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Developing Sustainable Behaviors for Underground Heritage Tourism Management: The Case of Persian Qanats, a UNESCO World Heritage Property

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Abstract: The Persian Qanats, ancient underground aqueduct systems that have provided irrigation water to arid regions in Iran for over 3000 years, are recognized as a vital element of the country's cultural heritage. Eleven of these impressive structures have been included on the UNESCO World Heritage List, underlining their cultural, social, political, and physical significance. As these underground heritage sites offer a unique opportunity for fostering territorial collaboration and social capital between tourists and the local community, it is important to develop a comprehensive model to influence the behavior of tourists, officials, and natives in their treatment of these invaluable sites. This study aimed to design a sustainable behavior model for underground heritage tourism management in Persian Qanats that have been listed as UNESCO World Heritage properties. The research employed a theme analysis approach, utilizing a statistical sample of 22 base managers and Qanat tourism experts. The study used content and thematic analysis to develop a research model that guarantees the sustainable protection of these valuable underground heritage sites by shaping the behavior of tourists, officials, and natives. The proposed model serves as a guideline for effective behavior management, leading to the preservation of these significant underground heritage sites for future generations. In conclusion, this study provides valuable insights into the sustainable management of Persian Qanats and the promotion of a strong sense of territorial collaboration and social capital between tourists and the local community.

Keywords: underground heritage tourism; sustainable tourism management; tourist behavior; thematic analysis

Citation: Mousazadeh, H.; Ghorbani, A.; Azadi, H.; Almani, F.A.; Zangiabadi, A.; Zhu, K.; Dávid, L.D. Developing Sustainable Behaviors for Underground Heritage Tourism Management: The Case of Persian Qanats, a UNESCO World Heritage Property. *Land* **2023**, *12*, 808. https://doi.org/10.3390/land12040808

Academic Editor: Richard W. Stoffle

Received: 5 March 2023
Revised: 20 March 2023
Accepted: 31 March 2023
Published: 2 April 2023

1. Introduction

Underground heritage is an invaluable historical, cultural, and architectural structure in any country [1]. Currently, one of the most common uses of these sites is tourism, leading to a significant increase in the number of visitors, tour guides, and stakeholders [2]. Consequently, visiting these sites is no longer limited to adventurous tourists, as it was

in the past [3]. However, this trend poses a critical challenge as the behavior of tourists, local communities, and destination managers must be compatible with the sensitivities of these vulnerable structures [4]. Underground heritage sites are exceptionally vulnerable to specific issues, such as moisture and development pressures, and tourism activities can accelerate their destruction [5] Therefore, developing tourism at these sites requires a high level of sensitivity, and a behavioral framework for visitors, local communities, and destination managers must be defined. Thus, sustainability should be the most crucial aspect of underground heritage tourism management [6].

The deserts of Iran boast some of the world's most special and beautiful underground structures, including the Persian Qanats (PQs), which have attracted the attention of famous travel writers such as Alfons Gabriel and Sven Anders Hedin. Gabriel marvels at the natural and man-made structures of the Iranian deserts, stating that "The desert will never let go of someone who once fell in love with it", while Hedin is fascinated by the ingenuity of the Iranian desert natives in providing drinking water [7]. Rabats, caravanserais, castles, historic houses, and especially PQs are some of the magnificent structures in the desert regions of Iran for tourists to explore [8]. Aqueducts (Kariz or PQs in Iran) are an ancient water management system specific to the desert natives, which are now a tourist attraction due to their structure and water supply system [9]. Eleven PQs in Iran have been listed as UNESCO world heritage properties, each with its own unique structure, mechanism, architecture, and water supply technology [10].

However, the effects of destruction and density of footprints are evident in PQ sites due to the expansion of urban communities, development pressures, lack of adequate information, and improper organization of visitors [11]. The lack of a sustainable behavior model for underground heritage tourism is a significant reason for the negative effects on such sites [12]. Tourism models should aim to strengthen the sense of community and social connectedness. Sustainable tourism aims to minimize the negative impact of tourism on the environment and local communities while maximizing the positive benefits for those communities and the economy [13]. A sustainable footprint in tourism refers to the impact that tourism has on the environment and local communities and how that impact can be managed and reduced to ensure long-term sustainability [14]. Despite the recent popularity of underground heritage tourism in Iran, a sustainable behavior model for this type of tourism has not yet been formulated. Therefore, the present study is the first comprehensive study of PQs as a UNESCO World Heritage property, providing a sustainable behavior model for visitors, local communities, and tourism managers towards this valuable underground heritage. The research aims to conceptualize appropriate sustainable behaviors for the sensitive and fragile structure of PQs and develop a pattern for tourists' behavior in these global sites.

In summary, the present research adds significant value to the current literature on underground heritage tourism by providing a sustainable behavior model for PQs in Iran. The study emphasizes the importance of preserving these valuable structures and promoting sustainable tourism practices to ensure their long-term survival.

2. Literature Review

2.1. Qanat as Iranian Underground Heritage

The title of "Qanat" was first mentioned in an inscription by Sargon, the king of Assyria, in 700 B.C. [15]. The peak of prosperity and excavation of Qanats dates back to the Achaemenid dynasty (550–330 B.C.), particularly during the reign of Darius the Great, when this technology was transferred from Iran to Egypt [16]. During the Parthian period, this technology was further disseminated to China, and then in the Safavid period, the digging of Qanats experienced a resurgence due to the intensification of water scarcity. Almost all of Iran's excavated Qanats are from the last 200 years, or in other words, from the Qajar dynasty [17]. As a result, Iran boasts the highest number of Qanats in the world, with approximately 50,000 Qanats covering a total length of 360,000 km [18]. The longest and deepest Qanats in the world are located in the Yazd province and Gonabad city [19].

The simplicity of Qanat construction is a privilege that has undergone little change over the years [20].

The three primary internal components of Qanats are the mother well, wells, and channels. The ultimate point of each Qanat is called the "Pishkar," where the mother well is situated. The mother well, which is the deepest well in the chain of vertical shaft wells, is the head of the Qanat and the main source of the water supply, at which the underground channel terminates (see Figure 1). The deepest mother wells in Iran, with depths of more than 400 m, are located around Gonabad city. In the Qanat system, several wells are interconnected by an underground tunnel that conveys the groundwater downstream. As illustrated in Figure 1, the Qanat consists of a series of tunnels with varying depths that have been excavated from the beginning to the end. The most important function of wells is to transfer air into the ground and dredge the water path [21]. The other component is the channel containing various vertical wells that transport the water from the mother well area to the outlet point, known as the Mazhar. The Mazhar is located near the village and is the area where the Qanat reaches the surface after its underground journey.

In summary, the Qanat is a testament to our ancestors' knowledge of using underground water and its uniform distribution for life in the desert [22]. Naghibi [23] have argued about the structure of the Qanat, its function, and water quality, referring to the Qanat as an attractive man-made underground building. Sedghi and Zhan [18] presented a comprehensive study on Qanat structure engineering. Ebrahimi [9] highlighted Qanat tourism as an environmentally friendly activity, while Khorramrouei and Nasiri [24] discussed visiting the Qanat as a memorable experience for tourists. Profile of a PQ provided in Figure 1:

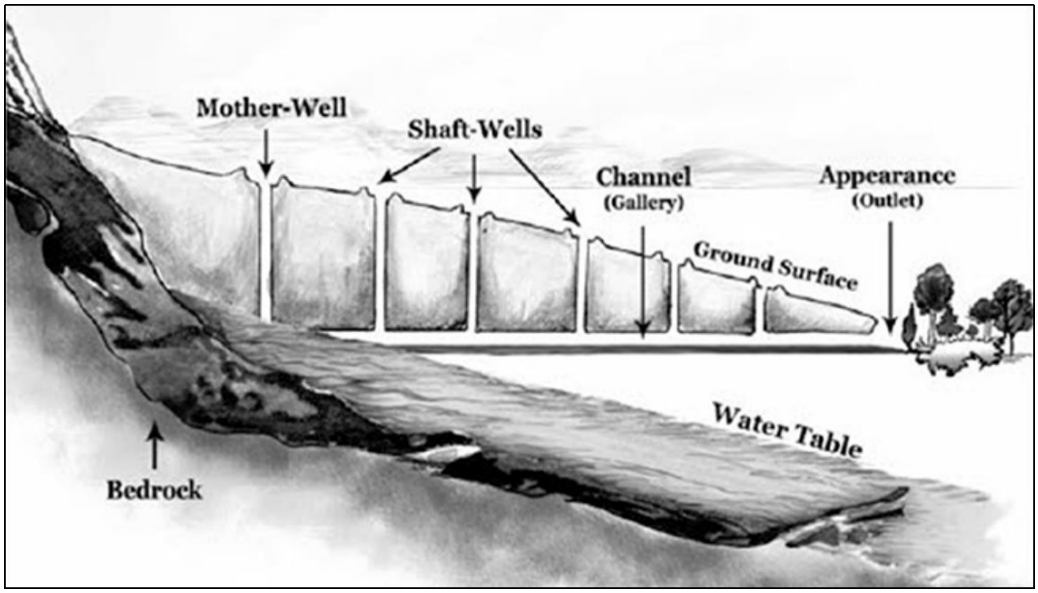

Figure 1. Profile of Persian Qanat [25].

2.2. PQ and Sustainable Tourism Management

Sustainable tourism management involves the scientific intervention of tourism at all levels to shape stakeholders' behavior toward sustainable development goals [26]. As the number of tourists interested in cultural and historical sites increases, it is crucial to establish behavioral frameworks centered on sustainable practices [27]. Passafaro [28] highlights the need to develop comprehensive sustainable behaviors tailored to tourism development, given the different viewpoints among tourists and stakeholders on the concept. Some researchers suggest that the type of travel style and personality of tourists influence their sustainable behavior in destinations. Agyeiwaah [29] recently found that backpackers exhibit more stable behavior in destinations compared to other tourist groups,

making them a positive example for others to follow. However, sustainable tourists, such as backpackers, constitute only a small percentage of visitors to underground heritage sites.

The nascent nature of underground heritage tourism in Iran, combined with the lack of corresponding sustainable behaviors, has led to evident negative effects of human development pressures on these sites [7]. The underground Persian Qanat (PQ) system is one of the most vulnerable underground heritage sites and is highly susceptible to threats from tourists, natives, and local authorities due to its sensitive structure. Zivda and Karimian [30] warn of the consequences of unsustainable behavior on Iran's aqueduct structures. Development pressures and uninformed behavior can cause some old aqueducts to break despite the potential for the beneficial protection of PQs through sustainable management approaches and stakeholder training [31]. Furthermore, the uncontrolled influx of tourists, regardless of the carrying capacity of the site, can also pose a significant threat to underground heritage sites [6]. Lukić [32] highlight the issue of "unscrupulous visitors" who pollute underground sites by leaving waste.

Considering the fragile nature of underground heritage sites, especially the PQs, which are now exposed to various groups of tourists without protection following global registration, combining sustainable management approaches with tourism can serve as a useful tool for preserving these sites [26].

3. Materials and Methods

3.1. Study Sites

In Iran, there are currently eleven PQs that have been designated as UNESCO World Heritage sites, with mills and underground cities being among the most important underground heritage sites in the country. Tourist routes have been established in each of these PQs, allowing visitors to explore the underground canals for hours. The locations of these PQs can be seen in Figure 2, while the specifications of the PQs that have been recognized as UNESCO World Heritage properties are presented in Table 1. The tourist routes in these PQs cover the distance from the Earth's surface to the depths of the underground canals, continuing until the water flow is reached. In the past, this path was used by the locals for water harvesting purposes. Please refer to Figure 3 for a visual representation.

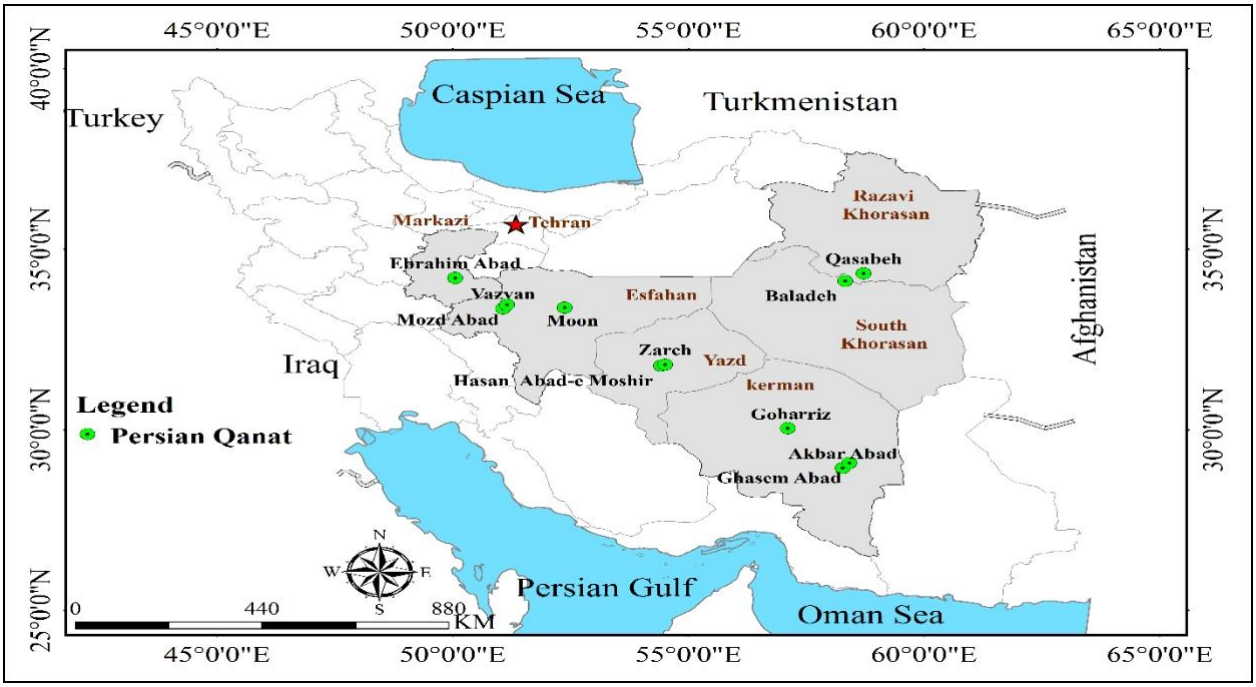

Figure 2. Study sites.

Table 1. PQs listed as UNESCO World Heritage properties.

R	Name	Location	Antiquity	Depth	Length	Highlights
1	Qasabeh	Gonabad, Razavi Khorasan	2500 Year	300 m	33 km	The deepest mother well in the world
2	Baladeh	Ferdows, South Khorasan	2000 Year	150 m	35 km	Includes 16 Qanats, 2 springs
3	Ebrahim Abad	Arak, Markazi	800 Year	110 m	11 km	It is the only conical Qanat in the world
4	Akbar Abad & Qasem Abad	Baravat, Bam, Kerman	200 Year	44 m	1100 m	Twin Qanats, Qasem Abad and Akbar Abad Qanats are twins. The mother well of these Qanats are close to each other, and on the UNESCO Identification of the property and documents, they are on one core and buffer zone.
5	Zarch	Yazd	3000 Year	23 m	120 km	The longest Qanat in the world
6	Hasan Abad-E Moshir	Mehriz, Yazd	2000 Year	40 m	71 km	The best water quality, Plaster and salt layers do not form along the channel path
7	Moon	Ardestan, Isfahan	800 Year	31 m	4 km	It is the only two-story Qanat in the world. On the floors of this Qanat, there are separate streams that never collide with each other.
8	Vazvan	Meymeh, Isfahan	2500 Year	18 m	1200 m	It has an underground dam that can close the outlet and store water for seasons when farmers need more water.
9	Mozdabad	Meymeh, Isfahan	2000 Year	100 m	18 km	The only Qanat with hot and cold water, It looks similar to a cave
10	Gowhar-riz	Joopar, Kerman	750 Year	50 m	3750 m	The most active Qanat water supply from the fault

Source: [33].

3.2. Methodology

This study aims to investigate the conceptualization of sustainable behaviors for Persian Qanats (PQs) listed as UNESCO World Heritage properties using a qualitative approach. Twenty-two PQ experts participated in the study. The selection process involved conducting face-to-face interviews with the managers of each Qanat, referring to the world heritage bases. The sample included eleven managers, selected based on a shared manager for Qasem Abad and Akbar Abad Qanats and Pahlavanpur garden manager, who oversees two UNESCO World Heritage Properties, including Hassan Abad Moshir Qanat and Pahlavanpur garden. Additionally, eleven experts were chosen based on the recommendations of the site managers, who are recognized as experts and guides in Qanat tourism, and a tourism expert and researcher of PQs and Persian gardens familiar with the area where Hassan Abad Moshir Qanat passes through Pahlavanpur garden.

The interviews were conducted in the buffer zone of the Qanats, with the experts of each Qanat present. Structured interviews were used to collect research data, with the aim of addressing the research objectives. Each interview lasted between 30 to 60 min and was transcribed and coded in the second step. The coding process is a crucial source for analysis, as it allows researchers to identify and assign codes to key themes that emerge from data [34].

Theoretical sufficiency and saturation were achieved when the researcher realized that there were no new data that differed from previous data and that these new data repeated earlier findings during data collection and analysis. This indicates that the data collection and analysis process was comprehensive and thorough, and the resulting findings are reliable and valid [35].

The interviews were conducted at the PQ sites, which provided a rich and immersive context for the study. The use of the content analysis method, specifically theme analysis, and Maxqda 2020 software allowed for a rigorous and systematic analysis of these data. By exploring the conceptualization of sustainable behaviors for PQs listed as UNESCO World Heritage properties, this study provides valuable insights into the conservation and management of these significant cultural and natural heritage sites.

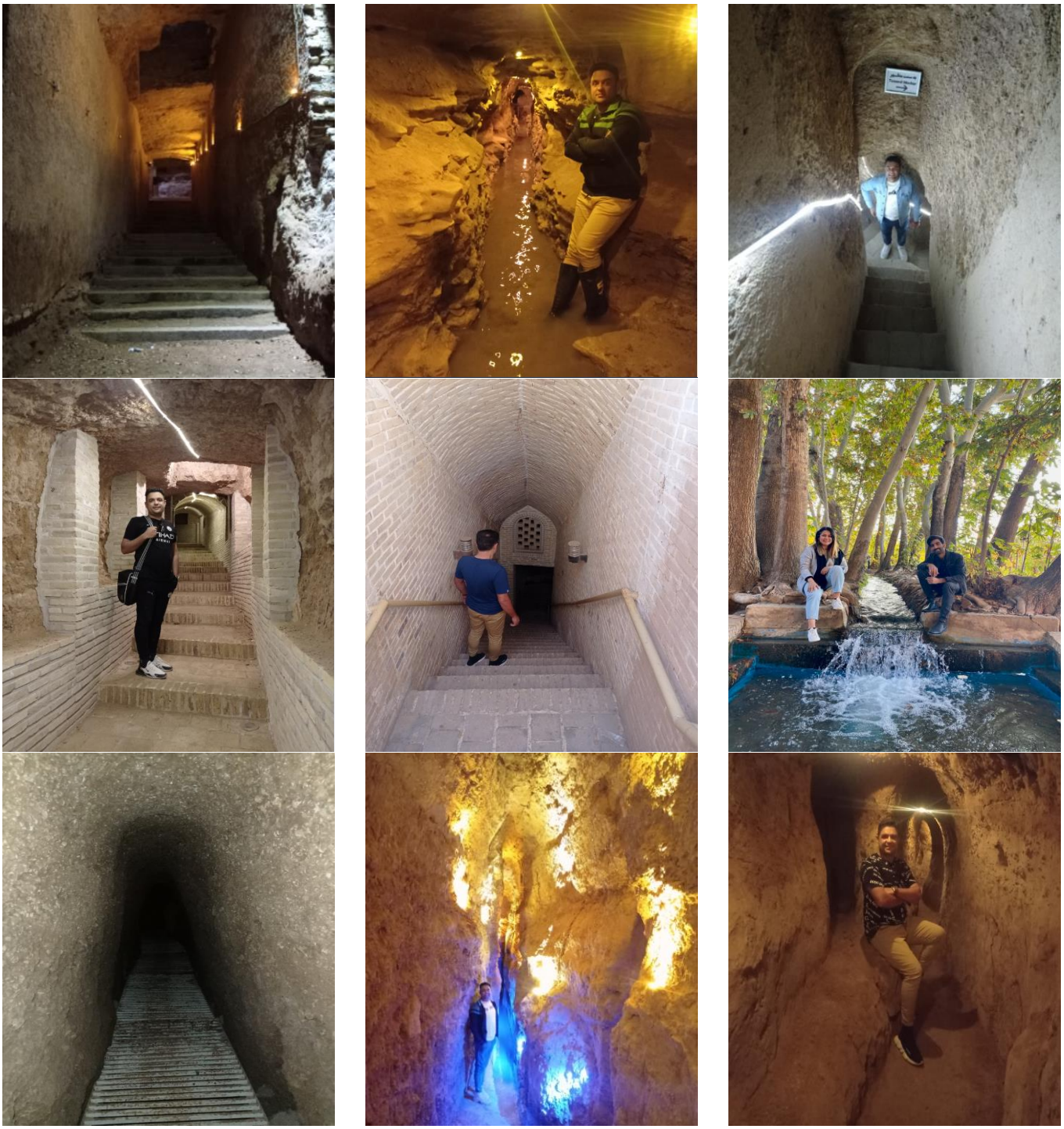

Figure 3. Tourism routes in PQs.

3.3. Validity and Reliability of the Research Model

Holsti's coefficient of reliability was used to assess the reliability of the designed model. To achieve this, another researcher who is an expert in the field analyzed these data, coded them, and categorized them without knowledge of how the codes and concepts were created by the first researcher. The codes were then categorized into concepts, and the themes presented by the second researcher were compared with those presented by the first researcher. Holsti's coefficient was calculated based on the percentage of agreements observed in the analysis by the two researchers using Holsti's method. If the percentage

agreement between the researchers was greater than 60%, then these research data were considered to be reliable [36].

$$PAO = 2\,M/(N_1 + N_2)$$

where M represents the common code and N_1 and N_2, represent the codes of the first and second investigators, respectively. The validity of the research model and themes was assessed through a survey of research experts. The final research model and themes obtained from the analysis of these research data were provided to the experts in the form of a questionnaire based on the Likert scale. Based on the results obtained from the research validation by experts, the internal and external validity of the research model was examined. Finally, an expert panel validated the results, and Holsti's coefficient of reliability was calculated to be 86%.

3.4. Data Processing

3.4.1. Results of the Theme Analysis Technique

After conducting each interview and implementing and writing the transcripts and in-depth analysis of these data, 360 primary codes were extracted. Then, 109 axial codes were described and extracted to search for subthemes of the research. Finally, 21 subthemes and 5 main themes were identified as conceptualizations of sustainable behavior for PQs. The steps of this process are presented in Figure 4. Based on this process, the final main themes and subthemes of the research are presented in Table 2.

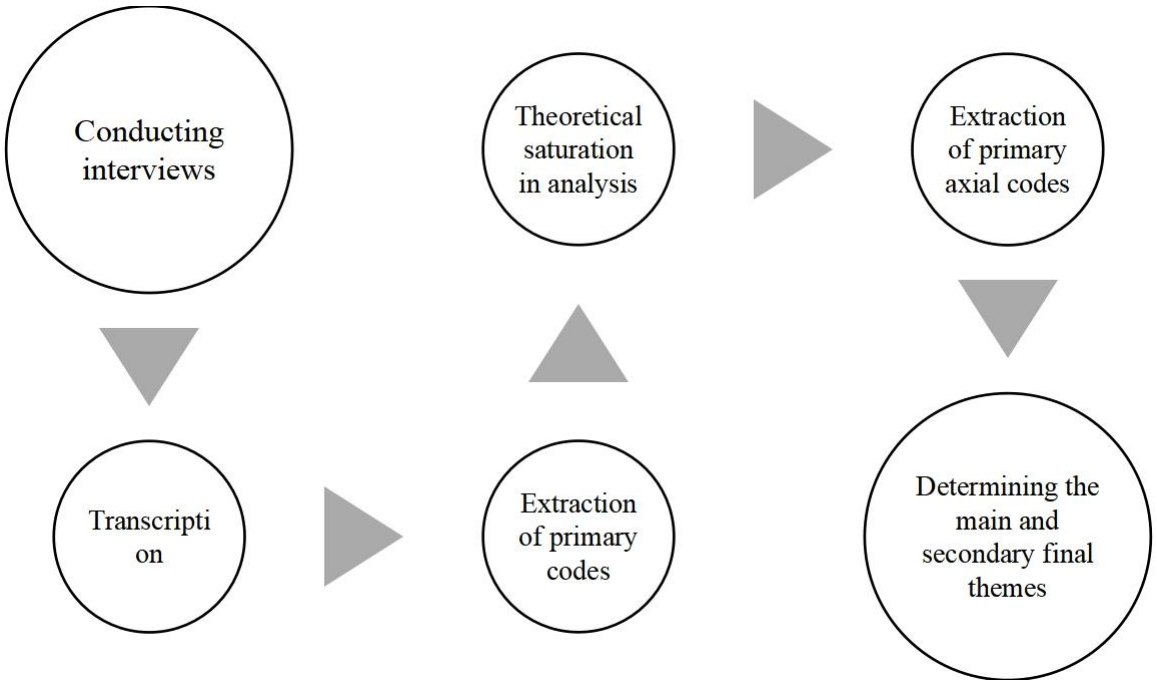

Figure 4. Process of obtaining the final themes of the model.

3.4.2. Designing the Final Research Model

The most significant indicators of sustainable behavior according to the current state of PQs are presented in Table 2. These indicators can be effective in shaping the behavior of tourists, locals, and PQ tourism experts. Based on Table 2, the final research model is presented in Figure 5.

Table 2. Theme analysis results.

Row	Main Themes	Row	Subthemes	Frequency
1	Sustainable footprint	1	Footprint traffic can be harmful to the PQs surface	22
		2	Tourist Walk through standard routes	19
		3	Use appropriate shoes	17
		4	Footprint restrictions on fragile historical routes	16
2	Tourists' noise pollution	5	Determining the limits for the number of PQs tourists	18
		6	Tourists are required to control the sound level	16
		7	The negative impact of noise pollution on PQs	14
3	Sustainable mobility	8	Restrictions on the movement of tourists	20
		9	How to visit without negative effects	18
		10	Follow the visit instructions	17
		11	Do not hit surfaces	15
		12	The strict control of the amount of tourists' equipment	14
		13	Routing based on tourism boards	14
4	Buffer zones controls	14	Respect to the privacy of the PQs buffer zones	22
		15	Severe traffic restrictions in buffers	19
		16	Prohibition of constructions in buffers	18
		17	Surface bearing capacity of soils	17
5	Sustainable routing	18	Standardization of the walking route for tourists	20
		19	Reconstruction of the walking path with the least change in texture	16
		20	The resilience of the path	17
		21	Complexity of reconstructing	16

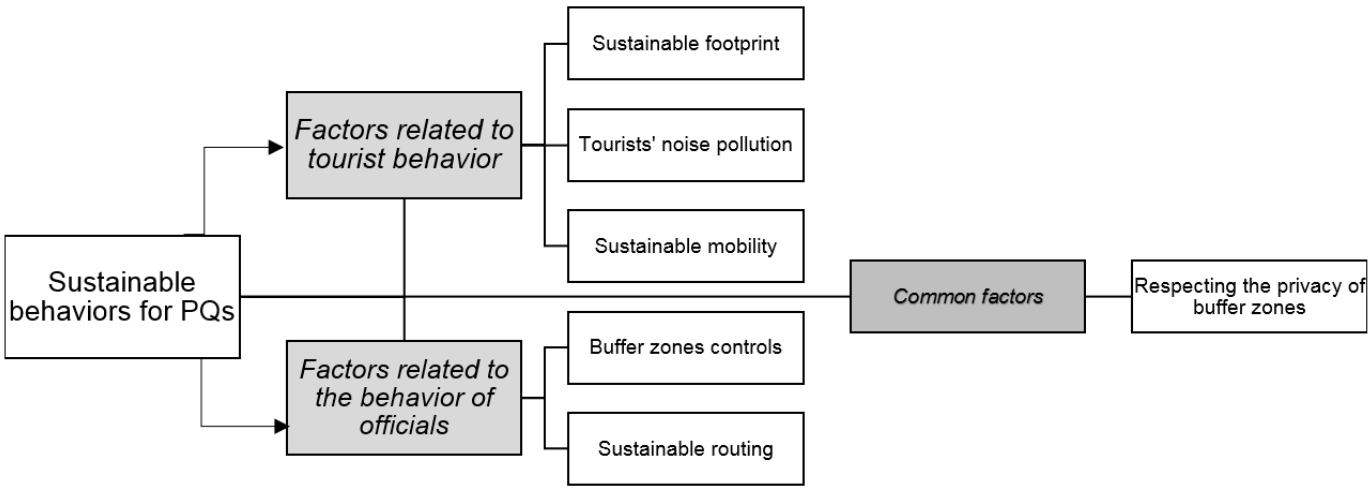

Figure 5. Sustainable behaviors model for PQs listed as UNESCO World Heritage property.

4. Results and Discussion

To ensure the preservation of the technical, cultural, and historical values of PQs, the research suggests the addition of a new function to Qanats tourism that justifies and guarantees their protection. Sustainable behavior development for PQs tourism management is proposed as one of these functions. By developing the areas where Qanats exist, tourism and its revenues can justify the protection of Qanats, and the inclusion of Qanats as a new attraction can help promote tourism in the regions [37]. However, comprehensive studies on PQs have not been conducted, and many people may not be familiar with PQs or the reasons for their registration. Qanats are an environmentally friendly system with unique technical knowledge and engineering heritage that can attract many tourists from around the world. These measures can help to maintain and stabilize PQs. In the final part of the research, the dimensions of the model will be examined separately.

4.1. Sustainable Footprint

When large numbers of tourists flock to a Qanat site, they can cause damage to the environment, structures, and artifacts through physical wear and tear, pollution, and other factors. This can lead to a loss of authenticity and value of the site over time. It is important to manage visitor numbers and behavior to ensure that world heritage sites are protected for future generations to appreciate [38]. A sustainable footprint is crucial for world heritage sites because these sites represent the cultural and natural heritage of humanity and are irreplaceable treasures that need to be preserved for future generations [39]. World heritage sites are places of outstanding universal value, and they are often located in fragile ecosystems that are easily damaged by human activities [40]. A sustainable footprint ensures that the impact of human activities on the environment and the site itself is minimized [41]. so that the site can continue to be enjoyed by visitors without compromising its integrity.

Footprint traffic can be harmful to the PQ surface. The Qanats are underground aqueducts that have been used for thousands of years to provide water to arid regions in Iran. These underground tunnels are often lined with stone or brick, and the surface is vulnerable to damage from foot traffic. When visitors walk on the surface of the Qanats, they can cause damage to the delicate lining of the tunnels. This can lead to cracks and other types of damage that can compromise the integrity of the Qanat system. In addition, foot traffic can cause erosion and sedimentation, which can also negatively impact the Qanats. Similarly, a 55-year-old man (a PQ manager in Cultural Heritage, Tourism, and Handicrafts) said:

> *"To protect the Persian Qanats from the harmful effects of foot traffic, it is important to limit the number of visitors allowed in the tunnels at any given time. Visitors should also be required to wear soft-soled shoes and avoid touching the walls or other surfaces of the Qanats. Currently, there are special boots for tourists, but they are not enough".*

Promoting tourist walking along standard routes can be an effective way to promote sustainable tourism practices and reduce the environmental footprint of tourism [42]. By providing opportunities for visitors to connect with the environment and local communities, destinations can help ensure that tourism contributes positively to the social, economic, and environmental sustainability of a destination [43]. The importance of tourists walking along standard routes in Persian Qanats lies in the cultural, educational, sustainable, and economic benefits it can bring. By promoting these unique and fascinating underground water systems, visitors can help ensure their preservation and promote a greater understanding of Iran's rich cultural heritage. A 42-year-old man (PQs tourism expert) stated:

> *"In Zarch Qanat, we have two water mills, Vazir and Kushk-e-no, which are unique in their own way. Parts of these mills have been worn out and destroyed due to the excessive traffic of tourists and the use of local people. Currently, the major parts of these destructions caused by footprint traffic have been restored, but for a sustainable footprint in PQs, tourist walking along standard routes can help preserve them".*

4.2. Tourists' Noise Pollution

Tourists' noise pollution can pose a significant challenge to world heritage sites, which are recognized by UNESCO as places of exceptional cultural or natural value to humanity [44,45]. These sites are often popular tourist destinations and can attract large crowds of visitors who generate significant noise levels [46]. At PQ sites, tourists' noise pollution can have several adverse effects, such as damaging historic structures and disrupting the experience of other visitors [47]. Furthermore, excessive noise can impact the integrity of the site itself, potentially leading to its removal from the world heritage list. To address this issue, UNESCO has established guidelines for managing tourism in world heritage sites, including recommendations for mitigating noise pollution. These guidelines emphasize the importance of involving local communities in tourism planning and management, promoting sustainable tourism practices, and implementing measures to minimize noise impacts [33].

Local authorities can also take several steps to mitigate tourists' noise pollution in world heritage sites. These measures may include establishing noise regulations and monitoring compliance, using technology such as sound barriers and low-noise equipment, and providing education and awareness-raising programs for visitors [48]. Ultimately, the key to addressing tourists' noise pollution in PQs is to strike a balance between the benefits of tourism and the need to safeguard the cultural and natural values of these unique places [49]. By adopting a collaborative and sustainable approach to tourism management, it is possible to ensure that world heritage sites remain accessible and enjoyable for visitors while preserving their distinctive character and significance [50].

A 38-year-old woman (a PQ tourism expert) stated the following:

> *"The lack of guide signs for tourists to reduce noise pollution in the aqueducts is strongly felt. By using these signposts, tourists can be reminded to be mindful of their impact on the nature and culture around them and take steps to reduce noise pollution in PQs. Signs like "Listen to the Sounds of Nature": This sign can encourage visitors to take a moment to appreciate the natural sounds around them, rather than creating their own noise."*

To address tourists' noise pollution, it is important to educate tourists on the impact of their actions, enforce noise regulations, and promote sustainable tourism practices that prioritize respect for the environment and the local community [51].

Overall, it is important to balance the benefits of tourism with the need to protect the environment and the well-being of local residents [52].

In this regard, a 40-year-old man (a PQ base manager) said:

> *"Many PQs are in the historical context of cities. It has been observed many times that the residents of the neighborhoods where the Qanats are located have complained to us that the noise of tourists is causing them harassment. It is hereby suggested that guidance and training be given to tourists to prevent noise pollution to maintain the sustainable tourism relationship and the quality of life of the local communities".*

4.3. Sustainable Mobility

Sustainable mobility is a crucial aspect of preserving World Heritage sites [53]. Car-free zones designated for pedestrians and cyclists in certain areas within the World Heritage site can create a more pleasant and safer environment for visitors while reducing the impact of vehicles on PQs. By implementing such strategies, PQs can promote sustainable mobility and reduce the environmental impact of transportation on the site. The advantages of using qanats for sustainable mobility are numerous. The tunnels provide a safe and comfortable mode of transportation, shielded from the harsh weather conditions and extreme heat of the desert environment. Additionally, the use of electric vehicles would significantly reduce air pollution and carbon emissions in the region [54].

However, several challenges are associated with the conversion of qanats into a transportation network. The first challenge is to ensure the preservation of the historical and cultural significance of the qanats. The second challenge is the need for extensive renovation and restoration work to ensure that the tunnels are safe for public use. Finally, the cost of such a project could be substantial, and funding would need to be secured from various sources. Despite these challenges, sustainable mobility in the Persian Qanats holds great promise for the future. It would not only provide a sustainable and efficient mode of transportation but also help to preserve an important aspect of Iran's cultural heritage for future generations.

World Heritage sites are often located in areas that are sensitive to environmental damage and are at risk from increased visitor numbers, transportation pollution, and other negative impacts. Sustainable mobility options need to be developed that are appropriate for each individual site to address this issue. Encouraging the use of low-emission vehicles and supporting local businesses that offer these services is one solution. It is also crucial to consider the impact of transportation on local communities and involve them in the development of sustainable mobility solutions. This can help ensure that the needs of both

visitors and locals are met and that the benefits of sustainable mobility are shared more widely. Overall, sustainable mobility solutions can play an important role in protecting vulnerable PQs. By adopting a range of measures that are appropriate for each site, we can help preserve these significant cultural and natural treasures for many years to come.

A 46-year-old woman (Manager of the World Heritage Base of Vazvan Qanat) stated the following:

> *"It is obvious that Vazvan Qanats plays an important role in the economy of region, and local community would face challenges without them. Due to the vulnerability of Vazvan Qanat, guide signs have not been provided for tourists and local people near the qanat and inside the qanat. This can cause the destruction of the qanat over time. Like what we see in the Ghasabeh Gonabad qanat".*

Additionally, a 29-year-old man (a Ph.D. student in tourism management and PQs tourism expert) stated:

> *"The Qanats are a sophisticated system of tunnels, shafts, and wells, and require specialized knowledge to operate and maintain. It is important to approach the Qanats with respect and care and to work closely with local communities to ensure that they are properly managed and maintained. For this purpose, policymakers, managers, and local governments should consider visit instructions for tourists to help the sustainable mobility of qanats".*

4.4. Buffer Zone Controls

Buffer zones surrounding PQs play a crucial role in preserving the cultural and natural heritage of the sites. These zones are established to protect the PQs from a variety of negative impacts, including urbanization, industrialization, and other forms of human development that may harm the integrity of the site. The regulations within buffer zones vary depending on the site and the threats it faces. For example, some buffer zones may prohibit the construction of new buildings, while others may require sustainable development practices that are compatible with the site's cultural and natural values. It is essential to include buffer zones in the overall management plan for the site, which should outline the strategies and actions needed to protect and manage the PQ. The management plan may include a range of measures, such as public education and outreach, monitoring and reporting, and collaboration with tourists, local communities, and policymakers [26].

Human activities, such as construction, agriculture, and mining, pose a significant threat to qanats and can damage or disrupt underground aqueducts. It is crucial to limit these activities in the vicinity of qanats to ensure their long-term sustainability. Buffer zones can be an effective way to restrict harmful human activities and protect PQs from negative impacts. They can also help to raise awareness about the importance of preserving these unique cultural and natural treasures.

In conclusion, buffer zones play a crucial role in protecting PQs from the negative impacts of human activities. These zones should be included in the overall management plan for the site and should be designed to minimize the threats to the site's cultural and natural values. By taking a proactive approach to buffer zone management, we can help to ensure the long-term preservation of PQs for future generations.

In this regard, a 67-year-old man (a PQ expert as a Moghanni, who works on the PQs and is known as a local Qanat specialist and dug the Qanats) said:

> *"The most serious concern about the Gowhar-riz qanat is the expansion of mining activities and settlements around it. If we had not determined the boundary line of the qanat, maybe they would have built buildings to the end of the outlet of qanat! Human activities do not have a direct impact on this sector, but activities such as mining intensify ground shaking. Unfortunately, mining activities have entered the buffer zone of Qanat, and they must be stopped as soon as possible. In this area, mine explosions cause tremors that people sometimes feel. These vibrations also affect the wall of the aqueduct and cause its well to subside".*

To prevent damage to the sites and their surrounding environments, severe traffic restrictions may be necessary for buffer zones around PQs. These restrictions can include measures such as limiting the number and types of vehicles allowed or even prohibiting motorized vehicles altogether. Such restrictions can reduce air pollution, noise pollution, and vibrations, which can negatively impact the sites and their buffer zones. Given the significant effects of urbanization on world heritage sites, it is essential to consider its impact on PQs [55,56]. As many PQs are located in urban areas (e.g., Moon and Zarch), urban expansion can encroach on PQs and cause physical damage, such as erosion and pollution. Moreover, urbanization can lead to increased traffic and noise pollution, which can further damage the sites and their cultural and natural significance. Additionally, urbanization can alter the authenticity and integrity of world heritage sites by changing their original features and cultural significance. For example, constructing modern buildings and infrastructure around PQs can change their traditional appearance and cultural significance, reducing their authenticity and undermining their cultural value. Therefore, it is vital for urban planners and policymakers to take steps to mitigate negative effects, including measures to limit development and protect the qanats, educate local communities about the importance of these sites, and promote sustainable tourism and development in the surrounding areas.

A 39-year-old man (a local leader as a PQ tourism expert) highlighted:

> *"The city of Ardakan, with the only two-story qanat in the world (Moon), has an ancient historical context. However, with unnecessary and hasty development, it has failed to develop proper urban development. With the expansion of urbanization around the neighborhoods where Moon qanat is located, it has put pressure on the main aqueduct and its zoom buffer. Although aqueducts have been considered today, construction permits are still given regardless of aqueduct crossing".*

4.5. Sustainable Routing

Sustainable routing is critical in World Heritage Sites as they are often sensitive areas that require careful management to preserve their unique natural and cultural values [57]. Sustainable routing involves designing and implementing systems that minimize traffic's impact on the environment, cultural heritage, and local communities [58]. Promoting sustainable modes of transport, such as walking, cycling, and public transportation [59], can reduce traffic impact. Facilities such as bike lanes, pedestrian walkways, and well-connected public transportation systems can achieve this [60]. Engaging with local communities and involving them in the design and implementation of sustainable routing systems can ensure that these systems are effective, socially acceptable, and supported by the community. Sustainable routing in PQs involves designing and implementing routing systems that minimize human activities' impact on the qanat system and ensure that the qanats continue to function effectively and efficiently. Moreover, raising public awareness about the importance of qanats and the need to protect them can help build support for sustainable routing practices.

Standardizing walking routes for tourists can be advantageous. On the one hand, it can provide a clear and consistent experience for PQ tourists, improving their satisfaction and reducing the risk of confusion or loss [60]. It can also ensure that important landmarks or attractions are included in the route, providing a comprehensive experience of the PQs. The walking route should be safe and well-maintained, with clear signage and instructions to help tourists navigate the route without difficulty. The route should be designed and managed in a way that minimizes its impact on the PQs. Ultimately, the decision to standardize walking routes for PQ tourists will depend on the specific destination, visitors' needs and preferences, and the goals of the local community and tourism industry. A balance must be struck between providing a consistent and high-quality experience for tourists and preserving the authenticity and diversity of the destination.

A 46-year-old man (a PQ manager) stated:

> *"The Qanats of Vazvan benefits from underground dam technology that in its time was a breakthrough engineering construction. According to the world registration of Mozd*

> *Abad Qanat and its role in promoting tourism and developing the economy of the region, it was decided to build guide signs for Qanat tourists. Since this Qanat is very vulnerable, with this measure, it prevented the Qanat from falling and provided a Standard walking route for tourists".*

Furthermore, a 37-year-old woman (a PQs tourism manager) said:

> *"The materials used to resilience the path of PQs should be durable, such as stone or brick, and resistant to water damage and erosion. The use of high-quality materials can help ensure that the path remains intact and stable over time. In Gowhar-riz Qanat, tourists can walk on the water, so they put metal scaffolding on the water that tourists can walk on. As a result, for the stability of the path, materials must be used that, in addition to standardizing the path for tourists, the Qanat will not be damaged".*

5. Conclusions and Policy, Practical and Academic Implications

The Qanats are a unique example of ancient Iranian technical innovation for groundwater exploitation on the ground and have the potential to be a popular tourist attraction. Tourists seek cultural experiences when visiting a destination, and this study aims to fill the gap in the field of Qanat tourism. We reviewed 11 Qanats across six provinces in Iran using a new qualitative research method and proposed a sustainable behavior conceptualization for underground heritage tourism management. By introducing Qanats as a platform for expanding tourism in areas where they are located, we believe that the field of tourism in the Qanat civilization can be useful. This can be achieved by increasing tourists' and locals' awareness about the importance of the Qanats and the significance of protecting and preserving them [61–63].

Our results indicate that sustainable practices such as sustainable footprint, reduction in tourists' noise pollution, sustainable mobility, buffer zone controls, and sustainable routing can ensure the sustainable protection of PQ heritage by shaping the behavior of tourists, officials, and natives. The study also confirms that creating solo trips to these areas can protect them from destruction and damage. We recommend that the negative effects of mass tourism on the environment and pristine areas be objectively explained through field studies and scientific research and that postmodern ecotourism be promoted in future studies. The findings of this study have implications for Iran's alignment with the goals and programs of international institutions and organizations such as FAO, IFAD, UNICEF, UNWTO, and WHO. Furthermore, international organizations such as FAO can assist Iran in strengthening the current sustainable saffron production system using Qanat water and aligning production and productivity with the goals of food security programs. Tourism management of heritage sites, especially underground heritage tourism, is a crucial topic to address. The PQs, a UNESCO World Heritage property in Iran, serve as an interesting case study to develop sustainable behaviors for underground heritage tourism management. A key challenge in managing underground heritage tourism sites, such as PQs, is ensuring that tourism activities do not harm the site or the surrounding environment. This can be achieved through managing visitor numbers, developing appropriate infrastructure, and educating visitors about the importance of preserving the site. Several strategies can be implemented to promote responsible tourism at the PQs, such as providing information on water conservation and the role of the Qanats in supplying water to the region. Encouraging visitors to take part in conservation efforts, such as volunteering for maintenance and preservation tasks, can also be an effective approach. Developing sustainable behaviors for underground heritage tourism management at the PQs requires a coordinated effort from all stakeholders, including local communities, tourism operators, and government agencies [64,65].

Practical and academic implications must also be considered based on research results. The article emphasizes the importance of developing sustainable tourism practices that preserve the natural and cultural heritage of the PQs. The article also stresses the importance of educational programs for tourists and local communities to raise awareness about the cultural and natural significance of the qanats and promote sustainable tourism practices.

The article also draws on behavioral science research to develop strategies for promoting sustainable tourism behavior. So, this framework can be used by other researchers or heritage site managers as a guide for developing sustainable tourism practices. Other underground heritage sites can learn from the successful sustainable tourism practices implemented at Persian Qanats and adapt them to their own sites. This can contribute to the academic understanding of human behavior and decision-making in the context of tourism. Moreover, this research provides insights into the management of tourism activities in underground heritage sites. This can be useful for the development of tourism policies and practices that balance the economic benefits of tourism with the need to preserve natural and cultural heritage. By adopting sustainable behaviors, we can ensure that the Qanats are preserved in their original condition for tourists to enjoy and learn from. Sustainable behaviors for underground heritage sites are crucial for the tourism management of PQs tourism as they help to preserve this valuable heritage, ensure the long-term viability of tourism in the area, and promote a responsible and ethical approach to tourism. This research highlights the importance of sustainable behaviors for underground heritage tourism management in other underground heritage sites that are in danger. In such a way that if sustainable behaviors are not observed in these sites, the same disaster that happened to Qanbarabad Sheikhi Qanat, which was blocked due to non-compliance with sustainable behaviors within its limits, may befall these sites.

Examining the architecture and structure of Qanats can be a very interesting topic for future research. As per the Ministry of Energy, approximately 36,300 Qanats have been identified in Iran, and it is suggested that in future research, the attractions and tourism capabilities of these Qanats be examined. It is also suggested that new strategies for the maintenance and reconstruction of PQs be examined in future research. As Qanats are valuable water resources in agriculture, future research should focus on managing Qanat water resources and preventing Qanats from drying up. In the arid climate of the central region of Iran, most of the water needed for agricultural purposes has been supplied by Qanats for thousands of years, and the area under cultivation for agricultural purposes depends on the number of Qanats and the amount of irrigation from these ancient water structures. Given the debate over Qanat agriculture and food security, future studies can undoubtedly focus on these issues. To introduce pristine and amazing areas in tourism management, it is suggested that researchers should use these methods in future research related to tourism management. Although recent studies and researchers in this study emphasize the high value and credibility of qualitative studies in tourism research, future research can examine the quantitative components related to Qanat tourism based on quantitative studies. The findings indicate that local government officials, policymakers, and tourism managers need to be aware of the negative effects of tourism on PQs. They should also respect the privacy of the buffer zones surrounding the PQs, enhance the creation of designated tourist routes, ensure a balanced development of tourism resources, control the number of tourists in a scientific manner, raise tourists' awareness about protecting the PQs, and work toward achieving sustainable development for the local community.

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

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data developed in this study will be made available on request to the corresponding authors.

Acknowledgments: This research was supported by the Hungarian University of Agriculture and Life Sciences and the Doctoral School of Economic and Regional Sciences (MATE), Hungary.

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

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