Mapping Vulnerability of Industrial Heritage for Adaptive Reuse: A Spatial Multi-criteria Analysis Approach

John Cullen Sayegh[1], Federica Cadamuro Morgante[2], Rossana Gabaglio[2], Oana Cristina Tiganea[2], and Marta Dell'Ovo[2(✉)]

[1] Politecnico di Milano, Piazza Leonardo da Vinci, 32, 20133 Milan, MI, Italy
[2] Department of Architecture and Urban Studies (DAStU), Politecnico di Milano, 20133 Milan, MI, Italy
marta.dellovo@polimi.it

Abstract. Renewing unused industrial buildings and landscapes has gained attention in academia and industry. Often clustered due to agglomeration effects and zoning, industrial sites form complex spatial systems across territories. Frequently polluted and located near key infrastructure, these areas faced decline and abandonment as economies transitioned to service-based models. Adaptive reuse of this "industrial heritage" offers cost-effective, sustainable solutions that preserve cultural and historical value.

While significant projects can revitalize economically and demographically depressed regions, the lack of coherent spatial planning often leads to suboptimal outcomes when redeveloping sites individually. Despite increasing interest from both public and private sectors, decisions about site location, scale, and future use remain unclear.

To address this, the paper proposes a replicable, context-specific, multi-scalar framework to identify optimal uses for sites within their broader industrial systems. Geospatial Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) are particularly effective, enabling the overlay and weighting of geospatial attributes to assess strengths and weaknesses. Once sites are scored, building-scale MCDA integrates technical and social analyses to determine optimal reuse strategies.

Keywords: Adaptive Reuse · Spatial Multicriteria Analysis · Industrial Heritage

1 Introduction

1.1 Background: Industrial Heritage

The rapid pace of innovation that characterized the Industrial Revolution meant that much of the built heritage related to newfound industrial production was quickly superseded, often replaced with newer nearby structures [1]. The resulting spatial pattern of these industrialized areas reflected an evolving relationship between urban development and

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production; usually, industrial sites clustered together to form industrial districts because of agglomeration effects, resource availability, and transportation access [2]. The advent of deindustrialization in the latter half of the 20th century in Western Europe and North America has led to the gradual abandonment of many obsolete industrial sites while at the same time throwing many urban areas into economic crisis. Occurring at the same time as deindustrialization, a burgeoning sub-discipline of cultural heritage concerned with the valorization of industrial buildings and landscapes has appeared.

At this time, the preservation and reuse of industrial heritage became a topic of serious academic and economic discourse. Since then, so-called "industrial heritage" has joined the ranks of other types of cultural heritage as worthy of valorization. These former industrial areas' tangible and intangible memories have recently received greater appreciation as a form of cultural heritage, particularly for communities closely tied to former industrial activities [3]. This recognition of inherent artistic value, coupled with the high demand for land in critical urban areas and contamination, has made them subjects of reuse by both public and private actors [4]. The problem of what to do with such abandoned properties remains a question for urban planners, developers, city governments, and nearby residents.

1.2 Adaptive Reuse

In the past, historic buildings have often hosted functions that did not represent the intended original use of the structure. This process of adaptive reuse, which can be defined as the "[introduction of] new content into an existing container (building, infrastructure, place, area), content that differs from the one for which the container was originally designed," has recently expanded to industrial heritage [5, 6]. The latter half of the 20th century witnessed the widespread clearing of historic and obsolete industrial structures, which were considered highly contaminated and incongruent with new functions. Several studies focusing on small and medium-sized towns have underscored the unique socio-economic vulnerabilities and governance challenges in these contexts, requiring tailored adaptive reuse frameworks [7–9]. The closure of these industrial areas particularly impacts communities located beyond large metropolitan centers characterized by economic diversification and a strong service sector, where the disappearance of a single industry or company can have significant negative financial consequences, demand for the redevelopment/reuse of existing buildings is low, and the properties' size is disproportionate to the existing urban context [8, 10]. Moreover, adaptive reuse efforts in such contexts must contend with environmental remediation, complex governance frameworks, and the coordination of multiple and often conflicting actors, including public authorities, private investors, and local communities [10, 11].

While adaptive reuse has many challenges, especially concerning industrial heritage, it offers several benefits. If done well, the adaptive reuse of industrial structures can develop a solution that honors the area's history and local culture, offers a much more sustainable solution than new construction, and provides an area with new economic and employment opportunities [5, 10]. Typological and locational features of industrial buildings—such as large open floor plans, generous ceiling heights, robust structural grids, and location near key infrastructure—make them well-suited for transformation [6]. Existing industrial structures benefit from several typological factors—they are located

at central infrastructural nodes along regional transport systems and offer highly flexible structures with wide bays and high ceilings, modular structural systems, and extensive natural daylight [12]. Several examples of net-positive large-scale adaptive reuse projects exist; the IBA Emscher Park in the Ruhr region of Germany, the Ex-Pirelli/Bicocca area of Milan, Italy, and the HafenCity redevelopment located in Hamburg, Germany, attest to the latent possibilities of industrial heritage transformation. While many of these projects have been successful, they remain small and are all located in urban areas with high demand, expertise, and capital nexus. Lower-density areas and smaller towns do not have such advantages, and thus redevelopment of industrial heritage in these areas is significantly retarded.

The paper proposes an integrated multi-scale approach to support decision-makers in understanding the strengths and weaknesses of potential adaptive reuse scenarios for industrial heritage.

2 Literature Review

The literature review was conducted using Scopus, a database of academic papers with extensive peer-reviewed research. It allows users to easily choose keywords, authors, and topics of interest to locate the most relevant sources for their queries. The rehabilitation of abandoned and unused industrial buildings, especially those classified as industrial heritage, has become a vital area of research and practice within urban regeneration and cultural heritage conservation. Industrial heritage represents a crucial aspect of cultural and economic history, particularly in regions that have experienced significant industrialization [4]. The preservation and adaptive reuse of industrial sites have become important subjects of scholarly inquiry, especially in the context of sustainable development. An extensive literature review was conducted covering publications from 2008 to November 2024, with the search executed between July and November 2024, to explore potential methodological approaches for a comprehensive adaptive reuse plan at the regional and building scale.

From the initial Scopus search, other cited academic articles in peer-reviewed journals were examined to expand the literature review. More than thirty academic papers were selected for their relevance to specific keywords listed in Fig. 1—mainly focusing on a matrix of nine criteria, four of which dealt with methodological criteria (various multi-criteria methodologies, discourse/comparative analyses, case study approaches, and other analytical frameworks), followed by five thematic approaches (socio-cultural, environmental, governance, economic, and mixed). Figure 1 highlights the literature review process. Based on methodological approaches, case studies, and theoretical frameworks, these sources provide a comprehensive understanding of the current discourse around industrial heritage rehabilitation, decision-making processes related to cultural heritage, and planning approaches to small and medium-sized towns.

Given the complexity of the decision problem and the multiple dimensions and perspectives to be considered to assess the values elicited by the industrial heritage, after a first exploratory analysis of studies on the adaptive reuse topic [8, 13–19], the Multicriteria Decision Analysis (MCDA) has been used as a primary filter and keywords in combination with others. As shown in Fig. 1, five different combinations of keywords

have been tested, and the filters applied to screen the research have been based on the coherence of the title and the abstract. At the same time, additional contributions cited in other papers have been analyzed. In the following sections, the primary findings will be discussed.

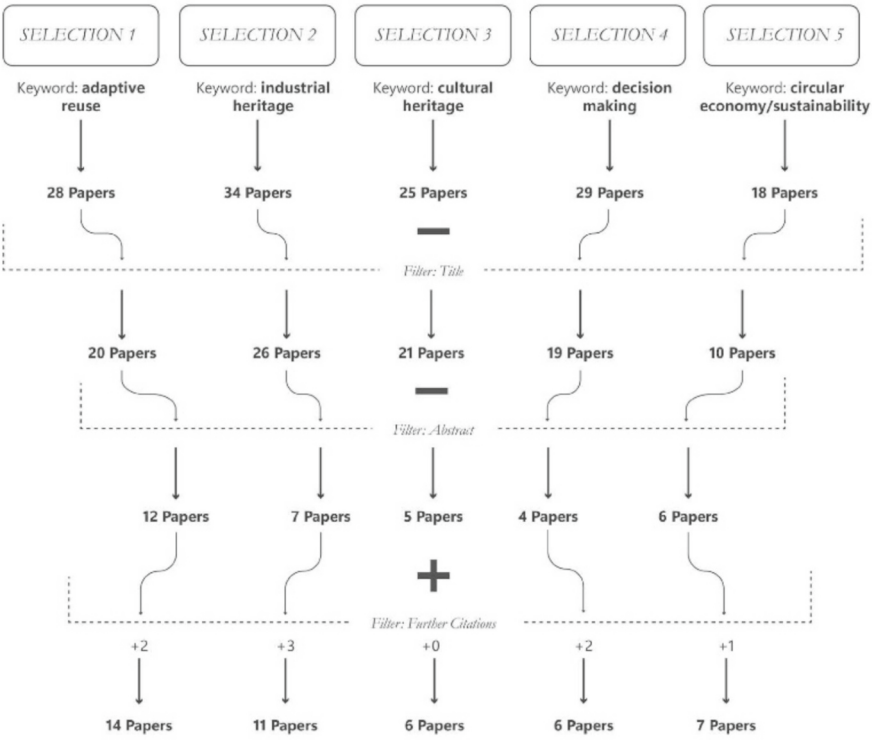


Fig. 1. Literature review process

2.1 The Value of Industrial Heritage

A recurring theme across the literature is the recognition of industrial heritage as an essential component of cultural heritage. Several authors [8, 9, 20–23] emphasize that the value of industrial heritage extends beyond its physical structure to include intangible cultural aspects such as memory, identity, and social history. [9] argue that industrial heritage should be considered a cultural asset contributing to communities' local identity and historical continuity. Their work highlights the importance of incorporating community values and memories into the decision-making process for industrial site rehabilitation. This approach is essential in preserving the physical aspects of industrial heritage and its socio-cultural significance. Similarly, [24] underscore the importance of recognizing industrial heritage as part of cultural heritage in their analysis of adaptive reuse projects in Norway. They argue that industrial sites should be rehabilitated

in ways that acknowledge and preserve their historical and cultural contexts, which often involve complex relationships between the site's physical and symbolic meanings. These studies support the notion that industrial heritage is about preserving buildings, maintaining a connection to the past, and fostering a sense of place. [25] expands on this by providing a theoretical framework for understanding cultural heritage, including tangible and intangible aspects. [25] traces the evolution of cultural heritage protection from the Athens Charter to the Krakow Charter, arguing that industrial heritage must be understood within the broader context of the preservation discourse. According to [25], industrial buildings are not merely relics of the past but repositories of collective memory and symbols of industrial society's socio-economic transformations. This perspective broadens the scope of industrial heritage preservation, suggesting that efforts to rehabilitate these sites must engage with their material and symbolic dimensions.

In the case of some places, the potentialities offered by a particularly striking natural landscape or built heritage can strengthen local regeneration attempts, building on network effects between nearby localities. [20] expounds on this point by focusing on 13 castles in the Val d'Aosta region of Italy, which were analyzed using an approach conceived around the idea of "-wares" (Orgware, Civicware, Ecoware, Finware, Hardware, Software) whereby each site was evaluated using an initial SWOT analysis and an analytic network process. Experts from planning, conservation, economics, and local administrators then worked together—via focus groups and targeted interviews—to assign weights to each "-ware," generate standardized suitability maps, and identify the strongest clusters of castles that could mutually reinforce one another. This networked approach highlights which sites are most "ready" for adaptive reuse and reveals where the greatest synergies lie in forging a shared regeneration strategy. The joining of weighted criteria (aspatial) and GIS data (spatial) offers a novel, relational approach to cultural heritage strategy, using an operational principle underlying the methodology proposed in this research work.

2.2 Community Participation and Social Value

In addition to cultural significance, community participation is a critical factor in successfully rehabilitating industrial heritage. Several studies highlight the need to include local communities in the planning and decision-making processes for these projects to ensure that redevelopment efforts align with the social and cultural needs of the community. [23] use Complex Social Value (CSV) theory to demonstrate how inclusive decision-making processes can harmonize diverging interests between official development proposals and community perspectives. Their case study illustrates the value of engaging community stakeholders in the redevelopment process, as it helps to preserve social cohesion and reduce conflict over how the site should be used. The role of local communities in shaping industrial heritage rehabilitation is further explored by [26]. They argue that local NGOs and community organizations play a vital role in advocating for preserving industrial heritage, mainly when these sites are at risk of being redeveloped in ways that prioritize economic gains over cultural conservation. By fostering civic engagement, communities can rehabilitate industrial heritage sites to reflect local values and contribute to long-term social sustainability.

This participatory approach contrasts with more expert-driven methods, such as the PROMETHEE method employed by [27] to evaluate adaptive reuse strategies. While the PROMETHEE method provides a structured, expert-based framework for decision-making, it has been critiqued for its lack of community input. In their evaluation of abandoned industrial heritage sites, the authors rely heavily on quantitative indicators such as architectural quality, accessibility, and property value while also considering the social or cultural significance of the sites to the local community. The correct weight between top-down, expert-driven approaches and bottom-up, community-centered, social-value-driven models highlights an ongoing debate regarding the decision-making process in industrial heritage rehabilitation.

2.3 Methodological Approaches to Heritage Regeneration

Various methodological approaches have been developed to guide the rehabilitation of industrial heritage, with many studies emphasizing the importance of multi-criteria decision-making frameworks. [27] apply the PROMETHEE method to evaluate adaptive reuse strategies based on 15 indicators, ranging from accessibility and architectural quality to environmental sustainability and social value. This multi-criteria approach allows decision-makers to weigh various factors when considering the viability of different reuse scenarios, ensuring that economic and cultural considerations are considered. [28] propose a similar decision-support framework using Multi-Attribute Value Theory (MAVT) to assess complex cultural heritage systems. Their study highlights the need for integrating public participation into decision-making processes, especially when managing public goods like industrial heritage. By combining quantitative and qualitative data, these decision-support systems offer a holistic approach to evaluating adaptive reuse projects, helping planners and policymakers make informed decisions that balance the competing demands of heritage preservation, economic development, and social sustainability. Other studies, such as the work of [20], integrate Geographic Information Systems (GIS) with multi-criteria decision analysis to evaluate the rehabilitation potential of industrial heritage sites. These multi-criteria spatial decision-support systems (MC-SDSS) allow planners to incorporate geospatial data into the evaluation process, making it possible to consider factors like landscape features, proximity to community services, and environmental impacts when assessing potential reuse scenarios. These methodological innovations provide valuable tools for guiding the rehabilitation of industrial heritage sites in a way that is both data-driven and responsive to local contexts. [29] utilize the MCDA approach and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) to compare adaptive reuse project alternatives for a cluster of abandoned industrial buildings in Salerno, Italy. The analysis was coupled with 14 adaptive reuse proposals evaluated using the aforementioned methodology, stakeholder input, and an operational circularity process. In their study of the revitalization of modernist architectural heritage in Ivrea, Italy, [30] utilize the Delphi Method, a methodology associated with a survey of experts.

Given these premises, the field has advanced methodologically by developing multi-criteria decision-making frameworks that evaluate adaptive reuse strategies holistically. These frameworks, which combine expert-driven quantitative indicators with qualitative assessments of cultural and social value, provide a comprehensive approach to industrial

heritage rehabilitation. The challenge will be to balance the often-competing demands of economic development, cultural preservation, and environmental sustainability to ensure industrial heritage's long-term viability and relevance in contemporary urban contexts.

3 Case Studies Analysis

In parallel with the literature review, adaptive reuse case studies have been analyzed and selected according to specific features to be compared. Four relevant case studies from across Europe were selected to observe how preservation and adaptive reuse of heritage assets can be applied in real-world examples. While approaches vary to preserve and reuse industrial heritage across geographic and cultural contexts, some commonalities emerge from a broad study of extant sites.

The selection of the case studies is based on an interconnected network of similar cultural, historical, economic, or geographic factors related to physical places that have undergone architectural and ecological restoration. They represent cultural landscapes with numerous examples of adaptive reuse projects where old functions are replaced with newer uses. The four selected case studies (the Hybrit Initiative in Norbotten, Sweden, the IBA Emscher Park in the Rhine-Ruhr area of Germany, the Leeds & Liverpool Canal redevelopment in the U.K., and the Mudejar Territory Routes in Zaragoza, Spain) vary significantly in geographic reach, infrastructural connections, architectural and landscape quality, and governance/economic model, but they offer examples of landscape-scale, regional planning in diverse European contexts. These case studies highlighted the real-world application of adaptive reuse processes, re-industrialization strategies, and cultural heritage preservation. They provided a valuable supplement to the literature review in developing a context-specific methodology.

Case studies have been analyzed considering the stakeholders involved in the process, the size, the year of the project, the new function, the cost of the intervention, and the architects and/or planners hired to design the new project. Table 1 below shows a comparative analysis of the four case studies. It is organized into six core criteria—Management Authority, Architect/Planner, Cost, Functions, Year, Size, Location, and Stakeholders—to ensure a coherent basis for comparison across diverse European contexts. The analysis provides a vital output related to tangible results and allows us to understand the most important factors that could influence the success or failure of a project. By systematically juxtaposing governance structures, funding scales, and functional outcomes, this comparative framework reveals underlying patterns and critical success variables that may remain obscured in narrative descriptions. Highlighting variations in management authorities and economic models demonstrates how institutional frameworks can accelerate or hinder adaptive reuse initiatives, while cost disparities underscore the impact of project scale on resource allocation and stakeholder engagement.

4 Methodology

This section outlines a proposed methodological framework rather than detailing application to a specific case study context. It draws directly on two foundations: (1) the literature review, which distilled a consistent set of thematic criteria (cultural-touristic,

Table 1. Case studies' comparative analysis

Criteria	Hybrit Initiative, Norbotten	IBA Emscher Park	Leeds & Liverpool Canal Corridor	Mudejar Territory Routes
Management Authority	Region Norrbotten, LKAB, H2 Green Steel & HYBRIT Consortium, SSAB	Planungsgesellschaft IBA Emscher Park GmbH	Canal & River Trust	Territorio Mudejar Association
Architect and Planner	N.A.	Karl Ganser (Managing Director), Christoph Zopel (NRW Minister for Urban Planning)	BDP	N.A
Cost	200billion SEK	€ 2.5 billion	£ 68–95 million	N.A
Functions	Economic-Technological, Governance-Public Services	Economic-Technological, Environ-mental-Ecological, Cultural-Touristic	Environmental-Ecological, Cultural-Touristic	Cultural/Touristic
Year	2022 - Present	1989–1999	2022 - Present	2018 - Present
Size	99 km^2	800 km^2 (Total Area)	37 km along Leeds & Liverpool Canal	17,274 km^2
Location	Norbotten, Sweden	North Rhine Westphalia, Germany	Lancashire, U.K.	Zaragoza, Spain
Stakeholders	Swedish Government, County Administrative Board of Norrbotten, Region Norrbotten, Local Municipalities (Luleå, Gällivare, Kiruna, Boden), LKAB, SSAB, H2 Green Steel & HYBRIT Consortium, Vattenfall, Luleå University of Technology	Emschergenossenschaft, Lippeverband, Kommunalverband Ruhrgebiet, Deutsche Bahn, RAG AG, Latz + Partner, 20 Municipalities, Federal State of North Rhein Westphalia, Landwirtschaftskammer Nordrhein-Westfalen, NABU, BUND, Deutscher Bauernverband e.V, Thyssen Krupp, University of Duisburg-Essen, TU Dortmund, FH Sudwestfalen	Canal & River Trust, SuperSlow Way Arts Programme, Historic England, Arts Council, Creative Lancashire, University of Central Lancashire, Lancashire County Council, Burroughs of Pendle, Burnley, Blackburn with Darwen, and Hyndburn, Newsground, Arts Partners in Pennine Lancashire, Incredible Edible, Lancashire BME Network	Territorio Mudejar Association, Local Munipalities, Province of Zaragoza, University of Zaragoza, College of Architects of Aragon, ICOMOS, Archibishopric of Zaragoza

governance-social, economic-technological, and environmental-ecological) and corresponding value functions; and (2) the comparative case-study analysis, which revealed empirical patterns in governance structures, cost scales, stakeholder configurations, and adaptive reuse outcomes. The literature review informs the choice and standardization of criteria. At the same time, the case studies lend insight into context-sensitive weighting, iterative phasing, and governance mechanisms that proved successful (or otherwise) in real-world settings. A methodology was targeted that could be applied to industrial-territorial spatial systems characterized by small and medium-sized cities and towns that suffer from post-industrial degradative processes, where the lack of sufficient economic resources or social capital dooms them to continued decline. This socio-economic planning model should be flexible and adaptive to regions undergoing post-industrial decline

and where adaptive reuse scenarios have amorphous and undefined goals, budgets, and stakeholders.

A two-phase iterative and flexible model is proposed to consider the former industrial area's territorial characteristics and the asset's physical specificity (Fig. 2). The methodology aims to define priority areas to be renovated and select suitable adaptive reuse scenarios for the industrial heritage resulting from the spatial analysis.

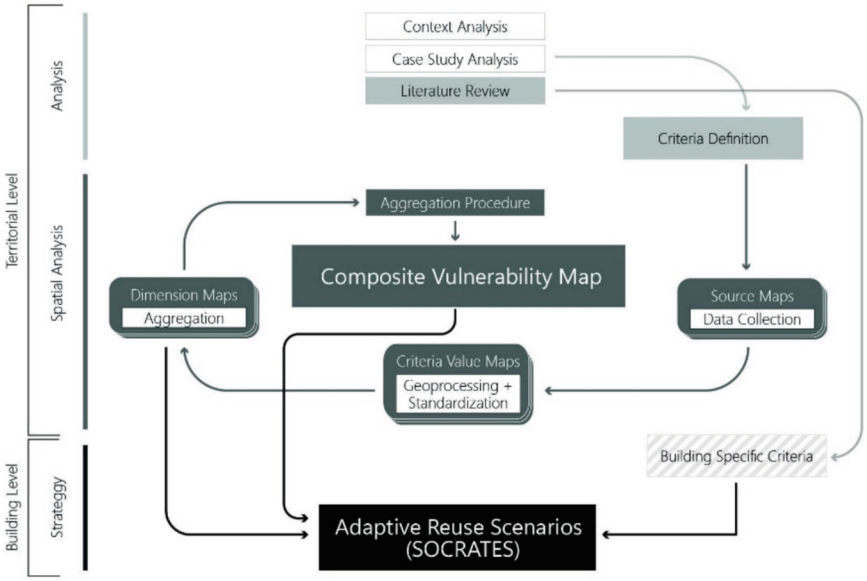


Fig. 2. Combined GIS + MCDA Adaptive Reuse Methodology

4.1 Territorial Level

Given the spatial characterization of the decision problem, a combined Geographic Information System (GIS) and Multicriteria Decision Analysis (MCDA) methodology is suggested [31] since it offers a robust framework for addressing complex decision-making processes like adaptive reuse planning [20] by integrating quantitative and qualitative data. GIS provides spatial data visualization and analysis. MCDA offers a structured decision-making process that identifies potential options regarding a decision problem and incorporates qualitative and quantitative criteria based on specified values [8]. Working together, GIS and multi-criteria decision analysis can be utilized to identify and evaluate options relating to spatial decisions. Applications of GIS and MCDA are numerous; the methodology has been used to assess drought risk [32], determine preservation strategies for cultural heritage [21], and the site location of public schools [33], among many other cases.

The strength of the GIS + MCDA approach lies in its flexibility; implementing a context-dependent component utilizing GIS ensures its adaptability across differing territories and scales, while the MCDA component introduces user-determined weighted judgments to narrow down policy and/or best-use case scenarios. Given that contextualization of the strategic planning/methodological model is a necessary step in testing the replicability of the approach in diverse post-industrial milieus, GIS was used to map and analyze context-specific geographical, environmental, and socio-economic factors to determine sites that are best suited for adaptive reuse scenarios. The multi-criteria decisional analysis (MCDA) portion is equally important; the MCDA process assigns value judgments to a standardized set of data (collected using GIS inputs), thereby uniting spatial and aspatial analyses [31, 34].

Considering Fig. 2, the preliminary analysis of the literature review, together with supporting the selection of the most coherent methodology, helps define a consistent set of criteria to understand the vulnerability and attractiveness of the site under analysis to determine the most urgent intervention to be done. Three inputs—an in-depth survey of established MCDA frameworks in the scholarly literature, examining salient contextual features from the four case studies (e.g., governance models, cost scales, stakeholder constellations), and the relevance and availability of context-specific data—first informed a detailed set of criteria and sub-criteria, which were then organized into the four overarching themes (cultural-touristic, governance-social, economic-technological, and environmental-ecological). Here, "vulnerability" refers to the degree to which the study area is exposed to various negative factors such as socio-economic decline, environmental contamination, or lack of infrastructure and educational opportunities, to name a few examples.

The value tree defined consists of criteria that could be georeferenced in space to be easily visualized. Within this context, it is possible to mention the main critical dimensions that deserve to be deeply investigated, such as: i) Cultural-Touristic: Identifying areas of historical and cultural significance and potential recreational and leisure opportunities; ii) Governance-Social Services: Assessing opportunities for community engagement and the benefits of revitalization for underserved populations; iii) Economic-Technological: Evaluating factors such as proximity to transportation infrastructure, market accessibility, and potential for job creation; iv) Environmental-Ecological: Considering contamination levels, remediation costs, and the feasibility of integrating renewable energy solutions. Once a robust set of criteria has been defined, it is possible to start collecting data, which includes raster and vector datasets from various authorities and official geoportals, as well as aggregated demographic data to obtain Source Maps. After a series of geo-operations selected carefully considering the nature of the criteria (e.g., Euclidean Distance, Density, Classification, etc.), it is possible to visualize Criterion Maps, which, after the standardization, a process that allows the making of homogenous different units of measurement, became Value Maps. According to the software selected for the elaboration, the new a-dimensional scale obtained after the standardization could be from 0 to 1 or from 0 to 10 (where 0 is the worst value and 1 or 10 is the best) [35]. With the support of the value functions generated with the knowledge shared by experts or the experiences detected by other researchers, it is possible to move from performance to value. The "suitability score" refers to the aggregated, weighted sum of

these value maps, indicating suitability for adaptive reuse (higher scores denote more favorable conditions for intervention). Figure 3 presents an example of the three-stage maps generated.

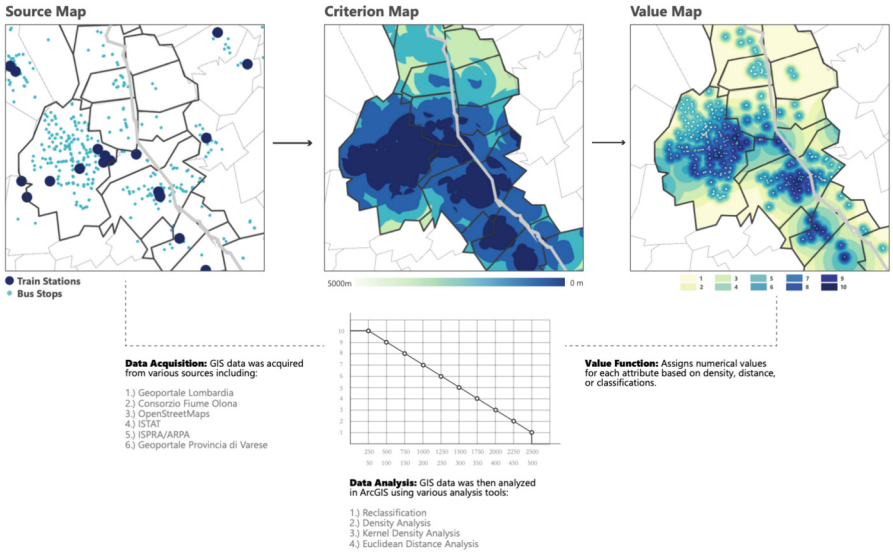


Fig. 3. Example of Source Map, Criterion Map, and Value Map

The final stage of GIS + MCDA involves the creation of Partial and Final Value Maps and the overlay of data layers to facilitate spatial decision-making. In this phase, the standardized criteria, weighted according to their relative importance, are combined to produce an overall suitability score for each location or area under consideration. Often using Weighted Linear Combination (WLC) or similar methods, the data overlay technique integrates the different layers of spatial data, each representing a specific criterion, into a single composite map. This Composite Vulnerability map visually represents various areas' suitability based on the requirements of the earlier stages. It enables decision-makers to quickly identify optimal regions that align with the set objectives, highlighting zones with the highest suitability scores. Additionally, sensitivity analysis is often conducted at this stage to assess the robustness of the results by evaluating how changes in criteria weights or data accuracy affect the outcomes [31, 34]. The conclusions drawn from the overlay process offer actionable insights for planning and policy, guiding decisions in land use, urban regeneration, or environmental management by clearly illustrating the spatial patterns of suitability across the study area.

4.2 Building Level

After applying the GIS + MCDA methodology and subsequent regional-scale territorial analysis, individual industrial sites at the building scale can be selected for further

investigation. The building-level MCDA outputs reveal each site's strengths and weaknesses across the four overarching dimensions (cultural-touristic, governance-social, economic-technological, and environmental-ecological), providing a clear basis for scenario development. Based on the MCDA scores, a set of preliminary adaptive reuse scenarios is drafted—each tailored to leverage a site's highest-scoring dimensions (for example, a cultural hub on a site with strong cultural-touristic potential, or a light-industrial incubator where economic-technological scores dominate). This relationship between territorial potential and building-specific characteristics will inform a differentiated approach to adaptive reuse. This methodological transition from territorial analysis to architectural intervention represents a critical contribution to the discourse on industrial heritage regeneration, demonstrating how multi-scalar approaches can inform more nuanced, contextualized, and sustainable adaptive reuse strategies. The importance of participatory processes has been underlined in the literature analyzed, and the model proposed by [8] could be taken as a reference since it can combine technical and social evaluation. This is possible by defining adaptive reuse scenarios coherently with the context analysis and the needs and expectations of different stakeholders and developing a Social Multi-Criteria Evaluation through the SOCRATES method [36–41]. By structuring the workflow in this way, the methodology maintains continuity—from broad territorial diagnostics to site-specific MCDA, then into the dual rigor of the technical and social (SOCRATES) analyses—ensuring that final design proposals are evidence-based and stakeholder-endorsed. This approach integrates technical compromise solutions with social compromise solutions, and it is particularly suggested to deal with public policy problems within an inter-multi-disciplinary, participatory, and transparent framework [7, 38]. The final aim consists of supporting decision-makers in making more conscious decisions and finding a trade-off among the values elicited by various groups of stakeholders while selecting a scenario of adaptive reuse.

5 Conclusions and Future Perspectives

This paper proposes a methodological framework for the strategic regeneration of industrial heritage assets through an innovative approach combining Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) at the urban scale and a Social Multi-Criteria Evaluation method (technical and social analysis) at the building scale. The research addresses a significant gap in current practice: despite growing recognition of industrial heritage's value, decision-making processes regarding intervention locations, scope, and future uses have remained largely unsystematic.

A crucial direction for methodological refinement involves expanding the stakeholder engagement component [42], particularly in the criteria definition phase. Future research should integrate more robust participatory methods that capture local knowledge, community aspirations, and cultural values. Such enhanced stakeholder engagement could generate more innovative and contextually appropriate adaptive reuse scenarios and features of the territorial context. This expanded participatory approach would strengthen the social legitimacy of interventions while potentially revealing adaptive possibilities overlooked in expert-driven analyses.

The GIS + MCDA methodology is a potential path in addressing the complex challenge of adaptive reuse of industrial heritage. Its future application will demonstrate how

systematic, multi-scalar analysis can transform what might otherwise be fragmented, suboptimal interventions into strategically coordinated revitalization efforts that honor historical significance while serving contemporary needs. The research opens several promising avenues for future theoretical development regarding the adaptive reuse of industrial heritage and strategic economic planning at the regional level.

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