1.12. Substituting into the formula gives the following result:

$$CR = (0.0821/1.12) = 0.0733$$

The use of the Consistency Ratio (CR) is essential for verifying the reliability and consistency of pairwise comparisons in the AHP method. The CR helps determine whether the decisions (comparisons) were logical and coherent. If the CR value is less than 0.1, it indicates that the comparisons are sufficiently consistent and the resulting weights are reliable.

In our calculation, we achieved a CR value of 0.0733, which is less than 0.1, confirming that the comparisons are consistent. This validates the proper application of the AHP method in this case, and the criterion weights are relevant.

Based on the analysis of tourism potential using the Analytic Hierarchy Process (AHP), values were calculated for the three selected quarries (Beňatina Quarry, Kral'ovany Quarry, and Škrabské Quarry), reflecting their attractiveness and development potential for tourism. The applied methodology allowed the consideration of multiple criteria, including tourist attractiveness, access infrastructure, natural values, availability, and social infrastructure.

The results of the analysis are as follows:

- Kral'ovany Quarry achieved the highest tourism potential with a score of 3.638. This quarry is characterized by a balanced profile, with strong ratings in the categories of access infrastructure and availability, making it a highly accessible destination. Its natural values and social infrastructure also contribute significantly to its high rating. The results suggest that Kral'ovany Quarry has the greatest potential for tourism development, primarily due to the balance between accessibility and an attractive natural environment.
- Beňatina Quarry scored 3.358, placing it just behind Kral'ovany Quarry. Beňatina excels in natural values, where it achieved the highest score among all quarries. Although its access infrastructure is weaker compared to Kral'ovany, Beňatina appeals to tourists seeking authentic natural landscapes and environments. This location holds significant potential for ecotourism and nature-based tourism activities.
- Škrabské Quarry received the lowest tourism potential score, with a result of 2.314. This lower potential is mainly due to weak ratings in the categories of access infrastructure and availability, which significantly reduce its overall attractiveness to a broader range of visitors. While its natural values and social infrastructure remain relatively favorable, deficiencies in accessibility represent the main limiting factor for further tourism development.

The results clearly show that the development of access infrastructure and improvement in availability can significantly enhance the tourism potential of these sites. Kral'ovany Quarry is the most balanced destination, while Beňatina offers great potential in nature-based tourism. Škrabské Quarry can improve its tourism potential through infrastructure investments.

5. Conclusions

In conclusion, this study provides significant findings and contributions to the evaluation of the recreational potential of flooded quarries, which can be utilized for various purposes, including tourism development. The combination of Method 1 (weighted average) and Method 2 (Analytic Hierarchy Process—AHP) in the evaluation process yielded a comprehensive and precise perspective on the assessment of individual sites.

Method 1 enabled a straightforward and systematic analysis of key criteria, such as access infrastructure, water quality, and service availability. This method provided a quick overview of the conditions of the evaluated sites and allowed for their comparison based on quantified indicators. Method 2 offered a more in-depth analysis through the weighting of individual criteria using pairwise comparisons, which allowed for a more objective assignment of importance to each factor. The combined use of these methods provided a detailed view of the recreational potential of the sites, contributing to an effective decision-making process in the development of tourist areas. The results of the numerical analysis showed that the Kral'ovany Quarry achieved the highest tourism potential with a score of 3.638. This quarry stands out due to its balanced profile, strong ratings in the categories of access infrastructure, ecological value, and service availability. These factors significantly contribute to its attractiveness for tourists focused on nature-based activities. Beňatina Quarry received a score of 3.358, indicating high potential, particularly in the area of natural values; however, its weaker infrastructure limits its overall appeal. Škrabské Quarry, with a score of 2.314, exhibited the lowest tourism potential, primarily due to weaker infrastructure and reduced accessibility.

A key contribution of this publication is the methodological framework, which allows for the identification and quantification of key factors contributing to the development of tourism potential in specific locations. This approach can be applied not only to the evaluation of flooded quarries but also to other abandoned industrial areas with potential for recreational use. The applied methodology is beneficial for both researchers and the public sector, as it provides an efficient tool for investment planning and resource optimization in the development of tourist destinations.

A review of the literature presented in this publication served as a valuable source of inspiration for the development of our own criteria in assessing the tourism potential of flooded quarries. Studies such as Bayat et al. [38], and Tsolaki-Fiaka et al. [44], provided methodological frameworks for the revitalization of former mining areas, which informed the design of our evaluation criteria. By building on these existing approaches, we were able to formulate a robust and tailored methodology for evaluating tourism potential, incorporating key factors relevant to sustainable development. This approach not only aligns with established methods but also enhances the practical applicability of the criteria to the specific context of the quarries studied.

Author Contributions: Conceptualization, L.D., B.I., L'.G. and D.T.; methodology, L.D. and B.I.; validation, L.D. and L'.G.; formal analysis, D.T.; investigation, L.D. and B.I.; resources, B.I. and D.T.; data curation, D.T.; writing—original draft preparation, L.D. and B.I.; writing—review and editing, D.T. and L'.G.; visualization, L.D. and B.I. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data are contained within the article.

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

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