

Employing a Digital Model for Determining the Value of Heritage: An Evaluation of the Industrial Area of Algiers, Algeria using a Fuzzy DEMATEL-ANP-GIS model

Guechi Imen¹ & Bouaziz Samia²

¹Department of Architecture, Laboratory of Evaluation of Quality in Architecture and In-built Environment, University of Arbi Ben M'hidi Oum El Bouaghi, Algeria,

²Architecture, Faculty of sciences and technology, University of Mohamed Khider Biskra, Algeria,

Email: guechi.imen@gmail.com; Bouaziz_ummto@hotmail.fr

Received	Accepted	Published
16.03.2025	24.07.2025	31.07.2025

<https://doi.org/10.61275/ISVSej-2025-12-04-02>

Abstract

Industrial heritage, encompassing both tangible and intangible aspects of industrial history, represents a vital component of cultural and historical identity. Despite its value, this heritage is frequently neglected and left to deteriorate, especially in urban areas facing redevelopment pressures. This study investigates how digital multi-criteria decision-making tools can support the evaluation of industrial heritage for potential reuse or demolition. It focuses on the El Hamma district in Algiers, Algeria.

The research begins by identifying and assessing key criteria such as historical importance, architectural integrity, and spatial context. It then develops a digital evaluation framework by integrating Fuzzy DEMATEL and the Analytic Network Process (ANP), combined with spatial analysis using Geographic Information Systems (GIS). This model is applied to a case study in El Hamma to explore its capacity for prioritizing industrial buildings based on their reuse potential.

The findings demonstrate that the integrated Fuzzy DEMATEL-ANP-GIS model provides a structured and effective approach to evaluating industrial heritage within a complex urban environment. The conclusions are specific to the El Hamma case and suggest that this methodological approach can assist local decision-makers in identifying buildings with high reuse value, while recognizing the contextual limitations of applying such models to broader scenarios.

Keywords: El Hamma Algeria, Industrial Heritage, Heritage Preservation, Fuzzy DEMATEL, Analytic Network Process (ANP), Geographic Information Systems (GIS), Cultural Heritage Evaluation.

Introduction

Cultural heritage, and more specifically industrial heritage, is increasingly recognised as an essential asset for local development and urban transformation (Ikiz Kaya et al., 2021; Daldanise et al., 2022). Since the 1990s, Europe has become aware of the importance of preserving its industrial heritage, which includes sites, structures, machinery and landscapes

associated with industrial processes (Krige, 2010; Benito del Pozo, 2012; Preamble, 2011). This heritage is crucial for understanding the history and identity of industrial regions (Arbab et al., 2022). However, despite growing interests, many of these structures remain abandoned or at risk of demolition, with only 6% included in the UNESCO World Heritage List (UNESCO, 2017).

The complexity of evaluating industrial heritage lies in determining which sites are worth preserving and which are not, based on a multi-dimensional assessment. These evaluations must consider a range of aspects such as historical authenticity, architectural integrity, economic feasibility, social utility, and landscape/urbanistic value. Unfortunately, these crucial aspects are often overlooked in policy and practice. While international charters like the Venice Charter (Erder, 1977), the Granada Convention (Council of Europe, 1985), and the Nizhny Tagil Charter (TICCIH, 2003) offer conservation principles, they do not provide operational tools to assess and compare preservation priorities. These documents emphasise the importance of incorporating intangible heritage (Australia ICOMOS, 1999; Vecco, 2010), and their application in the context of industrial heritage remains limited.

Today, the adaptive reuse of industrial sites is increasingly favoured to support urban revitalisation and economic renewal (Shan, 2022; Cuirong, 2022). Recent studies underline the role of industrial heritage in stimulating social innovation, reinforcing local identity, and creating opportunities for economic development (Scaffidi, 2019; Della Lucia & Pashkevich, 2023; Scaffidi, 2018; Sun & al., 2023). Examples from countries like the United Kingdom and Germany show how abandoned industrial sites can be successfully converted into museums, cultural hubs or tourist attractions, contributing to regional regeneration (Falconer, 2006; Reicher, 2009; Berger et al., 2017; Somoza-Medina et al., 2021). Yet, making informed decisions about which buildings to preserve requires robust and systematic assessment models.

In this context, this research examines the possibilities of employing a digital model for determining the value of heritage. It therefore carries out an evaluation of the industrial area of Algiers in Algeria using a Fuzzy Dematel-ANP-GIS model. The study aims to develop a robust and innovative decision-making framework to support the conservation and reuse of industrial heritage, particularly in regions where heritage structures are at risk of demolition. Its objectives are as follows.

1. To identify and structure the key value criteria for evaluating the reuse potential of industrial heritage, apply the Fuzzy DEMATEL method to analyse the causal relationships among these criteria, and prioritise both criteria and sub-criteria using the Analytic Network Process (ANP).
2. To integrate Geographic Information Systems (GIS) to spatially visualise the decision-making outcomes and enhance the applicability of the model in real-world planning contexts.
3. To validate through an empirical case study, the proposed hybrid Fuzzy DEMATEL-ANP-GIS model, ensuring both theoretical soundness and practical relevance.

Theoretical Framework

Understanding industrial heritage requires a foundational engagement with key theoretical concepts such as heritage value, authenticity, and the methodological tools used to assess reuse potential. As emphasized by the International Council on Monuments and Sites (ICOMOS, 2011), heritage embodies tangible and intangible attributes of the past that carry cultural, historical, and social significance. Specifically, industrial heritage refers to the remnants of industrial culture that are of historical, technological, social, or architectural value (TICCIH, 2003). According to Feilden and Jokilehto (1993), heritage conservation is not merely about preserving physical structures but involves safeguarding authenticity—a critical value dimension—by retaining the materials, design, and function that define the cultural meaning of the place.

Authenticity, as articulated in the Nara Document on Authenticity (UNESCO, 1994), is central to heritage evaluation, especially for industrial sites where original use and spatial configuration often carry deep historical meanings. Therefore, evaluating industrial heritage entails balancing competing demands—preservation versus development—while ensuring the integrity of the cultural message conveyed by the site.

From a methodological perspective, assessing such multidimensional values requires robust decision-making tools. According to Büyüközkan and Çifçi (2012), Multi-Criteria Decision Making (MCDM) methods are effective in dealing with the complexity and uncertainty inherent in heritage assessments. Fuzzy DEMATEL enables the identification of causal relationships among evaluation criteria under conditions of ambiguity (Tseng, 2009). It is particularly suitable for heritage contexts where expert judgments are often subjective. As Saaty (1996) explains, the Analytic Network Process (ANP) extends the traditional AHP by allowing interdependencies among criteria, which better reflects real-world decision problems. Moreover, Geographic Information Systems (GIS) provide a spatial dimension to heritage evaluation by enabling visualisation of urban patterns and supporting spatial decision-making (Malczewski, 2006).

By integrating these theoretical insights, the present study constructs a conceptual framework for evaluating the reuse potential of industrial heritage through a hybrid Fuzzy DEMATEL–ANP–GIS approach. This framework supports more accurate, transparent, and spatially grounded assessments of what industrial heritage assets are worth conserving.

Review of Literature

To support such decisions, multi-criteria decision-making (MCDM) tools offer significant potential. Techniques such as the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), and DEMATEL are widely used to structure and evaluate complex problems. For instance, Liu et al. (2021) have used AHP and Delphi to evaluate the Shanghai Iron and Steel Plant; Chen et al. (2018) have combined Fuzzy Delphi, ANP, and sensitivity analysis to evaluate heritage buildings. Similarly, Peng et al. (2019) have integrated DEMATEL with an improved VIKOR method, and Meng et al. (2023) have applied AHP-TOPSIS for industrial heritage transformation. Vardopoulos (2019) has employed Fuzzy DEMATEL in analysing value-added factors in the rehabilitation of industrial sites. These approaches show the diversity of strategies but also reveal a fragmentation of methodologies, with each model addressing only part of the decision problem.

However, no study to date has integrated Fuzzy DEMATEL, ANP, and GIS into a single unified framework to assess the reuse potential of industrial heritage. This research addresses that gap by proposing an original Fuzzy DEMATEL–ANP–GIS model, which integrates fuzzy logic with DEMATEL and ANP to more accurately and practically manage complex and uncertain decision environments. ANP is particularly effective in prioritising elements while accounting for their interdependencies (Büyüközkan & Güleriyüz, 2017; Meade & Sarkis, 1999), and its limitations in handling complexity are mitigated by integrating DEMATEL, which simplifies the analysis of causal relationships between factors (Tadić et al., 2014). Furthermore, fuzzy logic (Ait-Mlouk et al., 2022) enhances precision by addressing uncertainty and ambiguity in expert judgment. The integration of GIS further supports spatial visualisation and decision-making, enabling planners to translate analytical results into actionable, location-based strategies.

Research Methodology

This study proposes an evaluation framework for assessing the reuse potential of industrial heritage in order to decide whether to preserve or demolish it. First, the main groups and associated criteria are identified through a literature review and expert interviews. The framework is then developed using the Fuzzy DEMATEL–ANP–GIS method. Fuzzy DEMATEL calculates relationships between clusters based on expert opinions. This technique clarifies the cause and effect relationships between criteria. Fuzzy ANP assigns weights to clusters and criteria through pairwise comparisons using fuzzy set theory. Fuzzy theory is used

for pairwise comparisons in the DEMATEL and ANP techniques. As a result, experts make pairwise comparisons using fuzzy linguistic scales, which improves the accuracy and reliability of the assessment. The GIS classifies industrial heritage sites on the basis of an analysis known as Weighted Overlay Analysis (WOA), which uses weights calculated by the fuzzy DEMATEL-ANP method and carried out in the Arc GIS environment. This holistic approach ensures that the assessment framework is robust and is able to cope with the complexities and uncertainties associated with assessing the reuse potential of industrial heritage.

Figure 01 illustrates the main steps of the Fuzzy DEMATEL-ANP-GIS methodology and provides a detailed description of the process.

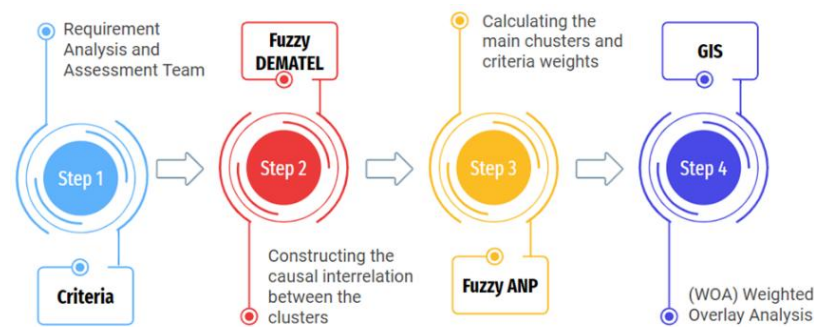


Fig. 1: The main steps of the Fuzzy DEMATEL-ANP-GIS method

Source: Author, 2025

Step 1: Identification of the criteria

To assess the potential for reusing industrial heritage, the primary clusters and associated criteria were derived through an in-depth literature survey and expert interviews. Firstly, the relevant factors and requirements for evaluating industrial heritage were gathered from existing studies and expert opinions. These factors were then categorised into distinct criteria. Similar criteria were then grouped into thematic clusters based on the expertise of the authors. As a result, ten key sub-criteria were identified to guide the evaluation of whether any industrial building should be conserved or demolished, as illustrated in the Figure 03.

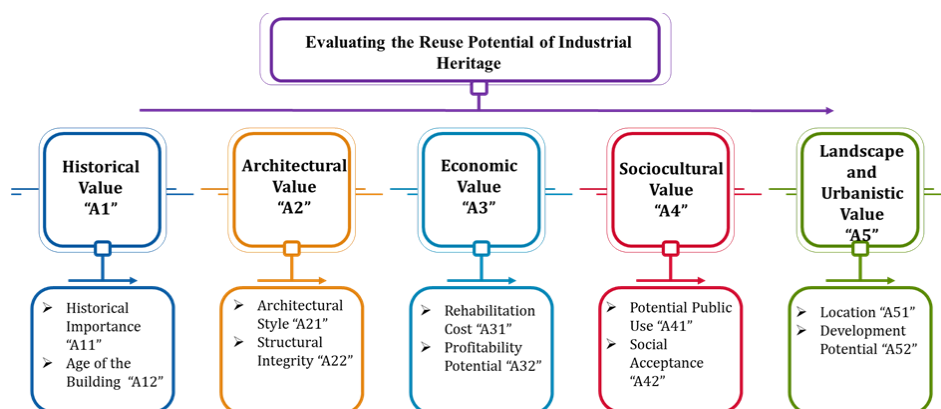


Fig. 2: Criteria and sub-criteria for the evaluation of industrial heritage

Source: Author 2025

Step 1.1. Producing the Framework

Rather than a generic review, a targeted literature survey was undertaken to systematically extract data regarding the factors that influence the reuse of industrial heritage. The purpose was to gather empirical and theoretical information that could serve as input for constructing an evaluation framework, not merely to summarize existing knowledge. Sources examined are as follows.

Following categories of documents were surveyed:

- Academic journal articles on industrial heritage assessment, urban regeneration, and adaptive reuse (Journal of Cultural Heritage, Sustainability, Urban Studies, Environmental Science and Pollution Research) (Dutta & Husain, 2009; Claver et al., 2020; Sun & Chen, 2023; Liu et al., 2021);
- Technical reports and charters from international organizations (The Burra Charter – Australia ICOMOS, 1999; TICCIH Nizhny Tagil Charter, 2003; UNESCO, 2017);
- Governmental and institutional case studies, including European and North African reports on post-industrial urban planning and rehabilitation (Guechi et al., 2023; Benito del Pozo, 2012; Cengiz & Akbulak, 2009);
- Published theses and empirical studies on industrial reuse and MCDM methods applied to heritage evaluation (Vardopoulos, 2019; Chen et al., 2018; Büyüközkan et al., 2017; Tadić et al., 2014).

Data Extracted

Each document was analyzed to identify:

- Criteria used in existing assessment frameworks (historical importance, location, profitability);
- Conceptual groupings of these criteria (historical, architectural, economic, social, urban);
- Definitions and measurement indicators (structural integrity, age, public use potential);
- Common MCDM methods used for analysis and prioritization (AHP, ANP, Fuzzy DEMATEL, VIKOR) (Meade & Sarkis, 1999; Sadeghi-Niaraki, 2020; Tadić et al., 2014);
- Empirical evidence showing the effectiveness of reuse projects (revitalisation impacts, adaptive reuse success stories) (Scaffidi, 2018; Mattone & Frullo, 2022; Shan, 2022).

Contribution to the Framework

Data were synthesized and grouped into clusters based on thematic similarity.

For instance :

- The TICCIH Nizhny Tagil Charter emphasized historical significance and typological uniqueness, leading to the inclusion of “Historical Importance” and “Age of the Building” (TICCIH, 2003);
- Studies of urban regeneration in Mediterranean and North African cities emphasized “Location” and “Potential Public Use” (Guechi et al., 2023; Cuirong, 2022);
- Economic evaluations consistently stressed “Rehabilitation Cost” and “Profitability Potential” as critical dimensions (Liu et al., 2021; Bonini Baraldi & Salone, 2022; Meng et al., 2023);
- Contributions on social innovation and sustainability helped integrate criteria like “Social Acceptance” and “Development Potential” (Della Lucia & Pashkevich, 2023; Ikiz Kaya et al., 2021).

This process resulted in a preliminary list of criteria and sub-criteria, organized into a hierarchical structure, that were then validated through expert interviews.

Step 1.2. Application of the Framework to the Case Study

Selection of Interviewees:

Eight experts were selected using purposive sampling based on their professional experience and relevance to the topic. Selection criteria included: over 10 years of experience in heritage conservation, involvement in heritage rehabilitation projects or academic research, and representation of diverse disciplines.

Interview Design and Process

Semi-structured interviews were conducted covering key areas such as the relevance of the identified criteria, the addition of overlooked criteria, the interaction between criteria, and suggestions for grouping them into coherent clusters. The interviews were recorded, transcribed, and analyzed using thematic coding.

Synthesis of Results and Expert Recommendations:

Experts validated most of the criteria derived from the literature review but suggested adding "Social Acceptance" as a distinct sub-criterion, splitting "Architectural Value" into "Architectural Style" and "Structural Integrity," and clarifying economic feasibility by distinguishing between "Cost" and "Potential Return." Their insights led to the finalization of the 5 main criteria and 10 sub-criteria, which were incorporated into the Fuzzy DEMATEL-ANP-VIKOR model.

Step 2: Fuzzy DEMATEL

Building the causal relationship model among the clusters and criteria within each cluster utilizing the Fuzzy DEMATEL technique. (Skrzeszewska, et al., 2020; Sadeghi-Niaraki, 2020). This will be achieved through the following steps:

Step 2.1: Creating a Fuzzy Linguistic Scale:

To handle the uncertainty in experts' preferences, relationships among the main clusters and criteria are identified using a pairwise comparison process. Preferences of the experts are gathered through linguistic expressions, which are represented by positive triangular Fuzzy numbers. These Fuzzy numbers are consistent with those used in the standard DEMATEL technique (Table 1).

Table 1: DEMATEL Fuzzy linguistic scale.

Source: Author

Linguistic Terms	Score	Triangular Fuzzy Numbers
No influence (No)	0	(0, 0, 0.25)
Very low influence (VL)	1	(0, 0.25, 0.5)
Low influence (L)	2	(0.25, 0.5, 0.75)
High influence (ML)	3	(0.5, 0.75, 1)
Very high influence (HL)	4	(0.75, 1, 1)

Step 2.2:

In this step, the initial Fuzzy direct-relation matrix is constructed by gathering the opinions of experts. This involves creating a square matrix $Q_{n \times n}$, where each element Q_{zij} represents the influence of one cluster or criterion on another. Experts provide their assessments through pairwise comparisons, which are then translated into triangular Fuzzy numbers. Each element Q_{zij} in the matrix is represented as a triangular Fuzzy (l_{ij}, m_{ij}, u_{ij}) where:

- l_{ij} is the lower bound of the triangular Fuzzy number.
- m_{ij} is the most likely value (the peak of the triangle).
- u_{ij} is the upper bound of the triangular Fuzzy number.

These Fuzzy numbers quantify the effect of one element on another, reflecting the level of impact as expressed by the experts.

Step 2.3: Creating and normalizing direct-relation fuzzy matrix

To construct and normalize the direct-relation fuzzy matrix, we start by forming the initial matrix A based on experts' opinions, where each element $Q_{ij} = (l_{ij}, m_{ij}, u_{ij})$ is a triangular fuzzy number representing the influence of one cluster or criterion on another.

We then calculate the row sums S_i of matrix A using the formula:

$$S_i = \sum_{j=1}^n Q_{ij} = \left(\sum_{j=1}^n l_{ij}, \sum_{j=1}^n m_{ij}, \sum_{j=1}^n u_{ij} \right)$$

Next, we normalize each element Q_{ij} by dividing it by the maximum row sum r , where:

$$r = \max_{1 \leq i \leq n} \sum_{j=1}^n u_{ij}$$

To obtain the normalized matrix X , we use the formula:

$$Q_{xij} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r} \right)$$

This process ensures that the normalized direct-relation fuzzy matrix X accurately reflects the proportionate influence of each element, with the row sums ensuring that the matrix is properly scaled.

Step 2.4: Calculating a Fuzzy Total-Relation Matrix

To calculate the fuzzy total-relation matrix, we first compute the matrix T by summing the normalized direct-relation matrix X and its powers until convergence. We use the formula:

$$TQ = XQ(I - XQ)^{-1}$$

where: XQ is the normalized direct-relation matrix, and I is the identity matrix. For matrix operations with triangular fuzzy numbers, we apply addition and multiplication rules. For two triangular fuzzy numbers $A = (l1, m1, u1)$ and $B = (l2, m2, u2)$

We perform iterative summation of the powers of X until the change between successive powers becomes negligible. By doing so, we ensure that the matrix T accurately reflects the total influence among the clusters and criteria in our system.

Step 2.5: Constructing cause and effect relation diagram

In the Step 8, we finalize our fuzzy DEMATEL analysis by calculating crisp values and constructing the cause-and-effect relation diagram. We start by obtaining the crisp values for the influences of clusters and criteria using defuzzification. Specifically, the crisp value ri for cluster i is calculated as:

$$r_i = \frac{l_i + m_i + u_i}{3}$$

where : $ri = (li,mi,ui)$ is the triangular fuzzy number. Similarly, the crisp value cj for criterion j is:

$$c_j = \frac{l_j + m_j + u_j}{3}$$

Finally, we construct the cause-and-effect relation diagram by representing clusters and criteria as nodes and drawing arrows to indicate the direction and magnitude of influence. This diagram is created using graphical tools to ensure a clear and accurate visual representation of the interactions and causal relationships.

Step 3: Fuzzy ANP

To begin the Fuzzy ANP analysis after completing the Fuzzy DEMATEL analysis, you need to use the results from the Fuzzy DEMATEL phase to determine the weights of the criteria and sub-criteria (Tadić, et al., 2014; Sadeghi-Niarak, 2020). Here are the steps and results you need to use:

Step 3.1: Calculating the Weights of Criteria/Sub-Criteria

Use the total influence matrix to assess the centrality of each criterion/sub-criterion. Centrality can be calculated by summing the direct and indirect influences for each criterion. For a criterion i , the centrality C_i is given by:

$$C_i = \sum_{j=1}^n T_{ij}$$

where: T_{ij} represents the elements of the total influence matrix T . The results from the Fuzzy DEMATEL phase also allow you to determine how much each criterion influences the others, which helps assign relative weights in the Fuzzy ANP phase.

Step 3.2: Constructing the Fuzzy ANP N&work

We define the nodes (criteria and sub-criteria) and arcs (relationships between them) in the ANP network using the identified influences. Specifically, we use the Fuzzy DEMATEL

results to create judgment matrices for the relationships between the criteria and the sub-criteria. To quantify these relationships, we use the pairwise comparison matrices A_{ij} and convert them into fuzzy pairwise comparison matrices $Q_{ij} = (l_{ij}, m_{ij}, u_{ij})$.

The weights w_i for each criterion and sub-criterion are derived from these matrices. We calculate the normalized weights by solving the following equations:

$$w_i = \frac{\sum_{j=1}^n Q_{ij}}{r}$$

where r is the maximum row sum given by:

$$r = \max_{1 \leq i \leq n} \sum_{j=1}^n u_{ij}$$

The goal of constructing the ANP network is to systematically analyze and quantify the relationships and dependencies between the criteria and the sub-criteria in a decision-making process. By defining nodes and arcs and creating weight matrices based on Fuzzy DEMATEL results, we aim to accurately represent the influence of each criterion and sub-criterion, leading to more informed and balanced decision-making.

Step 3.3: Constructing the Fuzzy ANP Network

After constructing the ANP model, we evaluate the weights of the criteria and the sub-criteria by analyzing the supermatrix. We start by forming the supermatrix S where each element s_{ij} represents the influence of criterion i on criterion j . The supermatrix is then normalized so that the sum of each column equals one, achieved by dividing each element by the sum of its column:

$$\tilde{s}_{ij} = \frac{s_{ij}}{\sum_{k=1}^n s_{kj}}$$

Next, we calculate the priority vector w by finding the principal eigenvector of the normalized supermatrix. This can be done using the following formula for the eigenvector w of the matrix S

$$S \cdot w = \lambda_{\max} \cdot w$$

where $\lambda_{\max}$ is the principal eigenvalue. Finally, we perform a consistency check to ensure that the pairwise comparisons and resulting weights are logically coherent, using the consistency index (CI) and consistency ratio (CR):

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad CR = \frac{CI}{RI}$$

where RI is the random index based on the size of the matrix. This process ensures that the ANP model provides a balanced and comprehensive evaluation of the criteria and sub-criteria.

Step 4: Ranking the Industrial heritage value using GIS

After determining the weights for each raster layer using Fuzzy DEMATEL - Analytic Network Process, a process known as Weighted Overlay Analysis (WOA) is performed in the ArcGIS environment. WOA involves the overlaying of standardised layers with different weights to assess industrial heritage (Zolekar and Bhagat, 2015). These weights reflect the relative importance of each criterion. The sub-criterion scores within each layer, representing different aspects of industrial heritage, are then multiplied by their respective weights to produce a final suitability map using the weighted overlay analysis technique (see Equation 18).

$$S = \sum_{i=1}^n W_i \times X_i$$

In this equation, S represents the total suitability score, W_i represents the weight of the selected value layer, X_i represents the sub-criteria score for value layer i , and n is the total number of value layers considered (Cengiz and Akbulak, 2009; Pramanik, 2016).

The Case Study

El Hamma, located East of Algiers in the Bay of Algiers, initially an agricultural marsh, began its industrial transformation in 1846, becoming one of the city's main industrial centers. Over time, it housed a mix of small workshops and large factories that defined its identity. The district's industrial legacy includes several key buildings such as the El Hamma Factory Complex, Former Warehouses on Rue de l'Industrie, Cement Factory (Factory A), El Hamma Distillery, and the Old Electric Plant, which were essential to the district's industrial development. El Hamma underwent two phases of de-industrialization: one during the French colonial rule, transforming it into a mixed-use area, and another after independence, when efforts were made to turn it into a commercial center. This shift led to the demolition of many industrial buildings, replaced by modern architecture unrelated to its industrial origins. Today, many of these industrial structures are deteriorating due to rapid urbanization and neglect, raising questions about their preservation or demolition.

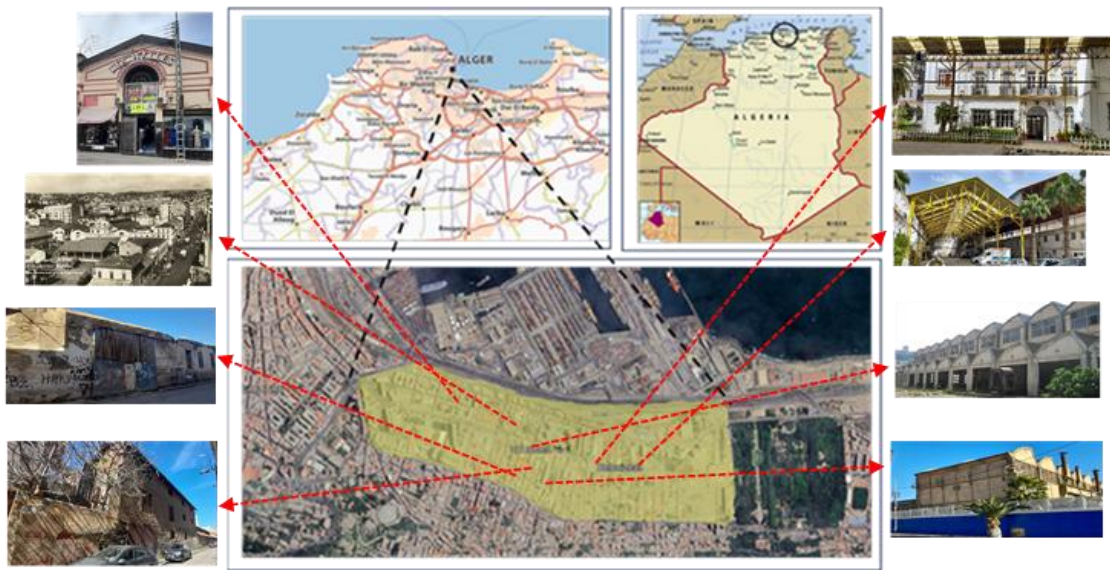


Fig. 3: The Case Study

Source: Author, 2025

This situation raises critical questions about the preservation or demolition of the district's industrial heritage. One of these questions is what criteria should be used to determine which buildings should be preserved or demolished in order to support the district's path towards more responsible and sustainable urban development.

Data Analysis and the Findings

This study proposes a comprehensive approach that integrates the Fuzzy DEMATEL-ANP-GIS model to evaluate whether industrial heritage buildings should be preserved or demolished. The process, which is detailed in this section, involves several steps: defining the problem, identifying criteria and alternatives through literature review and expert input, using the Fuzzy DEMATEL method to uncover the relationships and influences between the criteria, using the Fuzzy ANP method to assign weights to the criteria based on their relative importance and interdependencies, and finally using the Weighted Overlay Analysis (WOA) to evaluate and rank the alternatives according to the weighted criteria and relationships. This integrated approach ensures a systematic and robust evaluation by exploiting the strengths of Fuzzy DEMATEL, Fuzzy ANP and GIS.

Evaluation Criteria and Data Collection

According to the Nizhny Tagil Charter for Industrial Heritage (2003), industrial heritage includes remnants of industrial culture with historical, social, architectural or scientific values. They include buildings, machinery, workshops, factories, mines, warehouses, power plants, transport structures, and sites of social activities such as housing and cultural centres. Following these principles, we selected criteria that accurately reflect the essential characteristics of industrial heritage, guided by objective and independent standards (TICCIH, 2003; UNESCO, 2016; Boying & Kuang, 2006; Dutta & Husain, 2009; Pr  ambule, 2011). Drawing on heritage values and relevant literature, we developed a comprehensive set of criteria to evaluate industrial buildings in our study area. This set takes into account the neighbourhood's urban characteristics, historical and industrial heritage, architectural richness, and the specificity of its working class community. Key criteria include historical value (significance and age), architectural value (style and integrity), economic value (rehabilitation costs and profitability), socio-cultural value (public use and social acceptance), and landscape and urban design value (location and development potential). This approach, based on Meng et al. (2023) and Pr  ambule (2011), ensures a balanced assessment by integrating historical, architectural, economic, sociocultural and urbanistic dimensions (figure 03).

Evaluating the Interconnections between Criteria (Fuzzy DEMATEL)

In this section, we examine the interconnections between the criteria using the Fuzzy DEMATEL method. By following the steps of the Fuzzy DEMATEL process, we present the normalized fuzzy direct-relation matrix, the total-relation fuzzy matrix, and the values for ri , cj , $ri+cj$, and $ri-cj$, as illustrated in the Tables 2, Figure 04, and the Table 3, respectively. The causal diagram of the main criteria is then depicted in the Figure 05, based on the data from the Table 2.

Table 2: DEMATEL Fuzzy linguistic scale.

Source: Author

	A11	A12	A21	A22	A31	A32	A41	A42	A51	A52
A11	(0, 0, 0.167)	(0, 0.111, 0.25)	(0.333, 0.333, 0.333)	(0.333, 0.333, 0.333)	(0.667, 0.5, 0.333)	(0.667, 0.5, 0.333)	(1.5, 1.333, 1)	(1.5, 1.333, 1)	(1.5, 1.333, 1)	(1.5, 1.333, 1)
A12	(0, 0.111, 0.25)	(0, 0, 0.111)	(0, 0.167, 0.222)	(0.333, 0.333, 0.333)	(1, 1, 0.5)	(1, 1, 0.5)	(1, 1, 1)	(1, 1, 1)	(1.5, 1.333, 1)	(1.5, 1.333, 1)
A21	(0.333, 0.333, 0.333)	(0, 0.167, 0.222)	(0, 0.167, 0.111)	(0, 0.167, 0.222)	(1, 1, 0.5)	(1, 1, 0.5)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	(1.5, 1.333, 1)
A22	(0.333, 0.333, 0.333)	(0.333, 0.333, 0.333)	(0, 0.167, 0.222)	(0, 0, 0.111)	(1, 1, 0.5)	(1, 1, 0.5)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)
A31	(0.667, 0.5, 0.333)	(1, 1, 0.5)	(1, 1, 0.5)	(1, 1, 0.5)	(0, 0.167, 0.222)	(0, 0.167, 0.222)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)
A32	(0.667, 0.5, 0.333)	(1, 1, 0.5)	(1, 1, 0.5)	(1, 1, 0.5)	(0, 0.167, 0.222)	(0, 0.167, 0.222)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)
A41	(1.5, 1.333, 1)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)	(0, 0.167, 0.222)	(0, 0.167, 0.222)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)
A42	(1.5, 1.333, 1)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)	(0, 0.167, 0.222)	(0, 0, 0.167)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)
A51	(1.5, 1.333, 1)	(1.5, 1.333, 1)	(1, 1, 1)	(1, 1, 1)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)	(0, 0, 0.25)	(0, 0, 0.25)
A52	(1.5, 1.333, 1)	(1.5, 1.333, 1)	(1.5, 1.333, 1)	(1, 1, 1)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)	(0, 0, 0.25)	(0, 0, 0.25)

The normalized fuzzy direct-relation matrix is a crucial component of the Fuzzy DEMATEL method, as it captures the direct influence of one criterion over another within a fuzzy context. The values in this matrix (Table 03) range from 0 to 1, with higher values indicating a stronger influence between the criteria.

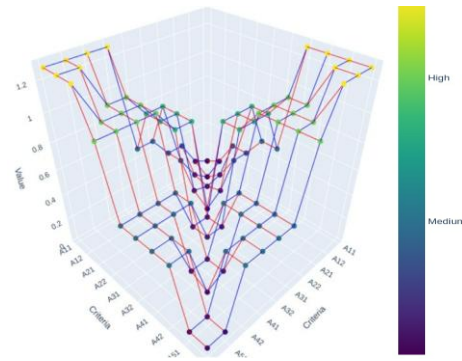


Fig. 4: The total-relation fuzzy matrix.

Source: Author 2025

Figure 04 shows the overall fuzzy DEMATEL relationship matrix for the criteria A11 to A52. Yellow points (e.g. the influence of A41 and A42 on several other criteria) indicate a strong influence, i.e. these criteria have a significant impact on the other criteria. Dark blue cells (e.g. the influence of A11 on A21 and A22) indicate a weak influence, i.e. these criteria have only a minor impact on the other criteria. Green cells (e.g. the influence of A11 on A12) indicate a moderate influence, i.e. these criteria have a significant but not dominant influence.

The exact values of ri , cj , $ri+cj$, and $ri-cj$, given in the Table 04 are used to draw up a cause-and-effect diagram. The table below shows the final result.

Table 3: The exact values of ri , cj , $ri+cj$, and $ri-cj$,

Source: Author

Code	ri	cj	$ri+cj$	$ri-cj$
A11	0.941	0.8	1.741	0.141
A12	0.577	1.167	1.744	-0.59
A21	0.786	0.772	1.558	0.014
A22	1.184	0.52	1.704	0.664
A31	1.101	0.559	1.66	0.542
A32	0.588	0.795	1.383	-0.207
A41	0.65	0.957	1.607	-0.307
A42	0.473	1.084	1.557	-0.611
A51	0.811	0.986	1.797	-0.175
A52	0.111	0.111	0.222	0

In view of these results, the cause-and-effect diagram can be presented in the Figure 05

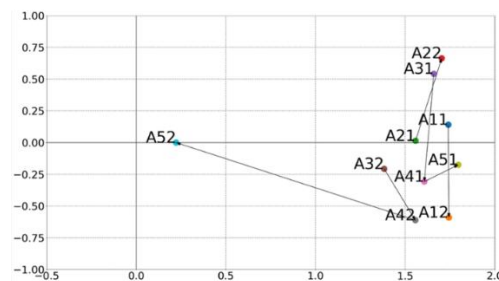


Fig. 5: The cause-and-effect diagram.

Source: Author 2025

The Structural Integrity (A22), Rehabilitation Cost (A31) and Historical Significance (A11) sub-criteria have the highest $ri-cj$ values, indicating that they receive more influence than they exert.

The sub-criteria Building Age (A12), Social Acceptance (A42) and Potential Public Use (A41) have significantly negative *ri-cj* values, indicating that they exert more influence than they receive.

The Development Potential sub-criterion (A52), with *ri-cj* = 0, shows a balance between influence received and influence exerted.

Evaluating the Criteria Weights (Fuzzy ANP)

In this phase, in order to start the Fuzzy ANP analysis following the Fuzzy DEMATEL analysis, the results of the Fuzzy DEMATEL phase must be used to determine the weights of the criteria and the sub-criteria. The influence matrices obtained from the Fuzzy DEMATEL analysis are used as input data for the Fuzzy ANP analysis. In this section, we analyse the relationships between the criteria using the Fuzzy ANP method. We present the centrality, the degree of influence, the construction of the ANP network and the weight matrices, following the steps of Fuzzy ANP. After building the ANP model, the weights of the criteria and the sub-criteria can be evaluated using the techniques such as supermatrix analysis.

Centrality and Degree of Influence

Centrality measures the overall influence each sub-criterion receives from and exerts on others. A more negative centrality value indicates a higher degree of interconnectedness. Degree of Influence measures the extent to which each sub-criterion influences the rest of the network. The values indicate the relative importance and impact of each sub-criterion in the overall analysis. After the calculation, we obtained the following results (Table 04).

Table 4: The Centrality and Degree of Influence
Source: Author

Code	Sub-criteria	Centrality	Degree of Influence
A11	Historical Importance	-12.0186	-12.9822
A12	Age of the Building	-12.6848	-8.6179
A21	Architectural Style	-13.3049	-6.3717
A22	Structural Integrity	-10.2894	-7.2350
A31	Rehabilitation Cost	-11.0815	-8.4882
A32	Profitability Potential	-9.9123	-8.3352
A41	Potential Public Use	-9.9428	-13.7472
A42	Social Acceptance	-10.6022	-10.3827
A51	Location	-9.6785	-16.3009
A52	Development Potential	-9.6380	-16.6922

Sub-criteria with higher absolute values for both Centrality and Degree of Influence (e.g. Location and Development Potential) play a more significant role in the network, either by exerting or receiving influence.

Sub-criteria with less negative values, such as profitability potential and social acceptance have a lower degree of influence and centrality, indicating a more balanced or less significant role in the network.

Construction of the ANP network

We define the nodes (criteria and sub criteria) and the arcs (relationships between them) of the ANP network according to the identified influences (Figure 06). We used the results of the Fuzzy DEMATEL phase to create weight matrices (Table 05) representing the relationships between the criteria and the sub-criteria within the ANP network.

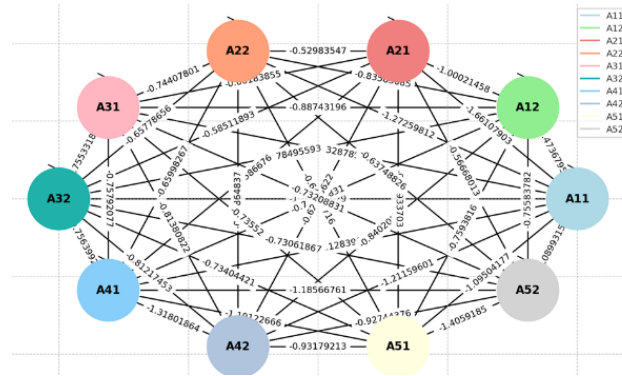


Fig. 6: ANP network nodes and arcs
Source: Author 2025

Table 5: Weighting matrices
Source: Author

	A11	A12	A21	A22	A31	A32	A41	A42	A51	A52
A11	0.128	0.073	0.059	0.067	0.077	0.074	0.125	0.091	0.149	0.152
A12	0.116	0.053	0.053	0.067	0.078	0.077	0.126	0.091	0.149	0.153
A21	0.124	0.063	0.063	0.058	0.078	0.075	0.126	0.092	0.150	0.154
A22	0.123	0.051	0.051	0.071	0.076	0.076	0.123	0.097	0.146	0.150
A31	0.119	0.059	0.059	0.067	0.084	0.073	0.124	0.090	0.148	0.151
A32	0.118	0.059	0.059	0.066	0.076	0.083	0.123	0.097	0.146	0.149
A41	0.113	0.059	0.059	0.066	0.076	0.076	0.137	0.096	0.146	0.149
A42	0.114	0.059	0.059	0.066	0.076	0.076	0.124	0.104	0.147	0.150
A51	0.113	0.058	0.058	0.066	0.075	0.075	0.123	0.096	0.162	0.149
A52	0.113	0.058	0.058	0.066	0.075	0.075	0.123	0.096	0.145	0.166

The analysis shows that Development Potential (A52) stands out as the most critical sub-criterion, both in terms of its relative importance and its influence on other sub-criteria. It has the highest comparative weight and exerts a significant influence within the network, making it central to the overall analysis. On the other hand, sub-criteria such as the age of the building (A12) are less influential and play a more peripheral role in the network. Architectural Style (A21) and Structural Integrity (A22) are also highly connected and influential, indicating their importance in the overall structure. This matrix highlights the different roles that each sub-criterion plays, with some being more central and others less important in shaping the dynamics of the network.

Evaluation of the Weights

Once the ANP model had been constructed, the weights of the criteria and the sub-criteria were assessed. This was done using methods such as supermatrix analysis as shown in the Table 06.

Table 6: The weights of the criteria and sub-criteria
Source: Author

Code	criteria	weights	Code	sub-criteria	weights
A1	Historical Value	0.2	A11	Historical Importance	0.11893544
			A12	Age of the Building	0.07895207
A2	Architectural Value	0.3	A21	Architectural Style	0.05837397
			A22	Structural Integrity	0.06628334
A3	Economic Value	0.1	A31	Rehabilitation Cost	0.07776391
			A32	Profitability Potential	0.0763624
A4	Sociocultural Value	0.15	A41	Potential Public Use	0.12594402
			A42	Social Acceptance	0.09512083
A5	Landscape and Urbanistic Value	0.25	A51	Location	0.14933952
			A52	Development Potential	0.15292449

The table shows the weights assigned to the criteria and the sub-criteria in an ANP analysis, reflecting their relative importance. Among the criteria, Architectural Value (A2) has the highest weight of 0.3, closely followed by Landscape and Urbanistic Value (A5) with a weight of 0.25. Within these criteria, Development Potential (A52) stands out as the most influential sub-criterion with a weight of 0.1529. Historical Value (A1), with a weight of 0.2, emphasises Historical Importance (A11) as the leading sub-criterion. Socio-cultural Value (A4), with a moderate weight of 0.15, highlights Potential Public Use (A41) as particularly important. Economic Value (A3), with the lowest weight of 0.1, is almost equally divided between the Rehabilitation Costs (A31) and Profitability Potential (A32). Overall, Development Potential (A52) emerges as the most critical sub-criterion, underlining the importance of architectural and landscape values in the analysis.

Evaluating the Buildings Using GIS

Figure 07 shows the evaluation of the industrial heritage buildings in Hamma based on specific sub-criteria. Each building is rated on a scale from 1 to 5 according to these criteria. By combining these ratings with the sub-criteria weights calculated in the previous phase, it is possible to rank the buildings according to their priority for conservation or demolition.

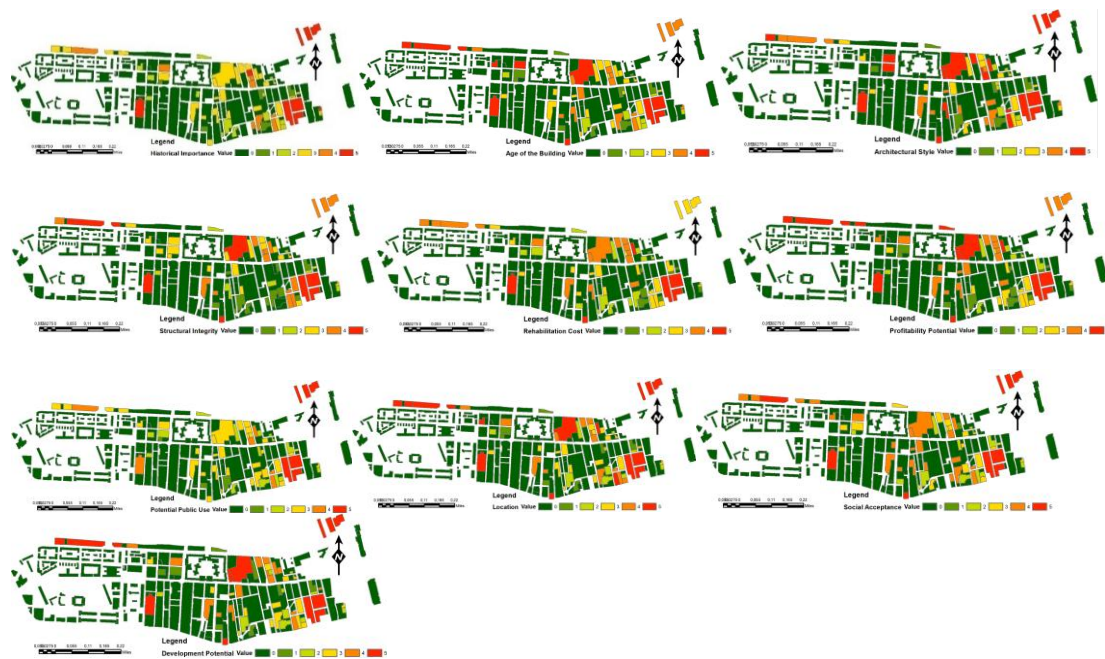


Fig. 7: The evaluation of industrial heritage buildings in Hamma based on specific sub-criteria

Source: Author 2025

It is clear that the red zones indicate buildings of high heritage value that warrant priority conservation due to their historic significance, age, distinctive architectural style, structural integrity and potential for public use or future profitability. In contrast, the green zones indicate buildings of lower value by these criteria, suggesting a lower priority for conservation. The integration of these assessments allows buildings to be ranked according to their potential for conservation or demolition, taking into account their overall heritage values.

Multi-value Weighted Overlay Evaluation of industrial heritage

After determining the weights using the Fuzzy DEMATEL-ANP method and evaluating the industrial heritage according to each criterion, we will apply the Weighted Overlay Analysis (WOA) in the ArcGIS environment. This analysis will allow us to study the possibilities of preserving or demolishing this industrial heritage (Figure 07)

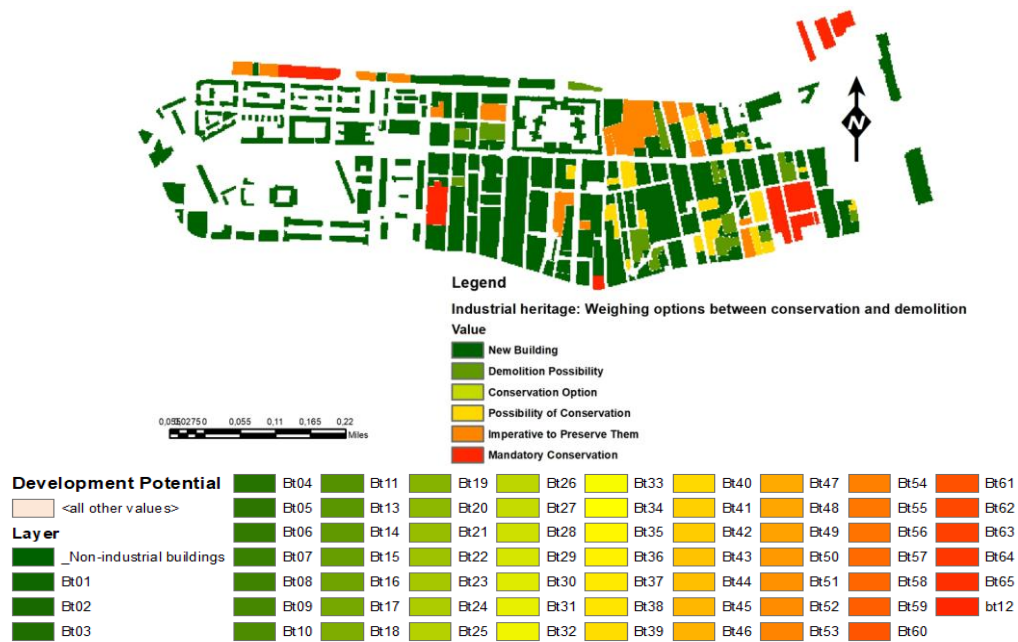


Fig. 8: Industrial heritage: Weighing options between conservation and demolition
Source: Author 2025

Table 7: The names of industrial buildings
Source: Author

Building Number	Identification	Building Number	Identification	Building Number	Identification
Bt 1	CYCMA Factory (Former Mechanical Workshop)	Bt 21	Workshop/printing house	Bt 42	Confectionery plant
Bt 2	Distillery	Bt 22	Depot/former mechanical workshop	Bt 43	Mechanical workshop
Bt 3	Vacant land	Bt 23	Former SNIC factory (vacant)	Bt 44	GETEX Hangar (Ex-ENAB)
Bt 4	Workshop (she& metal)	Bt 24	Former agricultural factory (currently rehabilitated/reconverted)	Bt 45	Former SNTA factory (currently Asga)
Bt 5	Private factory/packaging, pastry products	Bt 26	Private hangars (under state recovery)	Bt 46	Garage (currently car park)
Bt 6	Workshop/printing house	Bt 27	Set of mattress manufacturing workshops	Bt 47	USA warehouse
Bt 7	School/former Patex factory	Bt 28	Private hangar	Bt 48	Depots/hangar
Bt 8	Demolished hangars (vacant land)	Bt 29	Winding workshop	Bt 49	Garage/mechanical workshop
Bt 9	Private warehouse	Bt 30	Former ENADITEX factory taken over by Flamme Bleue	Bt 50	SNTA plant, under rehabilitation
Bt 10	Mechanical garage	Bt 31	SNTR archives warehouse	Bt 51	Plastic transformation plant (vacant)
Bt 11	Shoe factory formerly a stable (vacant)	Bt 32	Mechanical workshop	Bt 52	Plant/Lemonade factory
Bt 12	Former ONACO depot	Bt 33	Depot/store	Bt 53	Set of hangars

Bt 13	ENAP depot/former match factory	Bt 34	Hangar/battery unit	Bt 54	SNVI Commercial Directorate Garage
Bt 14	Set of private factories (furniture, packaging, printing)	Bt 35	Vacant factory (socks)	Bt 55	Former SONACOM Park (taken over by the military)
Bt 15	Former textile factory (now Renault garage)	Bt 36	Housing/former SNTA canteen	Bt 56	Ford/Monoprix garage (vacant)
Bt 16	Vacant land (former distillery)	Bt 37	SONATRACH warehouse (former Hammoud Boualem warehouse)	Bt 57	USA Garage/Workshop
Bt 17	Hangar	Bt 38	Set of manufacturers	Bt 58	Hangars, DG & USA
Bt 18	Diprochime plant	Bt 39	Hangar (APC)	Bt 59	Cosmetics factory (converted into depot)
Bt 19	GATMA archives warehouse	Bt 40	GATMA mechanical workshop	Bt 61	ENAD general management plant
Bt 20	Hangar/printing house	Bt 41	Former ONACO (ENAPAL ruins)		

This figure is the final result of the application of the Fuzzy DEMATEL-ANP method combined with the weighted overlay analysis, and illustrates how the weights of the criteria have been spatially applied to generate concrete recommendations for the management of industrial heritage. It shows a spatial distribution of industrial buildings, each categorised according to their conservation or demolition status, visually translating the multi-criteria analysis and serving as an essential tool for urban planning and heritage conservation. The red and orange-red zones, which are likely to be located in areas with buildings of high heritage value, require special attention for conservation, while the light green zones, where demolition is possible, seem to indicate buildings of lower heritage value, thus opening up the possibility of new construction or redevelopment. This map can be used by urban planners, policy makers and heritage managers to make informed decisions about the management of industrial heritage, and to quickly identify areas that should be preserved and those where demolition and redevelopment projects could be considered. The scoring and weighted overlay process used to produce this map integrates complex and weighted criteria, providing a sound basis for strategic decision making.

Discussion

The findings of this study, derived from the integrated Fuzzy DEMATEL-ANP-GIS model, align with previous research that emphasises the value of multi-criteria approaches in heritage decision-making. Similar to the results presented by Zhao et al. (2024) and Meng et al. (2023), this study confirms the importance of evaluating interrelated heritage criteria under uncertainty and in spatial context. Like Claver et al. (2020), this research identifies development potential as a decisive factor, which reinforces the relevance of balancing heritage values with urban redevelopment needs. Moreover, the classification of buildings using GIS-based Weighted Overlay Analysis follows methodologies used by Zhang et al. (2021), demonstrating that spatial decision-support systems are essential for visualising and managing industrial heritage. The categorisation of buildings into zones for the preservation or demolition is consistent with the patterns observed in urban regeneration projects globally. Therefore, the findings support existing literature while offering a refined methodology tailored to the specific context of El Hamma.

Differences in individual building evaluations may be attributed to local conditions, such as structural degradation or strategic location, which influence the weighting of criteria. This supports the utility of adaptable, data-driven frameworks in managing heritage assets under urbanisation pressure.

Conclusions

This study concludes that a total of 43 industrial buildings in the El Hamma district of Algiers should be prioritised for conservation due to their high heritage values, historical importance, architectural integrity and development potentials. Specifically, buildings located in the red and orange-red zones, as identified through Weighted Overlay Analysis using GIS, represent heritage assets that should be preserved and rehabilitated. Conversely, buildings primarily situated in the green or low-value zones exhibit limited architectural or historical significance and poor structural integrity and can therefore be considered for demolition or adaptive reuse under the urban redevelopment strategies.

This research examined the neglected and abandoned industrial heritage structures and aimed to establish a prioritisation framework for their management. This has been achieved through the application of a novel, integrated decision-making approach combining Fuzzy DEMATEL, Fuzzy ANP and GIS. This model has proven effective in clarifying the interdependencies between the criteria and in mapping the outcomes of the evaluations spatially. Through this application, the study has contributed to a better understanding of the buildings in El Hamma that warrant immediate attention and conservation and those which may be repurposed or removed in response to the urban development needs.

The study concludes that while the proposed methodology has demonstrated practical utility in the context of El Hamma, its findings are context-specific and cannot be generalised more widely. While the model offers a solid foundation for decision-making, it requires repetition and testing across other case studies and urban environments to verify its broader applicability and reliability. It should be regarded as a flexible, evolving tool, adaptable to different contexts with varying heritage profiles and urban pressures, rather than a fixed solution.

Conflicting Interests Statement

The authors declare no conflicting interests.

Acknowledgements: This research received no external funding. Nevertheless, the authors wish to acknowledge the academic support received from the Department of Architecture, Laboratory of Evaluation of Quality in Architecture and In-built Environment, University of Arbi Ben M'hidi Oum El Bouaghi, Algeria, and the Architecture, Faculty of sciences and technology, of the University of Mohamed Khider Biskra, Algeria,

References

- Ait-Mlouk, A., Ait-Mlouk, M., El Mazouri, F.Z., Dey, A. & Agouti, T. (2022) Fuzzy s& theory-based approach for mining spatial association rules: Road accident as a case study. In: A. Dey, S. Roy, A. Das & R. Das, eds. *AI and IoT for sustainable development in emerging countries: Challenges and opportunities*. Cham: Springer International Publishing, 353–370.
- Australia ICOMOS (1999) *The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance*. Canberra: Australia ICOMOS.
- Benito del Pozo, P. (2012) Territorio, paisaje y herencia industrial: Debates y acciones en el contexto europeo. *Documents d'anàlisi geogràfica*, 58(3), 443–457.
- Berger, M., Tilley, R. & Alverson, M. (2017) The role of museums and tourist attractions in industrial heritage preservation. *Heritage & Society*, 10(1), 99–115.
- Bonini Baraldi, A. & Salone, C. (2022) Local identity and industrial heritage: Enhancing regional development. *Cultural Studies*, 36(2), 307–323.
- Boying, L. & Kuang, L. (2006) Formation of industrial heritage and method of value evaluation. *Architectural Creation*, 9, 24–30.
- Büyüközkan, G., Güleriyüz, S. & Karpak, B. (2017) A new combined IF-DEMATEL and IF-ANP approach for CRM partner evaluation. *International Journal of Production Economics*, 191, 194–206.

- Cengiz, T. & Akbulak, C. (2009) Application of analytical hierarchy process and geographic information systems in land-use suitability evaluation: A case study of Dümrek village (Çanakkale, Turkey). *International Journal of Sustainable Development & World Ecology*, 16(3), 286–294.
- Chen, W., Li, S. & Zhang, Z. (2018) Combining fuzzy Delphi, analytic network process (ANP) and sensitivity analysis for heritage building evaluation. *Applied Soft Computing*, 64, 133–145.
- Claver, J., García-Domínguez, A. & Sebastián, M.A. (2020) Multicriteria decision tool for sustainable reuse of industrial heritage into its urban and social environment: Case studies. *Sustainability*, 12(18), 7430.
- Cuirong, W. (2022) Promoting regional revitalisation through industrial heritage adaptive reuse: A case study of [City/Region]. *Regional Studies*, 56(6), 856–871.
- Della Lucia, M. & Pashkevich, S. (2023) The role of social innovation in revitalising industrial heritage: Case studies from Europe. *Sustainability*, 15(3), 482–495.
- Dutta, M. & Husain, Z. (2009) An application of multi-criteria decision making to build heritage: The case of Calcutta. *Journal of Cultural Heritage*, 10(3), 237–243.
- Erder, C. (1977) *The Venice Charter: International Charter for the Conservation and Restoration of Monuments and Sites*. Venice: ICOMOS.
- Ertas Beşir, Ş. & Çelebi Karakök, M.E. (2023) Determination of conservation–reuse parameters for industrial heritage sustainability and a decision-making model proposal. *Sustainability*, 15(8), 6796.
- Falconer, J. (2006) Preserving and revitalising industrial heritage: A comparative study of the UK and Germany. *Industrial Heritage Review*, 14(2), 45–63.
- Guechi, I., Gherraz, H., Korichi, A. & Alkama, D. (2023) Predicting archaeological sites locations in desert areas using GIS-AHP-GeoTOPSIS model: Southwestern Algeria, Bechar. *Archaeologies*, 19(2), 471–499.
- Ikiz Kaya, D., Pintossi, N. & Dane, G. (2021) An empirical analysis of driving factors and policy enablers of heritage adaptive reuse within the circular economy framework. *Sustainability*, 13(5), 2479.
- Krige, S. (2010) "The power of power": Power stations as industrial heritage and their place in history and heritage education. *Yesterday and Today*, (5), 107–126.
- Lipe, W.D. (1974) Value and evaluation in the conservation of cultural resources. *Advances in Archaeological Method and Theory*, 5, 1–25.
- Liu, Y., Li, H., Li, W., Li, Q. & Hu, X. (2021) Value assessment for the restoration of industrial relics based on analytic hierarchy process: A case study of Shaanxi Steel Factory in Xi'an, China. *Environmental Science and Pollution Research*, 28, 69129–69148.
- Mattone, L. & Frullo, P. (2022) Job creation and technological advancement through industrial heritage projects. *Journal of Economic Geography*, 23(5), 945–960.
- Meade, L.M. & Sarkis, J.J. (1999) Analyzing organizational project alternatives for agile manufacturing processes: An analytical network approach. *International Journal of Production Research*, 37(2), 241–261.
- Meng, F., Zhi, Y. & Pang, Y. (2023) Assessment of the adaptive reuse potentiality of industrial heritage based on improved entropy TOPSIS method from the perspective of urban regeneration. *Sustainability*, 15(9), 7735.
- Pramanik, M.K. (2016) Site suitability analysis for agricultural land use of Darjeeling district using AHP and GIS techniques. *Modeling Earth Systems and Environment*, 2(1), 1–22.
- Preamble, P. (2011) *Joint ICOMOS–TICCIH principles for the conservation of industrial heritage sites, structures, areas and landscapes*.
- Reicher, C. (2009) Transforming industrial sites into cultural attractions: Best practices from Germany. *Tourism Management*, 30(3), 456–469.
- Sadeghi-Niaraki, A. (2020) Industry 4.0 development multi-criteria assessment: An integrated fuzzy DEMATEL, ANP, and VIKOR methodology. *IEEE Access*, 8, 23689–23704.

- Scaffidi, A. (2018) Social innovation in industrial heritage revitalisation: Emerging trends and implications. *Cultural Heritage Management and Sustainable Development*, 8(1), 15–32.
- Shan, Z. (2022) Adaptive reuse of industrial sites: Strategies and benefits for urban revitalisation. *Urban Studies Journal*, 59(4), 623–638.
- Somoza-Medina, A., Rodríguez-Navarro, M. & Fernández-González, A. (2021) Economic and cultural revitalisation through industrial heritage: Case studies from the UK and Germany. *Urban Regeneration Journal*, 12(1), 57–72.
- Sun, Y. & Chen, J. (2023) Revitalising industrial sites: Balancing economic growth and cultural preservation. *Urban Studies*, 60(7), 1430–1445.
- Tadić, S., Zečević, S. & Krstić, M. (2014) A novel hybrid MCDM model based on fuzzy DEMATEL, fuzzy ANP, and fuzzy VIKOR for city logistics concept selection. *Expert Systems with Applications*, 41(18), 8112–8128.
- TICCIH (2003) *The Nizhny Tagil Charter for the Industrial Heritage*. Russian.
- UNESCO, 2017. *Convention concerning the protection of the world cultural and natural heritage*. Revised Edition 2017. Paris: UNESCO.
- Vardopoulos, I. (2019) Critical sustainable development factors in the adaptive reuse of urban industrial buildings: A fuzzy DEMATEL approach. *Sustainable Cities and Societies*, 50, 101684.
- Vecco, M. (2010) A definition of cultural heritage: From the tangible to the intangible. *Journal of Cultural Heritage*, 11(3), 321–324.
- Zhang, P., Xiang, M., Zhang, T. & Yao, Y. (2021) Study on comprehensive value of industrial heritage in Yuejin Road historic district based on GIS technology. *Open Journal of Social Sciences*, 9(5), 440–454.
- Zhao, Q., Liu, F. & Qiao, W. (2024) Evaluating industrial heritage value using cloud theory and Dempster–Shafer theory. *Journal of Cultural Heritage*, 68, 364–374.
- Zhengyuan, H. & Zhigao, J. (2021) Technological innovation in the context of industrial heritage conservation. *Technology Review*, 58(4), 112–129.
- Zolekar, R.B. & Bhagat, V.S. (2015) Multi-criteria land suitability analysis for agriculture in hilly zone: Remote sensing and GIS approach. *Computers and Electronics in Agriculture*, 118, 300–321.