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MISCELLANEA

Computer-Aided Decision-Making for the Highest Sustainable Reuse of Historic Buildings

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ABSTRACT

The adaptive reuse policy aims to extend the functional life of the historic building in a way that suits its physical age. Recently, computer software has been utilized in decision-making processes as an assistant and accelerator to attain the best results. This paper seeks to create a program to achieve the Highest Sustainable Reuse - HSR of the historic building. The software is created by specifying two categories of urban and architectural requirements and restrictions. The first relates to the characteristics, capabilities, and limitations of the historic building, while the second describes the needs and conditions of the proposed function. By performing an algorithmic comparison, the program is able to provide percentages for a set of proposed functions based on the case study. The paper concluded the effectiveness of the proposed methodology by conducting it on the historic Al- Barood Khanah building in Mosul.

KEYWORDS

Preventive conservation, Adaptive reuse, decision-making, Highest Sustainable Reuse, MAROHB.

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Introduction

Historic buildings are distinguished by their prominent importance in understanding and appreciating the past and present.[1] They face a range of threats that weaken their capabilities and reduce their lifespans.[2] The goal of preservation, as stated in the Burra Charter, is to retain, recover, or reveal as much as possible of the historic significance of the heritage element, whether it is a building or an archaeological piece[3]. The challenges of urban conservation are divided into three levels: the physical condition level, which includes material behavior and structural systems, causes and mechanisms of deterioration, possible interventions, and long-term effectiveness of treatments, etc.; the management level, which includes resource availability and utilization, including finances, trained staff, technology, political and legislative conditions, land use issues, etc.; and the cultural significance and social values level, which includes the importance of the place, reasons for its preservation, and the impact of interventions on its understanding or perception, etc.[4] The fundamental principle of preserving historic buildings lies in the fact that the higher the level of intervention, the greater the risk of damage to the historic building. Due to their unique importance and irreplaceability, extreme caution must be exercised in selecting and implementing preservation strategies.[5] The required degree of intervention is determined in relation to the building's condition, and the minimum intervention is always preferred in the preservation process.[6]

Adapting historic buildings for sustainable preservation involves either within-use adaptation, modifying the building while keeping it in the same function, or across-use adaptation, modifying the building while changing its function.[7] This includes the policy of adaptive reuse, aiming to adopt a new and s function for the historic site or structure that enhances cultural, social, and economic values.[8] Reuse is often sought due to the aging of single-purpose structures or their inability to achieve suitable economic gains, as well as changes in the demand for construction based on social

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1 ICOMOS, Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance (Australia: Australia ICOMOS, 1999).

2 Cristina Garzillo et al., Adaptive Reuse of Cultural Heritage: An Examination of Circular Governance Models from 16 International Case Studies (Synthesis, California: ICLEI Europe, 2020).

3 ICOMOS, Burra Charter, 1999.

4 Erica Avrami, Randall Mason, and Marta de la Torre, Values and Heritage Conservation (Research Report, Los Angeles: The Getty Conservation Institute, 2000).

5 Ehab M. Okba and Mohga E. Embaby, *"Sustainability and Heritage Buildings,"* International Journal of Engineering Research & Technology 2, no. 8 (2013): 1682–90.

6 Bernard M. Feilden, Conservation of Historic Buildings, 3rd ed. (Rome: Elsevier, 2007).

7 G.D.R. De Silva, B.A.K.S. Perera, and M.N.N. Rodrigo, *"Adaptive Reuse of Buildings: The Case of Sri Lanka,"* Journal of Financial Management of Property and Construction 24, no. 1 (2019): 79–96.

8 Imad Hani Al-Allaf, Ahmed Youssef Al-Omari, and Mumtaz Hazem Al-Diwaji, *"Alternatives to the Reconstruction of Al-Hadbaa Minaret in Old Mosul,"* Sulaimani Journal for Engineering Sciences 6, no. 2 (2019): 13–24.

and economic transformations and aligning them with the nature and density of settlements in desired areas.[9] The most sustainable level of reuse is the highest and optimal level of adaptation, relying on the installation strategy, which involves adding new parts or elements to the current building without changing the basic structure. This allows for the removal of these new parts later and restoring the building to its original state. This strategy is often used in historic buildings for preservation purposes.[10] Finding the appropriate use is often necessary to prevent the deterioration or destruction of the building, posing one of the most challenging problems in architectural preservation practice.[11] Contributing to the enhancement of historic buildings and the preservation of their social, historic, and cultural values, highlighting the role of financial and governance models in heritage preservation, increasing opportunities for collaboration between multiple stakeholders, reducing resource usage, and renewing values, capital, and knowledge.[12]

This study initially analyzed previous studies to provide a theoretical framework for a comprehensive methodology for the most sustainable reuse mechanism, addressing the cognitive deficit in finding the most sustainable alternative for reusing historic buildings. After identifying the research gap, the study explored the use of computer capabilities to find the most sustainable alternative for reusing historic buildings. The aim of this study is to design a computer program based on a multi-criteria decision-making methodology. The program is created by defining two categories of urban and architectural requirements and constraints. The first relates to the characteristics, capabilities, and limitations of the historic building, while the second describes the proposed function's needs and conditions. Through algorithmic comparison, the program can provide percentage scores for a set of proposed functions based on a case study. This study assists decision-makers in making the most accurate, timely, and effective decisions for reusing historic buildings, contributing to prolonging the physical and functional life of the building without causing harm due to incorrect reuse decisions.

9 S. Mutal, "Adaptive Reuse for the Future Development of the Historic Centres: Some Thoughts and Considerations," Handout 7 (2015): 1–7.

10 Graeme Brooker and Sally Stone, Re-readings 2: Interior Architecture and the Principles of Remodelling Existing Buildings (London: RIBA, 2018).

11 Feilden, Conservation of Historic Buildings, 2007.

12 Lucia Della Spina, "Adaptive Sustainable Reuse for Cultural Heritage: A Multiple Criteria Decision Aiding Approach Supporting Urban Development Processes," Sustainability 12, no. 4 (2020): 1363.

Preventive Conservation and Decision-Making Management

The foundation of the current interest in preserving urban heritage is a result of increased awareness of history and the recognition of cultural diversity. Preservation has gradually become accepted as the modern approach to protecting historic buildings and artworks, serving as the primary reference for maintenance and restoration policies.[13] The conservation of heritage buildings contributes to the sustainability of the built environment and urban diversity, shaping the character of the city.[14] The fundamental principle of urban preservation is that the higher the level of intervention, the greater the risk of damage to historic buildings. Due to their unique importance and irreplaceability, extreme caution must be exercised in selecting and implementing preservation strategies.[15] The required degree of intervention is determined in relation to the building's condition, and the minimum intervention is always preferred in the preservation process.[16] Preventive conservation is indirect preservation that includes proactive preventive operations and non-intrusive activities on the structure. These efforts contribute to delaying or preventing the deterioration and disappearance of historic buildings. Preventive conservation involves information management and organizing data for appropriate decision-making purposes.

The reuse of historic buildings for contemporary purposes is a multifaceted and complex design process. Therefore, a multi-criteria decision-making process can enhance decision-making by providing a transparent and efficient selection process among design alternatives.[17] The Multi-Criteria Decision-Making (MCDM) process is a cognitive and organized approach developed to address decision-making problems in various fields, seeking the most suitable alternative. It aims to improve the quality of decision-making to become more rational and efficient, involving steps such as problem identification, stating the problem in clear and measurable terms, developing alternatives, summarizing the advantages and disadvantages of each alternative, and evaluating them to ultimately choose the best alternative that achieves the goals.[18] [19] [20] One of the objectives

13 Jukka Jokilehto, A History of Architectural Conservation (England, UK: Routledge, 1999)

14 Buildings Department, Practice Guidebook for Adaptive Re-use of and Alteration and Addition Works to Heritage Buildings 2012, 2019 ed. (Hong Kong: Buildings Department, 2019).

15 Okba and Embaby, "Sustainability and Heritage Buildings," 1682–90.

16 Feilden, Conservation of Historic Buildings, 2007.

17 Beser Oktay Vehbi, Kağan Günçe, and Aminreza Iranmanesh, "Multi-Criteria Assessment for Defining Compatible New Use: Old Administrative Hospital, Kyrenia, Cyprus," Sustainability 13, no. 4 (2021): 1922.

18 Rahul Misra, Introduction to Management: Principles of Management (India: KMRO, 2015).

19 Fatma Eltarabishi, Omar Hassan Omar, Imad Alsyouf, and Maamar Bettayeb, "Multi-Criteria Decision Making Methods and Their Applications – A Literature Review," International Conference on Industrial Engineering and Operations Management, Dubai, UAE, 2020.

20 Maria Rita Pinto et al., "Building Reuse: Multi-Criteria Assessment for Compatible Design," International Journal of Design Sciences and Technology 22 (2017): 165–93.

of decision-making processes is pre-assessment, determining the consequences of different actions before implementation. Multi-criteria analysis is a useful tool for evaluating various alternative options in the field of cultural heritage preservation.[21]

Adaptive Reuse

It is the process of upgrading and enhancing the performance of a building to meet modern standards and adapt to changing user requirements while retaining the original structure as much as possible.[22] [23] [24] [25] This involves the transformation of an inefficient structure and modifying it into a new form that can be used for a different purpose while preserving its good structural condition and safeguarding it from damage. It often includes significant changes in usage, renewing a historic building with both material and economic values. This entails alterations to the structure or spaces to meet new needs, helping to rehabilitate the building and integrate it into the economic and social environment of the city rather than leaving it as a closed and abandoned place.[26] [27] [28] [29] [30] The goal of these modifications to the current building is to make it compatible with contemporary use while preserving parts of the building and its valuable characteristics. Successful heritage reuse projects are usually those that respect the heritage values of the building, preserve them, and add contemporary advantages that provide sustainable value for the future. Adaptation and new uses for the building may be the only way to preserve its heritage significance, resulting in environmental, social, economic, and creative benefits. The assessment and strengthening of heritage building

21 Pinto et al., "Building Reuse," 165–93.

22 De Silva, Perera, and Rodrigo, "Adaptive Reuse of Buildings," 79–96.

23 Yasmine Sabry Hegazi, Heidi Ahmed Shalaby, and Mady A. A. Mohamed, "Adaptive Reuse Decisions for Historic Buildings in Relation to Energy Efficiency and Thermal Comfort—Cairo Citadel, a Case Study from Egypt," Sustainability 13, no. 19 (2021): 10531.

24 Despo Parpas and Andreas Savvides, "Sustainable-Driven Adaptive Reuse: Evaluation of Criteria in a Multi-Attribute Framework," WIT Transactions on Ecology and the Environment 217 (2018): 29–37.

25 Shreya Chandrakar and Sandeep Singh, "Adaptive Reuse of Heritage Building," International Journal of Creative Research Thoughts (IJCRT) 10, no. 5 (2022): C330–C336.

26 Markus Kip and Heike Oevermann, "Neighbourhood Revitalisation and Heritage Conservation through Adaptive Reuse: Assessing Instruments for Commoning," The Historic Environment: Policy & Practice 13, no. 2 (2022): 242–66.

27 Kripa Shakya and Sudarshan Raj Tiwari, "Sustainability Assessment of Adaptive Reuse Buildings in Kathmandu – A Study of Three Cases in Patan," Proceedings of 10th IOE Graduate Conference, Kirtipur, Nepal, 2021.

28 Buildings Department, Practice Guidebook, 2019.

29 Marika Gaballo, Mecca Beatrice, and Francesca Abastante, "Adaptive Reuse and Sustainability Protocols in Italy: Relationship with Circular Economy," Sustainability 13, no. 14 (2021): 8077.

30 Fenk D. Miran and Husein A. Husein, "Introducing a Conceptual Model for Assessing the Present State of Preservation in Heritage Buildings: Utilizing Building Adaptation as an Approach," Buildings 13, no. 4 (2023): 859.

structures for comprehensive reuse are evaluated throughout the duration of addition, modification, and post-operation. [31] [32] [33] [34] [35] [36]

The policy of reuse plays a crucial role in building sustainability by extending the productive life of the current building. It assists communities, governments, and developers in reducing costs. This policy can develop old or historic buildings for their cultural value by giving them new sustainable uses and preserving the historic building stock and urban fabric. It contributes to finding and enhancing values related to history, continuity, affinity, identity, and sustainable human development. Additionally, it acts as an economic stimulus for the region and the city as a whole, promoting dynamic relationships within cities by transforming old buildings while introducing new architecture into old settings, achieving a balance between preserving the building and enhancing its role in the urban environment. This approach reduces energy waste, construction and maintenance costs, and land consumption, making it more sustainable. Heritage buildings are locally and internationally appreciated by current and future generations and tourists, providing an effective method for self-financing that contributes to the economic foundation of sustainable development. The transformation of heritage buildings into accessible and usable places is executed by setting clear guidelines with a vision for clear and long-term projects to avoid the destruction of heritage instead of its development. [37] [38] [39] [40] [41] [42] [43] [44] [45] [46]

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31 Hegazi, Shalaby, and Mohamed, "Adaptive Reuse Decisions for Historic Buildings," 10531.

32 Yan Zhang and Qi Zhang, "A Model Approach for Post Evaluation of Adaptive Reuse of Architectural Heritage: A Case Study of Beijing Central Axis Historical Buildings," Heritage Science 11, no. 1 (2023): 1–17.

33 Royal Australian Institute of Architects, Adaptive Reuse: Preserving Our Past, Building Our Future (Australia: Department of the Environment and Heritage, 2004).

34 Buildings Department, Practice Guidebook, 2019.

35 Chiara Bertolin and Arian Loli, "Sustainable Interventions in Historic Buildings: A Developing Decision Making Tool," Journal of Cultural Heritage 34 (2018): 291–302.

36 Act No. 645, National Heritage Act (Malaysia: The Commissioner of Law Revision, 2005).

37 Parpas and Savvides, "Sustainable-Driven Adaptive Reuse," 29–37.

38 Itohan Esther Aigwia, Jason Ingham, Robyn Phipps, and Olga Filippova, "Identifying Parameters for a Performance-Based Framework: Towards Prioritising Underutilised Historical Buildings for Adaptive Reuse in New Zealand," Cities 102 (2020): 102756.

39 Gaballo, Beatrice, and Abastante, "Adaptive Reuse and Sustainability Protocols," 8077.

40 Hegazi, Shalaby, and Mohamed, "Adaptive Reuse Decisions for Historic Buildings," 10531.

41 Chandrakar and Singh, "Adaptive Reuse of Heritage Building," C330–C336.

42 Miran and Husein, "Conceptual Model for Assessing Preservation in Heritage Buildings," 859.

43 Mutal, "Adaptive Reuse for the Future Development," 1–7.

44 Rawan Abdullatif Alhojaly, Abeer Abdulaziz Alawad, and Noura Abdulrahman Ghabra, "A Proposed Model of Assessing the Adaptive Reuse of Heritage Buildings in Historic Jeddah," Buildings 12, no. 4 (2022): 406.

45 Okba and Embaby, "Sustainability and Heritage Buildings," 1682–90.

46 Ayman Ahmed Ezzat Othman and Heba Elsaay, "Adaptive Reuse: An Innovative Approach for Generating Sustainable Values for Historic Buildings in Developing Countries," Organization, Technology & Management in Construction: An International Journal 10, no. 1 (2018): 1704–1718

Previous Studies

Previous studies have focused on the effective contributions of the Highest Sustainable Reuse in enhancing the importance of historic buildings, preserving them from disappearance, and reducing demolition and damage operations while utilizing the built environment to achieve investors' goals. High attention has been given to the physical, cultural, social, economic, financial, environmental, and political aspects in the analysis of buildings proposed for reuse or with suggested functions for several buildings. The analysis process is conducted according to a set of criteria and indicators, studying their availability in historic buildings that are being reused.

Yildirim study[47] concentrated on presenting a methodology to determine the Highest Sustainable Reuse for historic buildings and has been applied to Khan Diyarbakir Hassan Pasha by applying the proposed methodology in six steps: assessing the state of the historic pattern, the state of the environment, the safety of the place, the reuse of alternatives and their advantages and disadvantages, the requirements of owners and users, and evaluating the results to determine the best re-use of the structure. Its unique methodology was applied, and decisions were made using interviews, with a primary focus on physical, cultural, social, economic, financial, and environmental aspects. Alallaf study[48] aims to explore and analyze several reuse practices in the ancient city of Mosul using the REs4 methodology, which combines topics that highlight embodied energy, including the reduction of consumption, reuse, rehabilitation, and recycling, and the possibility of preferring a new type of use to propose to different buildings. on applying the REs4 methodology using Microsoft Excel. It emphasized physical, cultural, social, economic, financial, environmental, and political aspects. Elsorady study[49] concentrated on providing a methodology to assess and determine the Highest Sustainable Reuse for historic buildings. The Alexandria National Museum was taken as a case study, focusing on three objectives: to assess indicators derived from literature; the second is to investigate the museum's sustainable adaptation; and the third is to assess the heritage building's ability to meet reuse standards. Its methodology was applied through interviews, with a primary focus on physical, cultural, social, economic, and environmental aspects. Tan, et al.

47 Mücahit Yildirim, "Assessment of the Decision-Making Process for Re-Use of a Historical Asset: The Example of Diyarbakir Hasan Pasha Khan, Turkey," Journal of Cultural Heritage 13, no. 4 (2012): 379–388.

48 Emad Hani Alallaf, "The 4res Procedure for Preserving the Built Heritage of Old Mosul: A Sustainable Conservation Policy," Second Engineering Conference for the Golden Jubilee of Engineering College, University of Mosul (Mosul, Iraq, 2013).

49 Dalia Abdelaziz Elsorady, "Assessment of the Compatibility of New Uses for Heritage Buildings: The Example of Alexandria National Museum, Alexandria, Egypt," Journal of Cultural Heritage 15, no. 5 (2014): 511–521.

study[50] discussed the Highest Sustainable Reuse of industrial buildings in Hong Kong. By focusing on applying the Fuzzy AR fuzzy logic method to measure the suitability of the building for proposed uses through expert interviews. as this model provides decision-makers with multiple options according to their different preferences over standards. Their opinions on the Highest Sustainable Reuse were considered regarding physical, social, economic, environmental, and political aspects. Islami, et al. study[51] aimed to identify factors influencing the Highest Sustainable Reuse of historic buildings in Tehran. The study demonstrates the importance of the participation of different stakeholders in the decision-making process on the reuse of historic homes and the need to preserve the original form and context of historic buildings, as it is an important decision-making factor. Its methodology was applied using Multi-Attribute Decision Making (MADM) methods, with a primary focus on physical, cultural, social, and economic aspects. Pinto, et al. study[52] was applied to the monastery of Santa María del Geso at the historic center of Ragusa in Italy, which aims to help select the Highest Sustainable Reuse design among the many alternatives compatible in four phases: identifying future user needs; identifying obstacles to the building's transformation determined by its historic and artistic characteristics; designing alternative solutions to restore the building; and evaluating alternative design solutions concerning preservation and adaptation needs for new use. By focusing on applying the AHP and EVAMIX methods to evaluate the suitability of the building for the proposed use and select the most appropriate design using multi-criteria decision-making (MCDM) methods regarding physical, cultural, and environmental aspects. Barakat & Goriel study[53] concentrated on determining factors influencing the Highest Sustainable Reuse of historic buildings of the Qabhan School in Dohuk governorate in Iraq. The study used analysis at two different levels, the first by analyzing cultural, environmental, and architectural characteristics, and the second by analyzing the functional planning of the Space Syntax building. By focusing on physical and cultural aspects. Haroun, et al. study[54] applied the AHP methodology to assess the Highest Sustainable Reuse of Aziza Fahmi Palace in Alexandria Egypt. using Microsoft Excel, with a focus on physical, cultural,

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50 Yongtao Tan, Liyin Shen, and Craig Langston, "A Quantitative Approach for Identifying Adaptive Reuse Option for Industrial Buildings," in Proceedings of the 19th International Symposium on Advancement of Construction Management and Real Estate (Berlin: Springer, 2015), 505–495.

51 Seyed Gholamreza Islami, Davood Dehghan, and Hasan Sadeghi Naeini, "A Model Development to Adaptive Reuse of Iranian Qajar Houses: An Approach to Sociocultural Concept (A Case: Nasir Al-Din Mirza House)," American Journal of Civil Engineering and Architecture 4, no. 3 (2016): 84–89.

52 Pinto et al., "Building Reuse," 165–93.

53 Armange Ismael Barakat and Wafaa Anwar Goriel, "Factors Affecting the Adaptive Reuse Process for Historical Buildings in Kurdistan Region: An Analytical Study of Qubahan School as Historical Case Study," Sulaimani Journal for Engineering Sciences 6, no. 3 (2019): 29–46.

54 *Hebatu-Allah Abdul Fattah Haroun, Ali Fouad Bakr, and Asmaa El-Sayed Hasan, "Multi-Criteria Decision Making for Adaptive Reuse of Heritage Buildings: Aziza Fahmy Palace, Alexandria, Egypt," Alexandria Engineering Journal 58, no. 2 (2019): 467–478*

social, economic, and financial aspects. Ribera, et al. study[55] focused on applying AHP methodology to evaluate the Highest Sustainable Reuse for historic buildings using the AHP Priority Calculator, emphasizing physical, cultural, social, economic, and financial aspects. Joudifar & Türker study[56] focused on applying the Reuse Projection Framework methodology to determine the Highest Sustainable Reuse for architectural monuments in general and Othello Castle in the particularly walled city of Famagusta in Cyprus. The first step of the framework covers analytical and practical research based on the survey of literature and observation on the site. Then he explores the architectural and historic advantages of identifying architectural layers and modifications over time, finally looking at heritage values and evaluating importance, with a focus on physical and cultural aspects. Vehbi, et al.study [57] concentrated on applying AHP methodology to evaluate the Highest Sustainable Reuse of Kyrenia Administrative Hospital in Cyprus using 11 Choice Expert, emphasizing physical, cultural, social, economic, financial, environmental, and political aspects. Farjami & Türker study [58] focused on applying grounded theory methodology to evaluate the Highest Sustainable Reuse of historic buildings using collecting data from the survey of the literature and reviewing the common features of ARM and ERS to produce the outline of the proposed PCS basic preliminary standards, concentrating on physical, social, economic, environmental, and political aspects. Finally, El borolosy study[59] concentrated on applying the AHP methodology to assess the Highest Sustainable Reuse of Chamblion Palace in Egypt using the Analytic Hierarchy Process, focusing on physical, cultural, social, economic, and environmental aspects.

After analyzing previous studies, methodologies and measurement tools, their application levels, and the most influential aspects studied were extracted. Most studies relied on unknown methodologies, using interviews to verify their effectiveness on buildings in addition to Multi-Criteria Decision-Making (MCDM) methodologies. Based on various aspects, it can be noted that there is a research gap in the importance of selecting the appropriate use to prevent the failure of the building reuse process, which often occurs due to inappropriate choices for the new function of the building, leading to increased damage to the historic building. The

55 Federica Ribera, Antonio Nesticò, Pasquale Cucco, and Gabriella Maselli, "A Multicriteria Approach to Identify the Highest and Best Use for Historical Buildings," Journal of Cultural Heritage 41 (2019): 166–177.

56 *Farnaz Joudifar and* Özlem *Olgaç Türker, "A 'Reuse Projection Framework' Based on Othello's Citadel and Cultural Tourism," The Historic Environment: Policy & Practice 11, no. 2-3 (2020): 202–231*

57 Vehbi, Günçe, and Iranmanesh, "Multi-Criteria Assessment for Defining Compatible New Use," 1922.

58 Elnaz Farjami and Özlem Olgaç Türker, "The Extraction of Prerequisite Criteria for Environmentally Certified Adaptive Reuse of Heritage Buildings," Sustainability 13, no. 6 (2021): 3536.

59 Lobna Abd El Aziz El Borolosy, "Use Multi-Criteria Analysis MCDM to Determine the Most Appropriate Funding for the Adaptive Reuse of Heritage Buildings (Case Study of the Champollion Palace)," International Journal of Multidisciplinary Studies in Architecture and Cultural Heritage 5, no. 2 (2022): 1–29.

current study aims to provide a comprehensive methodology for the Highest Sustainable Reuse mechanism for historic buildings to extend their operational and functional lives.

Highest Sustainable Reuse

The highest and optimal level of adaptation relies on the installation strategy, which involves adding new parts or elements to the current building while avoiding changes to the fundamental structure. This approach allows for the later removal of these new components, returning the building to its original state. Often employed in historic buildings for preservation purposes, this strategy aligns with environmental, economic, and social sustainability.[60] It requires profitability, flexibility, energy efficiency, and environmentally friendly materials.[61] Moreover, it contributes to enhancing the historic building, preserving its social, historic, and cultural values, and highlighting the role of financial and governance models in heritage conservation. However, historic buildings face challenges in achieving sustainable use. Challenges include the potential loss of architectural authenticity due to a lack of clear distinction between the original elements and modern additions. Achieving self-funding for projects is possible but may be unsustainable without considering the proper financial balance between building operation technology and expected financial funding. An effective management process involving stakeholders is required, as without active community participation, historic buildings struggle to fully express the cultural identity of the community.[62]

The highest sustainable reuse mechanism is defined as the one where the building is compatible, enhances, and increases understanding of the cultural significance of the historic place.[63] Selecting the appropriate use is crucial to reducing potential conflicts between heritage preservation and modifying the building to meet current standards for new usage.[64] This process considers the heritage classification of the building to determine the allowed intervention extent, preserving architectural elements, details, and finishing materials that give the building a distinctive character.[65] Additionally, attention is given to community needs and desires, emphasizing the importance of buildings, protecting them, providing long-term management, using dismantlable and switchable systems, and offering

60 Brooker and Stone, Re-readings 2, 2018.

61 Elsorady, "Compatibility of New Uses for Heritage Buildings," 511–521.

62 Imane Djebbour and Ratiba Wided Biara, "The Challenge of Adaptive Reuse Towards the Sustainability of Heritage Buildings," International Journal of Conservation Science 11, no. 2 (2020): 519–530

63 Yıldırım, and Turan. "Sustainable development in historic areas: Adaptive re-use challenges in traditional houses in Sanliurfa, Turkey."

64 Buildings Department, Practice Guidebook, 2019.

65 *Mohannad Tarrad and Salam Mtawea Husban, "The Creation of Guidelines for Adaptive Reuse of Heritage Buildings in Jordan, Case Study Palace of the Ali Alkaid Basha (Jordan)," Architecture and Modern Information Technologies 3, no. 56 (2021): 64–78*

comfortable facilities. It is closely related to the main urban plan, involving design consultations with stakeholders to enhance the understanding of local housing practices[66] . The more significant the importance of the historic building, the more crucial it becomes to find the Highest Sustainable Reuse to minimize damage during the transformation process, maintain vitality, and enhance its significance.[67] [68]

The constraints of the Highest Sustainable Reuse include the need to differentiate new additions and ensure they do not impact the distinctive features of the heritage building. Changes, expansions, or internal and external additions should be minimal, avoiding alterations or damage to parts and spaces, maintaining compatibility with the new function, and allowing easy user access to all building facilities. The usage of the building throughout the day and its full utilization of all its floors are preferred. The process involves a combination of integrated operations, including restoration, renovation, maintenance, and infrastructure improvement, without compromising its artistic and historic value, with the approval of necessary internal modifications by relevant administrative authorities.[69]

MAROHB

The establishment of a decision-making management system for the reuse of historic buildings in the Old City of Mosul involves several stages. After extracting aspects, criteria, and indicators directly impacting this mechanism within the theoretical framework, the process begins by identifying and analyzing the essential system requirements. This ensures a comprehensive understanding of what the proposed Most Appropriate Reuse of Historic Buildings (MAROHB) system should offer in the current study and how it operates. Data is then collected and analyzed, followed by the design of detailed specifications. This phase aims to transform the acquired data into an interactive design that can identify user requirements and achieve their goals of finding the most suitable alternative. This stage includes the design of backend system operations, focusing on processes that will occur in the background to activate the system for the intended purpose. Data processing involves establishing relationships and equations to connect the impact of user interface entities with the basic data for indicator weights. The final result is derived by processing the linkage of requirements, building capabilities, and functions with indicator values. When inputting data into the user interface, it is transformed

66 Mücahit Yıldırım and Gizem Turan, "Sustainable Development in Historic Areas: Adaptive Re-Use Challenges in Traditional Houses in Sanliurfa, Turkey," Habitat International 36, no. 4 (2012): 493–503.

67 *ICOMOS, Principles for the Conservation of Heritage Sites in China (China: The State Administration of Cultural Heritage, 2015).*

68 Sara J. Wilkinson, Hilde Remøy, and Craig Langston, Sustainable Building Adaptation: Innovations in Decision-Making (United Kingdom: John Wiley & Sons, Ltd., 2014).

69 Yildirim, "Re-Use of Diyarbakir Hasan Pasha Khan," 379–388.

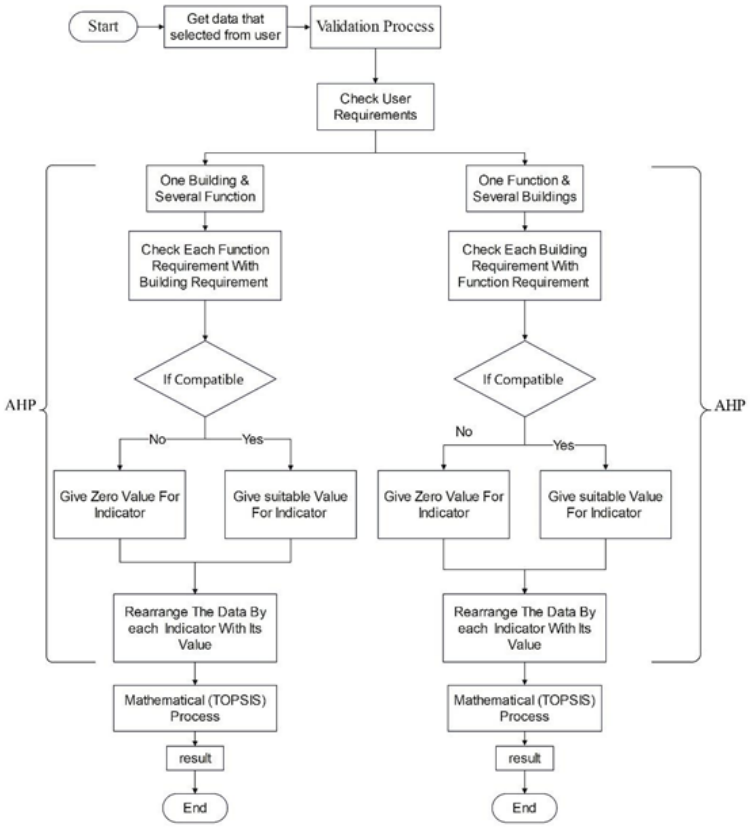

FIG. 1 MAROHB system process design algorithm. Imagine by authors

into system operations for analysis, uncovering relationships using equations and algorithms to reach the final result. This result is then clearly presented to the user on the interface, allowing for easy and clear understanding, as shown in Figure 1.

Following this, the user interface design is developed as shown in figure 2, to create what the user will see and how they will interact with the details. This includes designing pages, windows, menus, buttons, and other control elements for user interaction. This contributes to making the user experience smooth and logical, providing guidance and instructions through images and interactive explanatory texts to help users perform tasks. The system interface is designed to be responsive across various devices and screens (computers or mobile phones), allowing easy access from anywhere. The goal in this part is to ensure a comfortable and effective user experience, guiding them efficiently towards achieving their goals and successfully reaching the final result. The program provides the option to download the final results in both CSV and PDF formats.

The study outlined the most sustainable reuse mechanism for preserving historic buildings, prolonging their operational lifespan, and enhancing their value. Recognizing the actual need for a comprehensive and effective methodology to implement the most sustainable reuse, this study aims to design a computer program based on a multi-criteria decision-making approach. The program was created by identifying two categories of urban and architectural requirements and constraints. The first

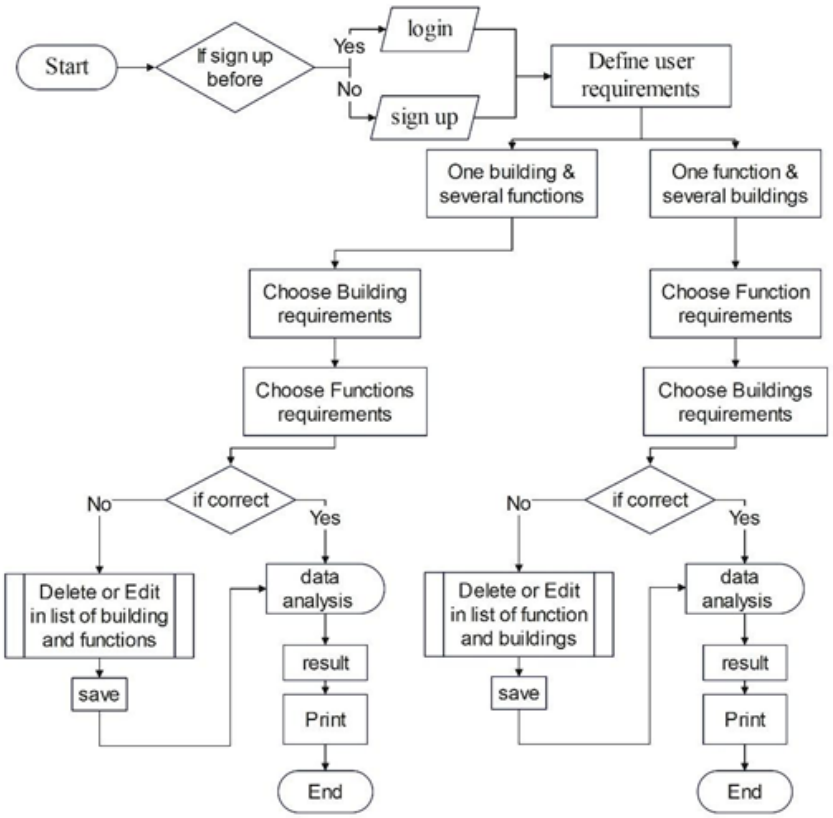

FIG. 2 User interface algorithm in the MAROHB system. Imagine by authors

relates to the characteristics, capabilities, and limitations of the historic building, while the second describes the proposed function's needs and conditions. Through algorithmic comparison, the program can provide percentage scores for a set of proposed functions based on a case study. This study helps decision-makers make more accurate decisions for the reuse of historic buildings in a more efficient manner, contributing to the extension of the building's physical and functional lifespan and avoiding damage resulting from incorrect reuse decisions.

The next section will analyze a historic building in the Old City of Mosul, testing its capacity to accommodate various proposed functions, including a museum, heritage restaurant, library, and a training center for the maintenance and restoration of antiquities.

Case Study Old City of Mosul

The Old city of Mosul is situated at a historically significant location, bordered by the right bank of the Tigris River to the east and surrounded by old walls. It is positioned on a gradually sloping plateau towards the Tigris River, constituting 5% of the current city's area. The Old City of Mosul holds a pivotal status as a cultural and historic center with substantial influence on regional history throughout old times. Mosul boasts a rich and diverse history, representing a multifaceted historic and cultural significance

ohat has witnessed various influences over the ages.[70 71 72] The city faced destruction during military operations from 2014 to 2017, resulting in the disappearance of many of its landmarks. Currently, international organizations and local efforts are directed towards revitalizing and preserving the city's heritage, aiming to restore it to its former glory.

Al-Barood Khana 1834 AD

The building dates back to the year 1834, during the reign of Mosul's governor, Muhammad Enjah Birqdar. The term 'Al-Barood Khana' translates to the Gunpowder Depot, and it stands as one of the most important structures from the Ottoman era. It is located in the Al-Shifaa district, in the northwest of the old city. The structure consists of three parts: the main building for storing gunpowder (Al-Danat), which still stands and has two metaphorically rectangular floors with two protruding wings on each side. It covers an area of 2374 square meters and has a height of 11 meters. The building is characterized by its thick walls and the presence of semi-cylindrical towers at its corners, supported externally by buttresses with dimensions of 5.5 meters, a height of 8 meters, and a thickness of 1.1 meters. As for the second building for the workers' residence and the third building for the officers, they are not currently present. The building was previously used as a cooperative society and later transformed into a museum for folk heritage.

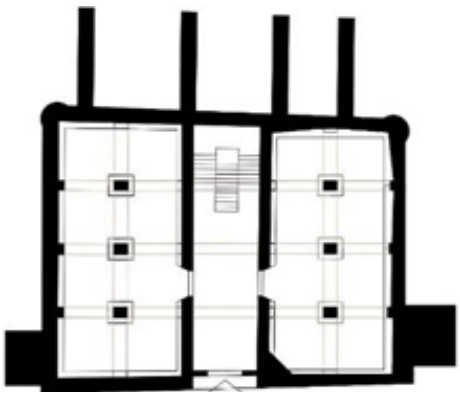

FIG. 3 Ground floor of Al-Baroud Khana

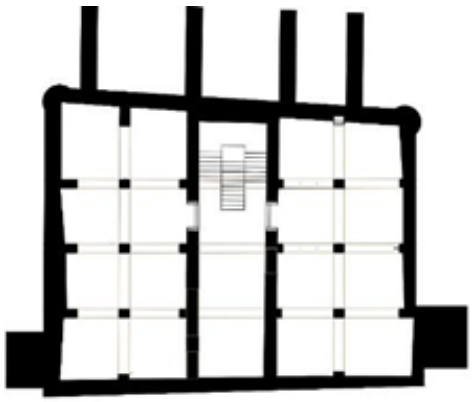

FIG. 4 First floor of Al-Barood Khana

Discussion

The results of applying the capabilities of the Al-Barood Khana building and job requirements in the MAROHB system indicate that the most suitable alternative is selected due to achieving the highest percentage of

70 Ahmed Qasim Aljumaa, The Old Arab City of Mosul Is Undergoing Reconstruction and Development (Mosul-Iraq: Mosul House, 2020), accessed September 1, 2023, https://www.baytalmosul.com/.

71 University of Mosul, Mosul Civilizational Encyclopedia, vols. 1–4 (Mosul-Iraq: Ibn Al-Atheer House for Printing and Publishing, 1991).

72 Saeed Al Diwaji, History of Mosul, vol. 1 (Mosul-Iraq: Iraqi Scientific Academy, 1982).

FIG. 5 Al-Barood Khana building. Irfaa Sawtak, Irfaa Sawtak, January 27, 2023, accessed September 28, 2023, Facebook.

Building Function	Museum	Library	Heritage restaurant	Training center
Barood Khanah Building	74%	48%	60%	45%

TABLE. 1 The most appropriate function for Al-Barood Khana from a set of proposed functions. By authors

compatibility conditions with job requirements. These requirements hold high importance and include factors such as space, capacity, number of rooms, ventilation, lighting, and required materials, among other less impactful requirements. The selection of Al-Barood Khana for the study was based on field documentation, referring to other sources, whether books, articles, or interviews with individuals directly related to these buildings, to fully understand their details. After completing the process of identifying the building's capabilities, heritage experts were consulted in the practical field to provide their opinions on the credibility of determining these capabilities. As for the functions to be tested, a set of functional programs was proposed within the current study and presented to architectural design experts, professors in the Department of Architecture at the University of Mosul, for review, criticism, and approval as suitable and efficient programs for the proposed functions, meeting the requirements of stakeholders and aligning with global standards for each. Based on this, several functions and a specific building in the MAROHB system were implemented to verify its efficiency in finding the most suitable alternative. The results showed that the museum with the highest percentage function is the most suitable, with a percentage of 74%, as it achieves the highest compatibility with the job requirements.

It is evident that the closer the capabilities of different buildings are, the higher the likelihood of multiple buildings getting the same function if their requirements match the building's capabilities. The degree of proximity or distance from the ideal alternative is measured, and a percentage is assigned to this proximity. The results of the application may change as a result of changes in the requirements and capabilities of the buildings and their proposed functions.

Conclusions

The most sustainable reuse mechanism is considered the most suitable for preserving and enhancing historic buildings, giving the structure or site a higher likelihood of protecting its construction and architectural characteristics. The effective contributions of sustainable reuse emphasize the importance of historic buildings, preserving them from disappearance, reducing demolition operations, and utilizing the built environment to achieve investors' goals. The current study proposes a computer program aimed at analyzing the detailed details of the system and how to transform user requirements into a practical and visual design in an easy and efficient manner for implementing its functions. The data processing in the system operations design led to the creation of relationships and equations to connect the impact of user interface components with the basic data for the weights of aspects and criteria and how to find the final output by processing the link between requirements and possibilities for buildings and functions with indicator values. After completing the system design process, it was applied to the historic Barood Khanah building, classified among the highest values in the Old City of Mosul, proving the effectiveness and accuracy of the system in finding the most suitable alternatives. The program is created by specifying two categories of urban and architectural requirements and constraints. The first relates to the characteristics, capabilities, and limitations of the historic building, while the second describes the needs and conditions of the proposed function. Through algorithmic comparison, the program can provide percentage ratios for a set of proposed functions based on the case study. The use of the MAROHB methodology facilitated sound decision-making by decision-makers, in addition to reducing the time required to complete the process of selecting the Highest Sustainable Reuse for the historsic building. The comprehensiveness of the information significantly contributed to covering and managing the process as thoroughly as possible.

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