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Research Article

Environmental risks and the impact of rehabilitation on the sustainability of affected buildings in urban communities

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ABSTRACT

This work explores how the rehabilitation sector can significantly minimize environmental risk by restoring, maintaining, strengthening, and installing practices in rehabilitation or new construction projects. The rehabilitation of affected buildings is considered an effective strategy to reduce the impact of pollution on the construction industry and rebuild the resilience of urban communities by preserving the structures and improving their performance capacity. Encouraging the reuse of more efficient materials and modern technologies and applying sustainability principles (Green, Local, and Digital). The results of the sample of 45 buildings surveyed and rehabilitated in the field show that around 80% are eligible, based on the building's various safety and hygienic conditions, an increasing number of affected buildings needing reconstruction, strengthening, and rehabilitation interest at percentages (17, 33, and 50) % respectively. A perspective on the indicators of failure of the building affected by the Türkiye-Syria earthquake has been presented. These were observed by analyzing the data reported and conducting field inspections of the phenomenon. The collapsed buildings index (CBI) and the main topic, the impact of rehabilitation on building sustainability, have been brought up.

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1. INTRODUCTION

Residential buildings in Syria are one of the largest sectors that have been damaged due to conflict and natural disasters. The crisis led to the destruction of more than 80% of buildings, with an extent varying from partial or total destruction [1, 2]. The Türkiye-Syria earthquake is considered one of the most severe disasters in the Middle East during this century. The event was catastrophic due to the loss of humans and the massive damage to the infrastructure in both countries [3]. The location of the Feb 06 earthquake was sensitive and affected several regions in Türkiye, Syria, Iraq, and the border zone between these countries. AFAD and the NEC reported an earthquake of 7.8 magnitudes in the southeast of Türkiye [4] centered about 70 kilometers from Gaziantep. About 78 aftershocks have been confirmed and near the Türkiye-Syria border.

Many aftershocks occurred after the earthquake in several zones in Türkiye and Syria Figure 1. All aftershocks were significant, ranging from magnitude 6 to 6.7 [4, 5].

More than 6000 buildings collapsed or were severely damaged in Türkiye and almost 2000 in Syria after the earthquakes. 102 significant buildings have been report-

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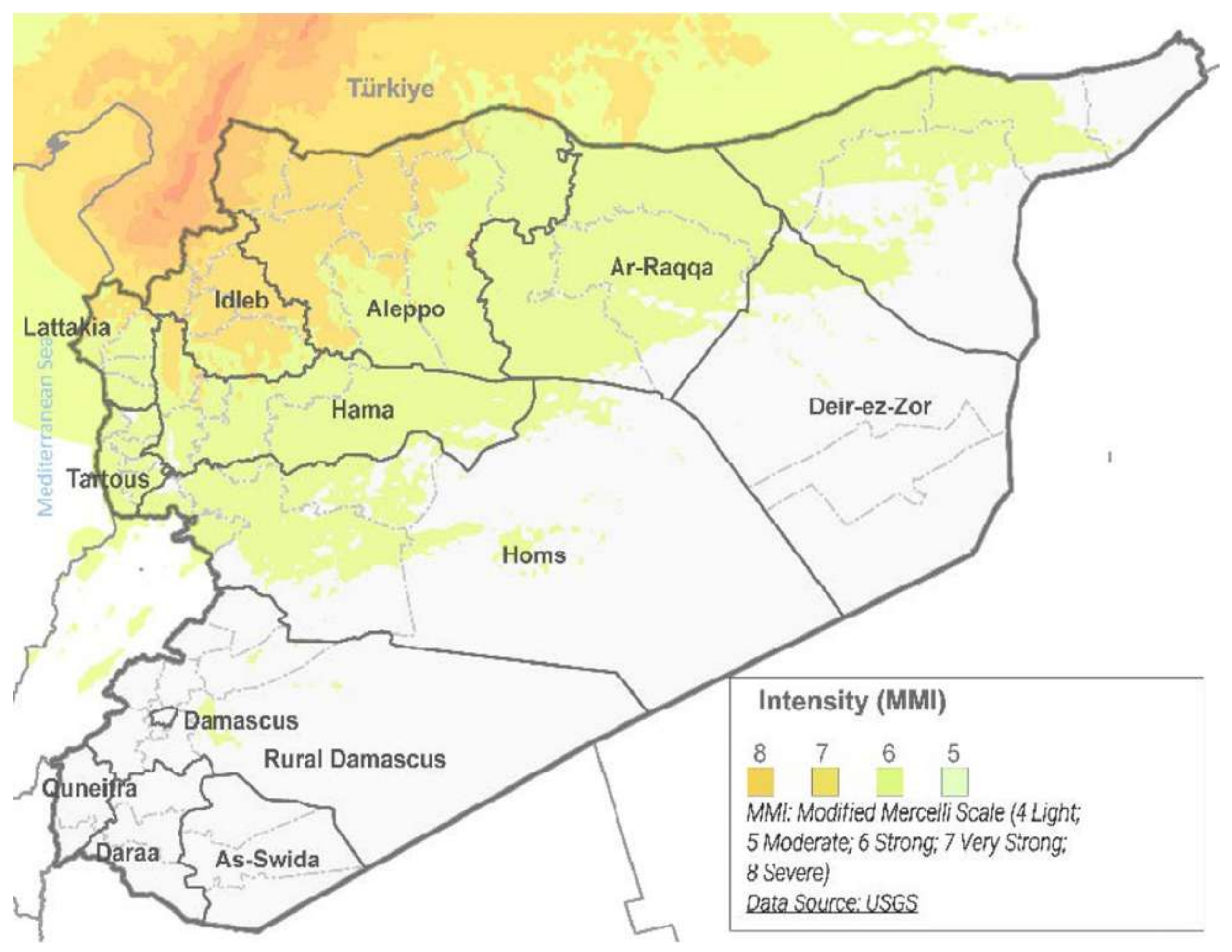

Figure 1. Maps on the earthquake affected areas in Syria generated by HCT.

ed to have collapsed in Tartous and Lattakia, 41 of which are in Jableh. Furthermore, the damage to the infrastructure was extensive throughout Aleppo. Statements that 54 buildings have collapsed, and an unknown number of buildings have partially impacted. In Hama, four buildings collapsed, and one building in Homs collapsed. In the northwest rural area of Hama, several houses have partially collapsed. The earthquake's effects included service structures, educational facilities, and wash facilities. In Syria, after 12 years of war, most of its infrastructure was destroyed, and millions of people needed safe buildings with a high risk of collapse of buildings that are sensitive to earthquakes and have already been damaged by the crisis.

The primary structure assessment in the significant areas of 'Red Zones' in the affected governors has been conducted by technical committees from the authorities and INGOs to determine the safety of buildings. Most of the assessment feedback focused on the design of buildings and the shape of the failure. The other significant effects have been overlooked, including the sewage system and base soil malfunctions, which are a significant factor in earthquake design. This led to an increase in construction debris and rubble. Consequently, this affected sector is responsible for producing significant environmental impacts. It depends, in short, on resources and circularity and the increase in construction waste in a limited geographical area. As well as the specific destination of the waste generated during the service life of the building. The movement of the population to other regions causes climate and demographic change in their original region and destination.

On the other hand, achieving sustainable development has become a global necessity because it is directly linked to all areas of the human life cycle in all sectors, including society, economics, and the environment [6]. However, achieving sustainability in civil facilities requires a specific evaluation to mitigate the negative impacts and increase the positive effects of its application on the building cycle. Design, construction, operation, maintenance practices, and the end of its life cycle.

The rehabilitation of damaged buildings is one of the most critical interventions conducted by INGOs, and stakeholders funded this type of project due to its significant impact on sustainability and its indirect effect on the economy, community, and the environment [7, 8]. The rehabilitation is part of the reconstruction phase. This transition phase leads to constructing permanent housing, which is relative-

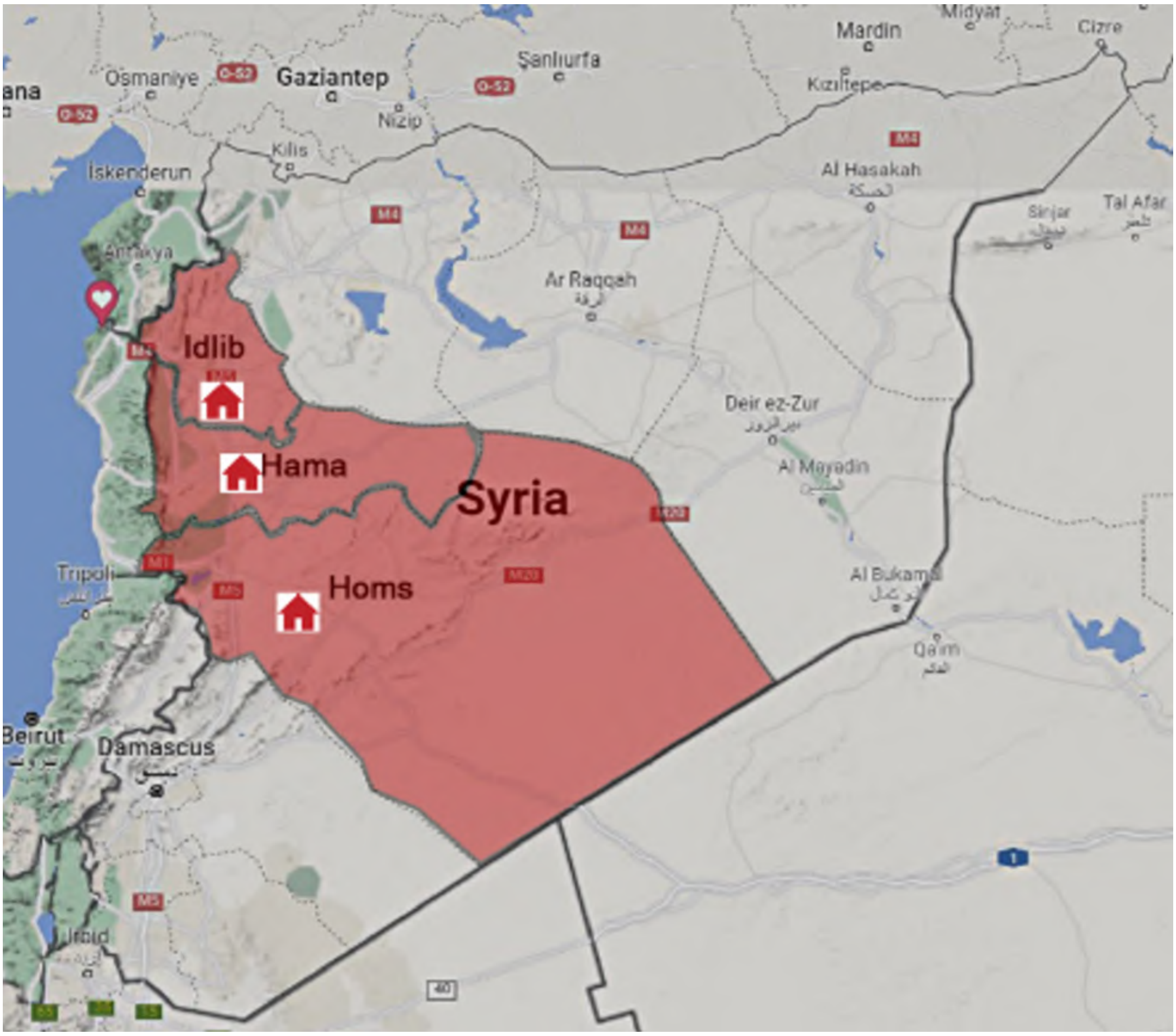

Figure 2. Survey target areas in Idlib, Hama, and Homs governorates.

ly more comfortable and crucial for users' well-being [9]. Since the lifecycle of the damaged buildings ranges between 20–50 years, considering the average operational lifecycle ranges from 50-80 years, this indicates that the most significant percentage of buildings can be intervened in. Rehabilitation work can be carried out due to the war that caused damage and the lack of regular care over time.

The rehabilitation shall be led by a successful and competent project manager [10] have at least the key competencies (technical, emotional, behavioral) and leadership styles to manage projects successfully. The survey conducted in the rehabilitated buildings in some Syrian governors, including Homs, Hama, and Idlib, Figure 2, led to improvements in the target area and the surroundings. It also enhanced scenarios for long-term maintenance and rehabilitation procedures for local and regional improvement.

The partial damage in the building does not constitute a justification for carrying out rehabilitation. The decision to carry out rehabilitation requires a transparent methodology. Taking safety and hygiene factors as a priority, conducting initial risk assessments and challenges in rehabilitating affected buildings [11]. Technical pre-assessment of the building and the area will determine the existing structure's condition and verify the relevant designs and documents that give information on it and the characteristics of the used materials. Thus, using pre-assessment, inspection, and evaluation tools supports the procedure more clearly where sustainability standards are integrated, which contributes to achieving other goals through integration with the environmental principles of the local community.

The principle of sustainability in the damaged building seeks to restore it, protect the ecosystem as a whole, and build a healthy, comfortable, and adequately protected community. Based on this approach, the paper aims to shed light on rehabilitating damaged buildings, explore alternatives to reduce the negative impacts, promote sustainable solutions to preserve the facility, and improve environmental and living conditions in the targeted area.

2. REVIEW OF LITERATURE

Sustainable construction practices cannot be achieved in the building construction industry without considering sustainability activities, including the environment, economy, and society. Okoye et al., [12] indicated the importance of sustainable construction practices in every building project and affirmed the indispensability of environmentally related activities among the tripod of sustainability in the effort towards achieving sustainable construction practices in the building industry. Highlighted the importance of salient activities that must not be ignored by building construction stakeholders in every building project. It further revealed that the five most essential construction activities for sustainable construction were using naturally occurring building materials, using recycled building materials, non-use of endangered materials, bioclimatic technology, and use of renewable resources, respectively. 35 variables were highlighted as having high critical levels of sustainability in 55 activities in Nigeria. Of this number, 18 were environmentally related, eight were economically associated, and nine were socially related. The average relative importance index RII of environmentally related activities is 0.841, economic activities are 0.828, and socially associated activities are 0.808, respectively.

Thus, the use of sustainable construction designs and construction strategies that are environmentally friendly has become the custom in Ghana. All construction activities should be subjected to an environmental impact assessment to determine potential risks and develop mitigation measures before execution. Ametepey and Ansah [13]. The conducted study in Ghana showed that, out of a total of 33 environmental impacts identified, the top ten most significant environmental impact factors are as follows: raw materials consumption, noise, and vibration generation, vegetation removal, interference with the ecosystems, water consumption, and electricity consumption, loss of edaphic soil, dust generation machinery, ordinary waste And fuel consumption. The 33 environmental impacts identified in the study were grouped into nine categories and ranked accordingly. The relative importance of the effects identified was calculated and ranked by the relative importance index RII. Atmospheric emissions (0.814), water emissions (0.753) / sanitary water (0.698), waste generation (0.852), soil alteration and land occupancy (0.67), resource consumption Electricity (0.922) / fuel consumption (0.898), local issues (0.891), transport issues (0.860), effects on biodiversity potential soil erosion (0.897), accidents and incidents fire outbreaks (0.795).

Despite the global concern about the impact of construction practices on the environment, the consensus is that sustainability in all phases of construction practice, including rehabilitation, has not been fully achieved regarding sustainability development. Therefore, the most important factors must drop into the criteria and environment assessment.

3. BUILDINGS FAILURE INDICATOR

In some cases, earthquakes are one of the reasons for the failure of the destroyed structural system. However, many other reasons and indicators must be considered. The fascinating collapses are similar forms that usually occur in buildings as an earthquake impacts, and different ones are observed as the "Pancake Collapse." This is considered a severe phenomenon [14], described as a progressive failure that generally begins at the bottom of the floor systems when there is no support in the basement or building foundations.

Even though the crisis in Syria caused unstable structures, the constructed buildings showed an appropriate and not dangerous response to the aftershocks in all areas, which can be noted in the affected war areas of Aleppo and the northern countryside of Hama.

This overview was found based on the zone level that included collapsed buildings compared to the total number of buildings in the urban center per governorate, defined as the collapsed buildings index (CBI) Equation 1, with a maximum value of 1.

$$CBI = \frac{\text{Collapsed Buildings in Zone}}{\text{Total Buildings in the urban center}} \text{ ... Eq. 1}$$

The methodology of CBI is important in determining the degree of a building's response to the disaster, providing preliminary details about the causes of the collapse of buildings, and comprehensive reports related to each case study. According to the Syria Central Statistics, the urban centers had reached 14011 in 2011 [15], in Hama had reached 767 centers, and Hama governorate witnessed the collapse of a number of buildings in the Al-Arbaeen neighborhood, including an 8-storey building Figure 3, and other buildings in Al-Ghab rural areas.

Two centers out of 767 were affected. This means an accepted indicator of CBI of buildings' behavior under the earthquake. On the other hand, field inspection, visual observation, and technical assessments were conducted in person by technical specialists on-site to ensure the reliability and validity of the data collected. All related collected data in the field, along with the available formal documents and any supporting information, can be obtained from the owners. In the next step, all collected data is reorganized and prepared for double-checking and analysis using manual and digital methods.

This case pointed out the failure of the buildings related to several indicators, including the main topics:

- The usage of a structured system designed to resist earthquake loads.
- The difference between the original structural design and what was implemented on the ground.
- The damage to the service connections (sewer/water) inside/outside buildings and effects on base soil.
- Others related to Inhabitant actions and caused negative impacts on the building due to human errors/negligence and structural problems.

Based on CBI, the main findings indicate a good response of buildings to the disaster, with a small percentage, 0.26% hard affected in the "Red Zone" and more than 99%

Figure 3. The collapsed 8-storey building in Hama.

classified as mild to moderate affected in the case study. The main reasons for the performance decline of buildings due to external effects are:

- Failures in standard design practices and meeting building codes.
- Malpractices in the building during its operational lifecycle.
- Lack of awareness among residents of early detection practices and proactive building rehabilitation can increase potential resistance and avoid significant damage.

The exposure of buildings to any external risk affects all aspects of their desired sustainability at the building level and even the area. The rehabilitation of the building in the life cycle is considered one of the fundamental issues that can be applied before the decision on demolishing and rebuilding. Because of its impact on the economic and environmental aspects [16, 17], thus the sustainability of the damaged building.

4. MATERIAL AND METHODS

The scope of the practical application of the rehabilitation of damaged buildings includes a series of stages, starting with the pre-assessment of the area and neighboring buildings, environmental assessment tools, and the technical assessment of the damaged structure. Then, determine the necessary work to restore the building's function and link it to sustainability requirements with its structural, social, and environmental trends [18, 19].

4.1. Site Preparation

An essential phase of the sustainability of the rehabilitation of damaged buildings is preparing the work site by maintaining cleanliness, ensuring the required protection requirements, and mitigating the negative environmental impact. Resulting from the accumulation of debris, the structure remains, dust emissions, and the remains of the used materials.

4.2. Rehabilitation

The primary purpose of rehabilitating damaged buildings is to protect residents by obtaining a characterized, more durable, and stable structure and to achieve sustainability in the original function of the building by providing construction materials and internal and external equipment.

As rehabilitation can be difficult in a damaged building, it is good practice to merge the rehabilitation and restoration works with construction projects, and this should be done in the associated planning and budgeting [18, 20]. It should be an integral part of the project through the planning, design, construction, and maintenance phases.

- Determine safety requirements: This involves the application of technical building requirements, "Safety Precautions" [21], and standards to ensure that the proposed rehabilitation will not hinder safety.
- Determine the aim of rehabilitation: This could include the provision of basic needs, restoring structure, visu-

al improvement, using alternative energy sources, or a combination of these.
- Selection of appropriate rehabilitation: The rehabilitation program needs to be selected according to the requirements and the impact of environmental values.

An appropriate sustainability technique could be achieved by applying sustainability and economic principles. However, there are many appropriate ways to integrate the local community into rehabilitation, such as planning all needs in advance, relying on local materials, implementing the work with local labor, and choosing appropriate solutions with community participation.

4.3. Regular Monitoring

The rehabilitation is paralleled by continuous monitoring during and after the completion of the process. Even though the building restoration process may not mimic the original construction scene, it is important to follow the procedure and monitor the results to achieve stability and obtain a method that meets sustainability requirements. Monitoring helps technicians decide whether rehabilitation is active based on the community's satisfaction and the result's impact.

Periodic monitoring of rehabilitation gives a noticeable indication of the effectiveness and importance of the procedure, seeking to develop the activity, address related issues, and find appropriate solutions by avoiding adverse impacts.

5. THE PROCEDURE OF DAMAGED BUILDING REHABILITATION

Rehabilitation of damaged buildings can be distinguished into two types:
- Light rehabilitation of the damaged building.
- Rehabilitation includes restoring and strengthening structural elements.

In both, the rehabilitation aims to increase the building's efficiency or restore its function. Rehabilitation of damaged buildings can be understood as processes aimed at raising the quality level of building systems and achieving compliance with sustainability standards and functional requirements. Restoration, renovation, maintenance, and retrofitting refer to a wide range of actions that seek to recover the usability of buildings and are considered the main concepts of building rehabilitation [22, 23]. They can be defined as:

Rehabilitation processes are strategies to adapt the building to reuse, and they must meet the functional requirements while being aligned with sustainability. In addition, one must analyze the motivation of the rehabilitation intervention and the use of sustainable solutions in the affected building [17], which justify the practice of rehabilitation of buildings which includes the following two topics:
- Reuse existing infrastructure in the building location and impact the affected landscape.
- More economy due to human deficit to reconstruction and more efficiency in environmental sustainability.

Sustainable urban development in the world continues to be a struggle. Despite the relative dearth of literature probing sustainable development conceptually [24], conceptualizing environmental, economic, and social/ community has gained widespread traction. Figure 4 shows that sustainability intersects with other social conditions, such as resilience, liveability, adaptation, innovation, and reconciliation, as essential conditions of positive social life. Community sustainability is defined as the long-term durability of a community [25], as it negotiates changing practices and meaning across all the domains of culture, politics, economics, and ecology. The economy is a social domain that emphasizes the practices, discourses, and material expressions associated with resource production, use, and management. The potential benefits include resource efficiency [26], reduced environmental risk, cost reduction, and job creation.

Figure 3. Conceptually sustainable development circle.

The natural realm includes a spectrum of environmental conditions, which refers to the extent of people's impact upon and involvement with nature that can enhance both their physical well-being and the capacity of the urban and hinterland environment to flourish in the face of external implications [25, 26]. Including recycling processes and considering energy use, passive use of natural resources, energy efficiency, water management, and savings. Waste management in buildings, air quality and the indoor environment, thermo acoustic comfort, and rational use of materials [27].

6. SUSTAINABILITY IN THE AFFECTED BUILDING REHABILITATION

To establish the principle of sustainable "Green" construction, several headings: go green, go local, and go digital [28–31].

Go green: Sustainable construction techniques and knowledge are incorporated into the rehabilitation work of damaged buildings and adapted to the old scenario.

Go local: It considers the knowledge of the local constructive culture, the constructive techniques, and the supply of the materials used in the construction. Thus, relying on local materials and implementation reduces the overall environmental impact of the building.

Go digital: By applying Building Information Modeling BIM techniques in design, construction, and maintenance practices.

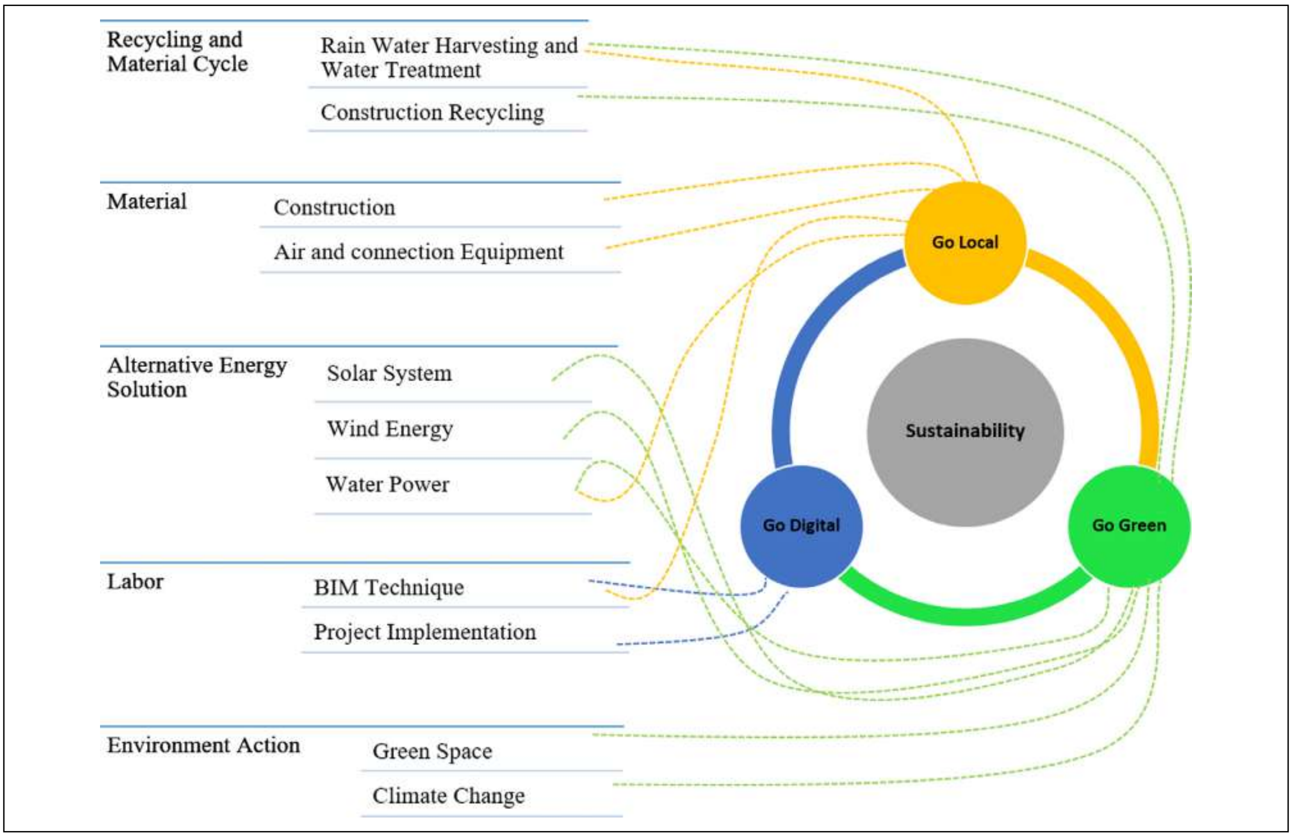

Figure 5. Applied principles of building sustainable requirements.

Building rehabilitation is more laborious and requires special techniques and more knowledge and experience in the building techniques used. In addition to achieving sustainability requirements, rehabilitation practices, when incorporated by sustainable modeling, must therefore take into account the following:

- Ensuring appropriate ventilation and lighting requirements for the building.
- Mitigating the negative environmental impact.
- Apply sustainable components and systems.

Rehabilitation is part of the scope of sustainable solutions. Because of its role in reusing the existing building Figure 5. Which is expanded and improved rather than demolished and abandoned, saving energy costs. Avoiding the creation of tons of discarded waste and the intensive consumption of new material required for a new structure [32, 33]. In addition, rehabilitation becomes an opportunity to benefit from the valuable space recovered, which can be converted into a healthier space with more efficient equipment from the water, energy, and duration perspectives, whose knowledge about adequate maintenance can be widespread.

Building rehabilitation is a concept in which interventions in a particular building aim to improve the habitability, safety, and energy efficiency of buildings and restore the functionality of a degraded or obsolete building [17]. To maintain and monitor strategies for long-term sustainability, rehabilitation will be an even more important activity, as affected buildings will need maintenance and renovation in the future. Urban regeneration is a priority, whether from an environmental, economic, or community point of need.

Rehabilitation. Knowing the various inspection methodologies and techniques and their costs is essential to involving the financial aspects in activity workflow planning and achieving the best technical and economic balance. This strategy includes the tests and measurements necessary to understand the reasons for this. It suggests interventions to be conducted in the building, which shall consist of measuring and evaluating the properties of used materials and the performance of buildings. Conduct field testing onsite, where buildings are monitored to assess their in-service behavior, and perform experimental testing in the lab for more verification and to know the physical properties. This is the best maintenance and monitoring methodology.

7. RESULTS AND DISCUSSION

Rehabilitation of damaged buildings in Syria requires a unique approach, as there is discrimination in buildings that were damaged due to the conflict, which reaches a percentage of 70-90% of the geographical area, which had a high negative impact on sustainability in all aspects social, economic and environmental. The other was affected by the Feb 06. The 2023 earthquake caused disturbances in buildings that were lightly affected by the crisis and collapses in those most severely affected.

In both cases, the rehabilitation aims to restore the affected building's architectural shape and structural strength and make changes at the lowest costs within a specific pe-

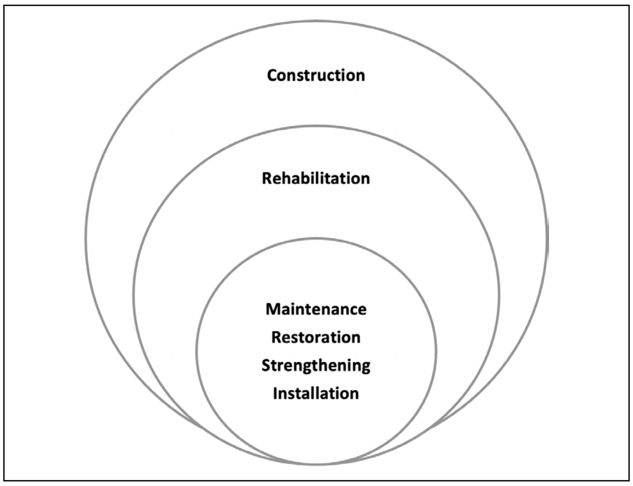

Figure 6. Rehabilitation activities in the construction cycle process.

riod, thus ensuring sustainability in building works and restoring the intended function. Since rehabilitation is a stage of the construction cycle process, Figure 6. It should, therefore, take a specific cost that does not exceed the cost of new construction. Its impact must be effective at building sustainability and re-occupancy by providing the basic requirements for sustainability at the lowest costs within a specific timetable.

Selection criteria for buildings to be rehabilitated have been organized to ensure that service is provided corresponding to the minimum standards and to achieve a dignified and fair life for the returning community, host community, and displaced people, Figure 7 as long as areas are considered under contingency response. The criteria shall cover two key points:

Safety criteria for the region and buildings and vulnerability/need Scale. Each one of the criteria has many factors, with a score defining the study case.

The selection criteria were conducted in two rounds, with mandatory safety in the first round and the vulnerability scale at the second level. Table 1 shows the first round of safety criteria for the region and buildings for some study cases. The passed cases transfer to the second round of the vulnerability scale, Table 2. Finally, the selection starts with the cases with the highest score.

Rehabilitation was conducted in 45 apartments in Khan Shiekhoun, rural Idlib. Buildings were damaged due to the conflict and the 06-Feb-2023 earthquake. The eligibility of buildings for rehabilitation is determined by conducting pre-assessment and relevant studies, bill of quantities, technical specifications, and drawings. Buildings that were destroyed approximately 17% and substantially damaged and needed structural strengthening amounted to 33%, and moderate to slightly damaged buildings were 50%.

The used methodology for the pre-assessment of buildings has a general form below Figure 8:

In case of a damaged structural system, including linear elements such as beams and columns and surface elements such as slabs and roofs, structural strengthening is mandatory to restore the integrity of buildings. Then, the complementary rehabilitation will be conducted, including supplying and installing doors, windows, electric/WASH connections, and equipment.

The rehabilitation target is to increase the structure element's capacity through structural strengthening or restore the strength of elements, thus allowing them to achieve functional performance and resist any potential future seismic events. Therefore, the rehabilitation of a building can be more complex than a new construction, as it was found that

Table 1. First-round process of selection criteria

First Round								
Owner, Area, and Building Information								
Case	**Governorate**	**District**	**Featured Code**	**Owner information**	**Access availability**	**Infrastructure availability**	**Building Structural Safe**	**Result**
1	Idlib	Khan Shiekhoun	#1	Info.	Safe	Yes	Safe	Pass
2	Idlib	Khan Shiekhoun	#2	Info.	Safe	Yes	Unsafe	Fail
3	Idlib	Khan Shiekhoun	#3	Info.	Safe	No	Safe	Fail
4	Idlib	Khan Shiekhoun	#3	Info.	Safe	No	Unsafe	Fail
5	Idlib	Khan Shiekhoun	#4	Info.	Unsafe	Yes	Safe	Fail
6	Idlib	Khan Shiekhoun	#5	Info.	Unsafe	Yes	Unsafe	Fail
7	Idlib	Khan Shiekhoun	#6	Info.	Unsafe	No	Safe	Fail
8	Idlib	Khan Shiekhoun	#7	Info.	Unsafe	No	Unsafe	Fail

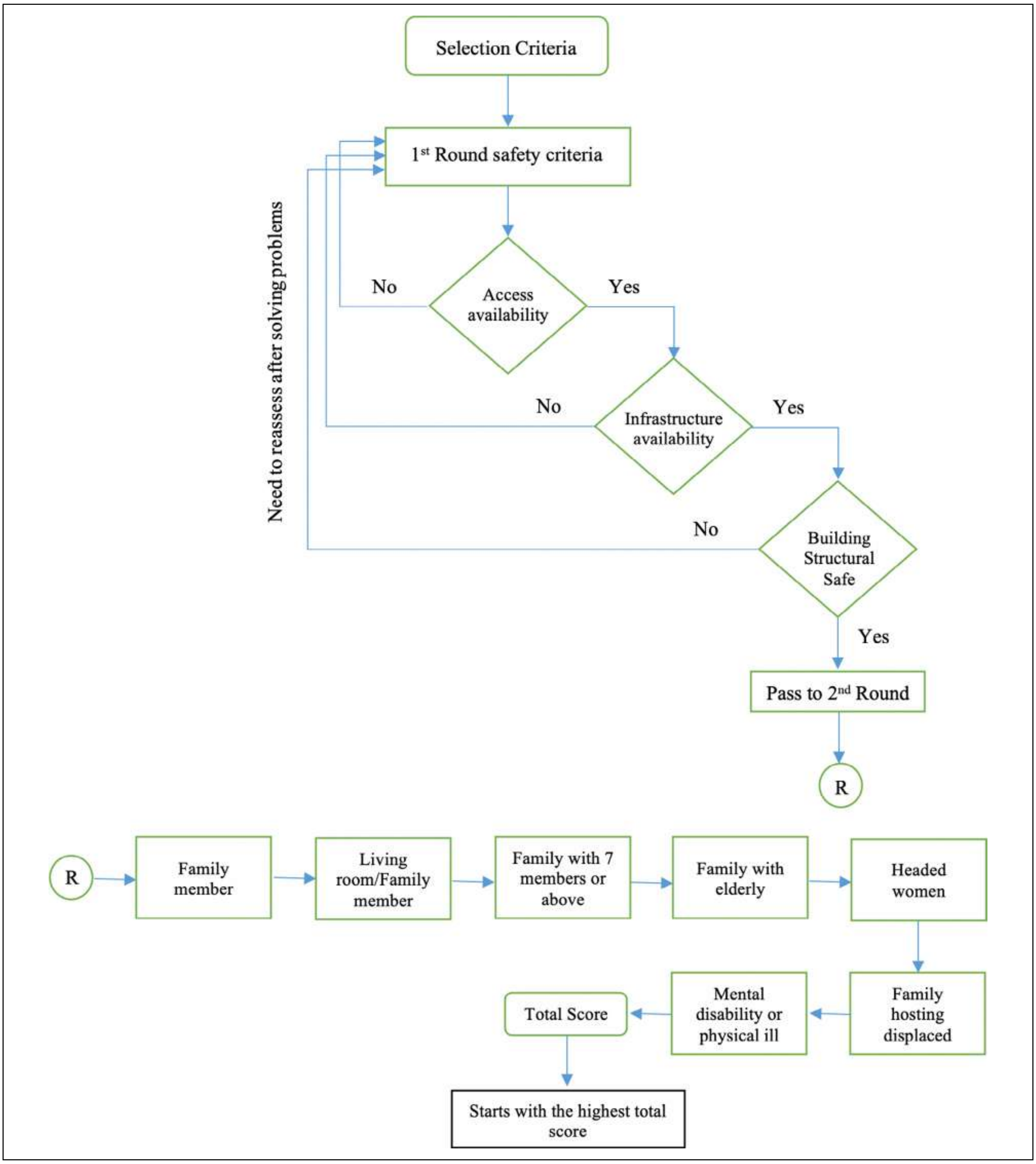

Figure 7. Flowchart of selection criteria processes.

each damaged building has a unique analysis, study, and rehabilitation that differs depending on the degree and shape of damage. Local communities could play a key role in the rehabilitation by providing the building with formal documents and supporting information, participating in suggestions and decisions, and integrating the community with rehabilitation works by providing the labor force, achieving benefits through encouraging them to rehab humanity and community. Regarding the potential ethical issues related to data collection or community involvement in rehabilitation projects, the operation included adhering to inclusive moral principles and recognizing consent and privacy as foundational elements in the ethical data process. Additionally, engaging the public in discussions about data protection is essential for maintaining trust and transparency.

The planned rehabilitation achieved sustainability in the short term at three levels: social, economic, and environmental Table 3. Social by securing the minimum standard living requirements for the resident family, as the number of beneficiaries exceeded 200 individuals. Preparing the

Table 2. Second round process of selection criteria "vulnerability scale"

Second Round								
Cases of vulnerability criteria								
Case	**Family member**	**Living room/ Family member (<=3,2 0r >=3,1)**	**Family with seven members or above (Yes=2, No=1)**	**Family with elderly (Yes=1, No=0)**	**Headed women (Yes=1, No=0)**	**Family hosting displaced (Yes=1, No=0)**	**Mental disability or physically ill (Yes=1, No=0, both=2)**	**Score**
1	3	2	1	1	1	1	2	8
2	4	2	1	0	1	1	2	7
3	5	1	1	1	1	0	1	5
4	6	1	1	1	0	0	1	4
5	7	1	2	1	0	0	0	4
6	8	1	2	1	0	0	0	4
7	8	1	2	0	0	0	1	4
8	6	1	1	1	0	0	0	3

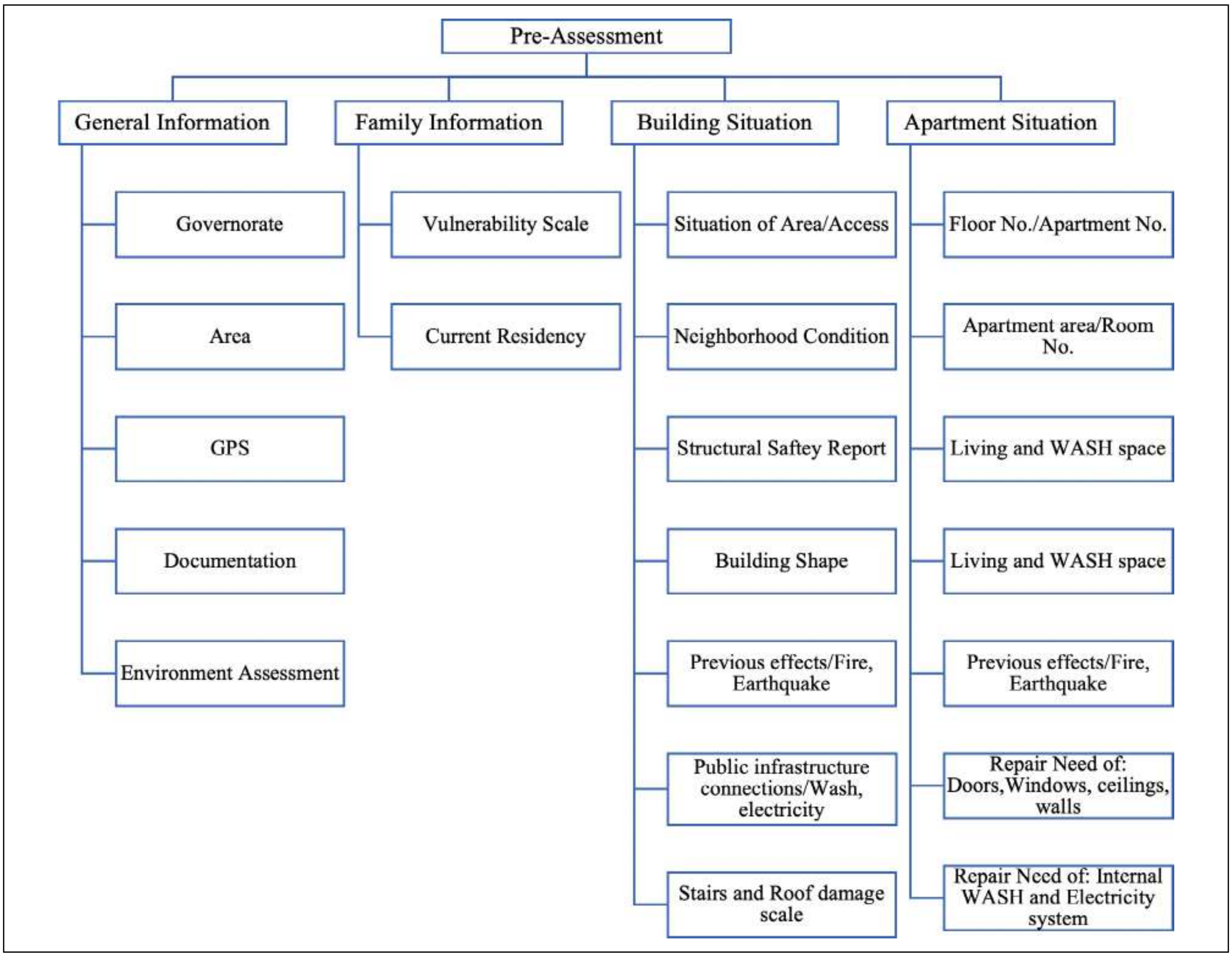

Figure 8. Pre-assessment methodology of buildings rehabilitation.

economic feasibility provides a clear vision for each case of rehabilitation or maintenance compared to the option of demolition and reconstruction, and environmental by removing rubble and cleaning the area, structural strengthening, and removing and rebuilding damaged walls—provision of electricity/WASH alternative solutions and security of safety by installing doors and windows.

The long-term benefit of building rehabilitation is that it can extend the service life and ensure inconveniencing-free operation during its usage phase as BIM provides all the

Table 3. Type of materials and sustainability methods

Type of Materials			Destroyed		Structural Strengthening		Slightly Damage	
Green	Digital	Local	17%		33%		50%	
Concrete and Cement Block			20%	70%	15%	25%	10%	10%
			10%		10%		5%	
			70%		75%		85%	
Wood and Aluminium			20%	13%	40%	35%	50%	50%
			30%		20%		20%	
			50%		40%		40%	
Electricity			30%	10%	50%	20%	50%	20%
			30%		10%		10%	
			40%		40%		40%	
WASH			30%	7%	40%	20%	40%	20%
			30%		10%		10%	
			40%		50%		50%	

Table 4. Results of rehabilitation impacts and risk on environmental concerns

Environmental Concern	Rehabilitation Impact		Environmental Risk	
	Level	Weight	Level	Weight
Location/Roads and Access				
Environment biodiversity value	Low	0.62	Null	0.38
Environment regenerative capacity	Low	0.56	Null	0.44
Water sources/Water Quality	Null	0.50	Null	0.50
Soil erosion	Null	0.58	Null	0.42
Building Design/Construction				
Indoor air pollution/heating	Null	0.60	Null	0.40
Manage solid waste	Medium	0.75	Null	0.25
Sanitation and disease	Medium	0.75	Null	0.25
Building Materials				
Management of waste/Debris	Null	0.60	Null	0.40
Extraction of resources from the local environment	Medium	0.78	Null	0.22
Power/Energy				
Rates of deforestation/Wood	Medium	0.71	Null	0.29
Indoor air pollution/heating/ventilation and cooking	High	0.81	Null	0.19
Extraction of resources from the local environment	Medium	0.73	Null	0.27

relevant information about the building and tools for rehabilitation. The integration of these tools guarantees the continuous development of the rehabilitation process. It can also include extra tools of durability and resilience specific to the location, such as sustainability and flexibility, land resources, regenerative capacity, demolition, reusability, and cost management. As a result, the methodology can become more detailed, precise, and valuable.

The environmental assessment deeply analyzed the rehabilitation impact, ecological sensitivity, and potential environmental risks related to the rehabilitation of the building. The factors influencing weights and criteria are inputs and data used in the assessment method Appendix 1. The key environmental concerns involved the siting topography, design, materials, construction, demographic details and household items, energy, road, and access. The quantitative data is categorized into complementary attributes, as shown in Figure 9.

The environmental impacts were measured by analyzing the nexus environmental assessment tools. This tool is designed to identify environmental concerns, natural, climate, erosion hazards, air pollution, and water security. The impacts of rehabilitation and potential environmental risk take a weight and classification on four levels (Null, Low, Medium, High), and mitigations for each case are suggested. Table 4 shows the results of rehabilitation impacts and risks

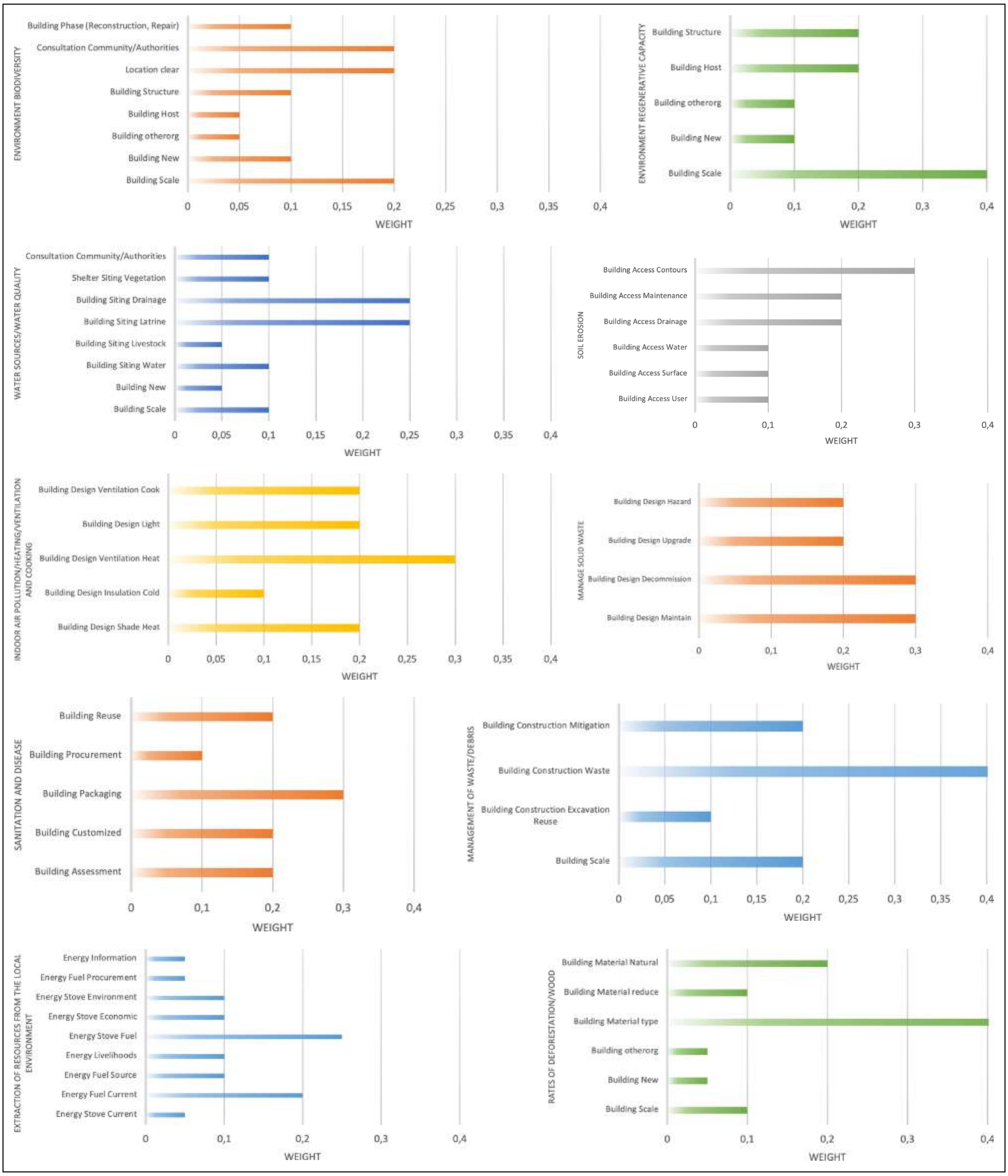

Figure 9. The categorizations of complementary attributes data.

on environmental concerns. As has been the case, many sustainability principles have been integrated into the rehabilitation process. Local: Lower costs will be achieved using locally available recycling materials and local labor. Green: Alternative power solutions and friendly environment power, like solar systems, can mitigate the carbon footprint and reduce the amount of household gas released into the atmosphere. Clean water is provided by harvesting and maintaining rainwater in the constructed underground tank. Digital: BIM tools are used to manage the project and prepare plans, using various software that can support the decision.

The sustainability of buildings depends on many factors that affect the building's lifecycle and the environment. Sustainable development involves an effort and mindset in utilizing best practices to ensure that our valuable resources are used at the lowest cost and most efficiently possible. The waste is minimized and sustains our human and natural environments now and in the future to protect the intrinsic sustainability of building rehabilitation and to increase the degree of sustainability. Daily follow-up by conducting site visits to investigate the quality of intervention, monitor and weekly report of rehabilitation achieved progress. Over time, rehabilitation is followed by a period of (3-6) months to ensure the impact and quality of the program by conducting the end of the inspection and the related post-survey. Comparing the environmental projects in other regions, using different influencing factors and tools of specific areas may change and affect the assessment results. However, they do not change the methodology and process; the approach remains on the same basic structure. In Ghana, voices are raised to subject to an environmental impact assessment to determine the potential risk in the sustainable construction designs identified. The 33 environmental impacts and the top 10 most significant ecological impact factors were identified. The relative importance index RII was determined as well. Out of 55 activities in Nigeria, 18 were environmentally related activities. The average relative importance index RII of environmentally related activities is 0.841. Several challenges were encountered during the rehabilitation process. Before building documents and information on used materials in the invisible elements, this challenge was addressed by completing pre-assessment data, collecting as-built data, and conducting required tests to ensure the structure's integrity before starting rehabilitation. During rehabilitation, this type of work involves a shortage of talented labor. This was addressed by subjecting the local labors to vocational training and development skills. After finishing, social responsibility increases as the need to rehabilitate more buildings is addressed through managing expectations between the community and capabilities. The procedure contains local materials and components that have a low environmental effect.

On the other hand, it should be made using modern/digital techniques that ensure the components remain intact and can be reused. Additionally, potential challenges could be faced in scaling up the rehabilitation. Such as the neglect of vernacular heritage, central components, and changes in local architecture and construction characterize. These could be addressed by realizing a wise response to the environment, social and geographical context in which they are intrinsically linked to the community, the environmental envelope, and the local economy of the place. Sustainability in building rehabilitation is therefore recognizable as capable of triggering powerful mechanisms in the area, such as activating local economies, mitigating adverse environmental risks, restoring social connections, and integrating approaches, including heritage preservation strategies.

8. CONCLUSION

The nature of building rehabilitation and its role in enhancing sustainability in urban areas has been presented, and how adopting sustainable rehabilitation practices is crucial for rebuilding the resilience of urban communities, particularly in the aftermath of the Türkiye-Syria earthquake, and making a difference in the internal and external environment, and providing practical methods of achieving energy efficient and healthy buildings for occupants.

The field inspection of 45 surveyed buildings revealed significant adverse human action among the failure indicators of the affected building. In contrast, around 80% of the surveyed affected buildings were eligible for rehabilitation for a sustainable service lifecycle, demonstrating significant improvements in safety, hygiene, and sustainability by applying principles of (Green, Local, and Digital). A strategy to rehabilitate affected buildings contributes to minimizing environmental change. As an outcome, a conceptual note of integrated building rehabilitation and framework for sustainable urban community development in affected areas with an ultimate goal of empowering its communities depending on the sustainability principles. It demonstrates that rehabilitation and the resulting modifications are possible regarding the principle and philosophical meaning of sustainability when integrated to restore and develop the affected community by focusing on providing these communities' basic and urgent needs while capitalizing on their strengths and opportunities. The importance of rehabilitating affected buildings for sustainability was highlighted, and rehabilitation efforts can minimize environmental risks and improve building performance using sustainable materials and modern technologies, setting targets to improve environmental performance and improving the sustainable design process integrated with building operation and maintenance.

Rehabilitation is an organized process that requires passing several critical stages to achieve the full effectiveness of the intervention and achieve the desired sustainability. The findings from Syria can be adapted to post-disaster contexts by meaningfully stating that rehabilitation is the permanent phase that begins after the temporary solution during initial relief action and lasts until the improvement process is completed. The length of the rehabilitation phase varies depending on the country's development level. Planning, evaluating, and monitoring all aspects of the method used during rehabilitation is crucial to meeting housing needs and ensuring the return to decent living conditions for people who have suffered losses in human life and property due to a disaster. According to the case study completed, we can conclude the following main points:

- Following a logical rehabilitation sequence by applying valued selection criteria and conducting pre-assessment contributes to achieving a rehabilitated sustainable building on the environmental, community, and economic levels.
- Rehabilitation increased the community's resilience by increasing protection, saving dignity, and providing basic needs for 200 individuals.
- Studies indicate that rehabilitation positively impacts some environmental concerns with a null risk level, a medium level of design, construction, and building materials with a weight up to 0.78, and a medium to high level related to energy with a weight up to 0.8.

ETHICS

There are no ethical issues with the publication of this manuscript.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

FINANCIAL DISCLOSURE

The authors declared that this study has received no financial support.

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Not declared.

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Appendix 1. Weights of complementary environmental attributes

Location/Roads and Access

Environment biodiversity	Weight	Environment regenerative capacity	Weight	Water sources/ Water Quality	Weight	Soil erosion	Weight
Building Scale	0.2	Building Siting Energy	0.4	Building Scale	0.1	Building Access User	0.1
Building New	0.1	Building Siting Electricity	0.1	Building New	0.05	Building Access Surface	0.1
Building other	0.05	Building Siting Livestock	0.1	Building Siting Water	0.1	Building Access Water	0.1
Building Host	0.05	Location clear	0.2	Building Siting Livestock	0.05	Building Access Drainage	0.2
Building Structure	0.1	Building Scale	0.2	Building Siting Latrine	0.25	Building Access Maintenance	0.2
Location clear	0.2	–	–	Building Siting Drainage	0.25	Building Access Contours	0.3
Consultation Community/ Authorities	0.2	–	–	Shelter Siting Vegetation	0.1	–	–
Building Phase (Reconstruction, Repair)	0.1	–	–	Consultation Community/ Authorities	0.1	–	–

Building Design/Construction

Indoor air pollution/heating	Weight	Manage solid waste	Weight	Sanitation and disease	Weight
Building Design Shade Heat	0.2	Building Design Maintain	0.3	Building Assessment	0.2
Building Design Insulation Cold	0.1	Building Design Decommission	0.3	Building Customized	0.2
Building Design Ventilation Heat	0.3	Building Design Upgrade	0.2	Building Packaging	0.3
Building Design Light	0.2	Building Design Hazard	0.2	Building Procurement	0.1
Building Design Ventilation Cook	0.2			Building Reuse	0.2

Building Materials

Management of waste/Debris	Weight	Extraction of resources from the local environment	Weight
Building Scale	0.2	Energy Stove Current	0.05
Building Construction Excavation Reuse	0.1	Energy Fuel Current	0.2
Building Construction Waste	0.5	Energy Fuel Source	0.1
Building Construction Mitigation	0.2	Energy Livelihoods	0.1
–	–	Energy Stove Fuel	0.25
–	–	Energy Stove Economic	0.1
–	–	Energy Stove Environment	0.1
–	–	Energy Fuel Procurement	0.05
–	–	Energy Information	0.05

Appendix 1 (cont). Weights of complementary environmental attributes

Power/Energy					
Rates of deforestation/ Wood	**Weight**	**Indoor air pollution/heating/ ventilation and cooking**	**Weight**	**Extraction of resources from the local environment**	**Weight**
Building Scale	0.1	Building Design Shade Heat	0.2	Energy Stove Current	0.05
Building New	0.05	Building Design Insulation Cold	0.1	Energy Fuel Current	0.2
Building otherorg	0.05	Building Design Ventilation Heat	0.3	Energy Fuel Source	0.1
Building Material type	0.5	Building Design Light	0.2	Energy Livelihoods	0.1
Building Material reduce	0.1	Building Design Ventilation Cook	0.2	Energy Stove Fuel	0.25
Building Material Natural	0.2	–	–	Energy Stove Economic	0.1
–	–	–	–	Energy Stove Environment	0.1
–	–	–	–	Energy Fuel Procurement	0.05
–	–	–	–	Energy Information	0.05