ECOLOGICAL PERSPECTIVE
An International Academic Journal
e-ISSN:2792-0062

YENİDEN İŞLEVLENDİRMEDE TEKNOLOJİLERİN GELİŞTİRİLMESİ: YAPAY ZEKA DESTEKLİ SİSTEMLER

(ENHANCING TECHNOLOGIES IN ADAPTIVE REUSE: AI SUPPORTED SYSTEMS)

Gamze AKYOL[1], Seda ŞİMŞEK[2]
[1]Süleyman Demirel Üniversitesi, Fen Bilimleri Enstitüsü Mimarlık, Planlama Tasarım Anabilim Dalı, ISPARTA/Türkiye
gamzeakyol7@gmail.com, ORCID: 0000-0001-6108-9529
[2]Süleyman Demirel Üniversitesi, Mimarlık Fakültesi, Mimarlık Bölümü, ISPARTA/Türkiye
sedasimsek@sdu.edu.tr, ORCID: 0000-0002-1881-186X

Doi: https://doi.org/10.53463/ecopers.20240278
Corresponding Author/İletişim yazarı: Gamze AKYOL
E-mail: gamzeakyol7@gmail.com

ÖZET
Yeniden işlevlendirme, tarihi binaların sürdürülebilir kentsel gelişimi için önemli bir rol oynamaktadır. Bu yaklaşım, kültürel mirasın korunmasını, çevresel etkilerin azaltılmasını ve çağdaş ihtiyaçların karşılanmasını mümkün kılmaktadır. Bu çalışma, yapay zeka (AI), makine öğrenimi (ML) ve karar ağaçları gibi ileri teknolojilerin yeniden işlevlendirme sürecine nasıl entegre edilebileceğini incelemektedir. Bu teknolojilerin karar alma süreçlerini iyileştirme, tasarım çözümlerini geliştirme ve sürdürülebilir yönetimi destekleme konusundaki potansiyelleri vurgulanmaktadır. Çalışmanın temel amacı, yapay zekâ ve makine öğrenimi gibi teknolojilerin, tarihi binaların yeniden işlevlendirilmesinde sürecin iyileştirebileceğini ve kentsel gelişimde sürdürülebilirliği üzerine etkileri araştırmaktır. Bulgular, bu teknolojilerin mimarlık, koruma ve inşaat kavramlarında önemli dönüşümler yaratma potansiyeline sahip olduğunu ve miras ile yenilik arasında denge sağlamak için bilinçli ve etik bir şekilde uygulanması gerektiğini ortaya koymaktadır.

Anahtar Kelimeler: Yeniden İşlevlendirme, Yapay Zeka (AI), Makine Öğrenimi (ML), Endüstriyel Miras, Sürdürülebilir Kentsel Gelişim

ABSTRACT
The adaptive reuse of historical buildings is pivotal for sustainable urban development. This also enables preserving cultural heritage, minimizing environmental impact, and addressing contemporary needs. This paper examines how advanced technologies such as artificial intelligence (AI), machine learning (ML) and decision trees, can be integrated into the adaptive reuse process. Their ability to improve decision-making, refine design solutions, and support sustainable management is emphasized. The main aim of the paper is to explore how advanced technologies like artificial intelligence and machine learning can improve the adaptive reuse of historical buildings while promoting sustainability in urban development. The findings highlight the potential of these technologies to bring about significant transformations in architecture, conservation and construction sectors, advocating for their conscientious and ethical implementation to strike a balance between tradition and innovation.

Key words: Adaptive Reuse, Artificial Intelligence (AI), Machine Learning (ML), Industrial Heritage, Sustainable Urban Development

Bilgi Notu : Bu makale Süleyman Demirel Üniversitesi, Fen Bilimleri Enstitüsü'nde hazırlanmakta olan Doktora Tezinin bir kısmından üretilmiştir.

1. INTRODUCTION

In the modern era, the preservation and adaptive reuse of historical buildings have become critical components of sustainable urban development. As societies evolve and cities expand, the need for adaptive reuse of existing structures to meet contemporary demands while preserving cultural heritage has garnered increasing attention. The process of adaptive reuse not only extends the life of buildings, but also contributes to environmental sustainability by reducing the need for new constructions and minimizing waste (Fufa, Flyen, & Flyen, 2021). This approach aligns with global sustainability goals, has economic, environmental, and social dimensions.

Adaptive reuse, particularly of historical buildings, offers unique challenges and opportunities to society. These structures are often the landmarks of a city's industrial past and require careful consideration to balance historical preservation with functional modernization. The integration of advanced technologies, such as artificial intelligence (AI) and especially machine learning (ML), into the architecture like adaptive reuse process represents an innovative opportunity (Hegazy & Saleh, 2023). These technologies can provide unlimited design ideas and alternatives for applying green architectural principles, contributing to the development of environmentally friendly design (Abd El- Maksoud & Ahmed, 2024)

Artificial intelligence (AI) and machine learning (ML) have brought revolutionary advancements across diverse domains, including their significant impact on architecture and construction. The ability of AI to analyze vast datasets and generate predictive models can significantly improve the efficiency and effectiveness of adaptive reuse projects (Baduge et al., 2022). Sustainable urban planning requires sustainable land use planning as well as sustainable strategies of urban planning and sustainable urban development planning (UN Habitat, 2007). Urban areas will always be important for sustainable growth. Urban planners and decision-makers prioritize ensuring the sustainability of cities (Eren, 2021). Therefore, AI techniques like machine learning can identify the suitable functions for refunctioned buildings, optimizing structural modifications, and ensuring that these projects align with sustainability goals.

This paper explores the intersection of adaptive reuse, AI, ML, and decision trees, providing a comprehensive overview of their applications and benefits in the context of sustainable urban development through the literature. Adaptive reuse is seen as a practical solution for sustainable urban development in terms of economic, environmental, socio-cultural, political aspects (Vardopoulos et al., 2021). It also highlights the importance of maintaining the cultural identity of vacant buildings while adapting them to new uses, and it addresses the technological advancements that facilitate this process. Additionally, this paper aims to explore how AI and ML can support the adaptive reuse of industrial heritage buildings, offering insights into their potential to ensure the sustainable management of the built. Especially industrial heritage buildings have been highlighted due to their large scale and expansive footprint within urban areas once they lose their original functions. The substantial spaces they occupy in inner cities can become significant challenges when left unused, often resulting in extensive vacant areas.

The adaptive reuse of buildings and structures, is a good strategy for sustainable development (Mohamed & Alauddin, 2016). The integration of AI and ML into this process may present innovative solutions to the challenges of preserving historical integrity while meeting modern functional requirements. This paper also aims to contribute to the ongoing discourse on sustainable architecture by examining the role of advanced technologies in adaptive reuse, ultimately advocating for a balanced integration of tradition and innovation in the built environment.

The target of the paper is to demonstrate the contemporary relevance of adaptive reuse, particularly its integration with developing technologies such as artificial intelligence (AI) and its subsets, through a comprehensive literature review focused on historical changes . According to study content, in the material and method section, the paper will delve into literature review details and results according to date intervals and keywords. In the “Adaptive reuse and Artificial Intelligence” section, the paper will discover the, explanations and researches about keywords.

2. MATERIAL AND METHOD

As part of the study, keywords were researched in different combinations, and 2 main sources were examined accordingly. The research was conducted through two different databases: "Google Scholar" (Table 1) and "Scopus” (Table 2) under the terms "Adaptive Reuse of Buildings", "Adaptive Reuse of Industrial Heritage Structures", "Adaptive Reuse of Industrial Heritage Structures and Sustainability", "Adaptive Reuse and Artificial Intelligence" and " Adaptive Reuse and Machine Learning". Considering the relevance of the concepts, the periods 1960-1980, 1980-2000, 2000-2010, 2010-2020, and 2020-2024 were searched for. The first two search periods were set at twenty-year intervals, the next two at ten-year intervals, and the last search period covered the last four years. The number of studies in each interval is stated.

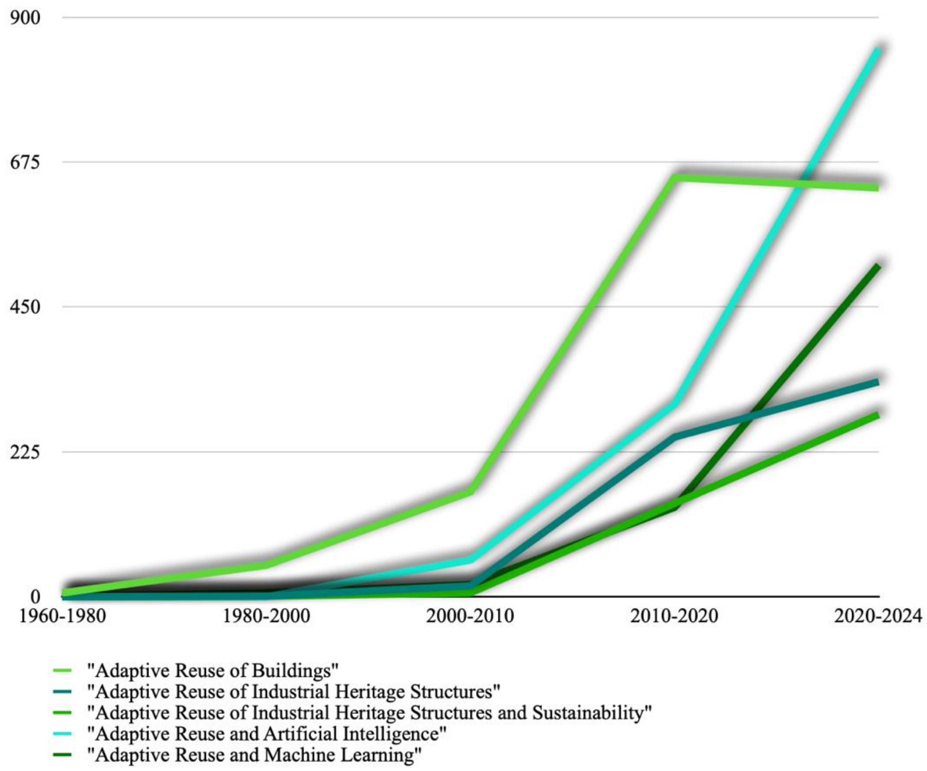
It is found that although studies on the adaptive reuse industrial structures and related concepts began between 1960 and 2000, the number of studies increased significantly from 2000 to 2010. This rate of increase accelerated further between 2010 and 2020. From 2020 to the present

(2024), the number of studies has continued to grow, suggesting that research on industrial heritage has gained increasing importance.

According to the graph obtained from the research conducted between 1960 and 2024, there are 2 breaking points in the graph. Those points refer to important dates and agreements. The first was in 2000 and the second was in the 2010s. Considering the reasons for these in 2000, International Council on Monuments and Sites (ICOMOS) and The International Committee for the Conservation of the Industrial Heritage (TICCIH) signed an agreement that established the concept of industrial heritage globally. Another important date is 2003, the Nizhny Tagil Charter, which clearly defined the concept of industrial heritage, was published. Similarly, the Dublin Principles focusing entirely on industrial heritage issues, played an active role in shifting the research focus in this direction in 2011. As previously mentioned, between 2020 and 2024, studies on both adaptive reuse and artificial intelligence increased significantly compared to the previous decade, indicating that the chosen topic is gaining importance as a major research field.

Table 1: Number of studies in Google Scholar within the specified date ranges

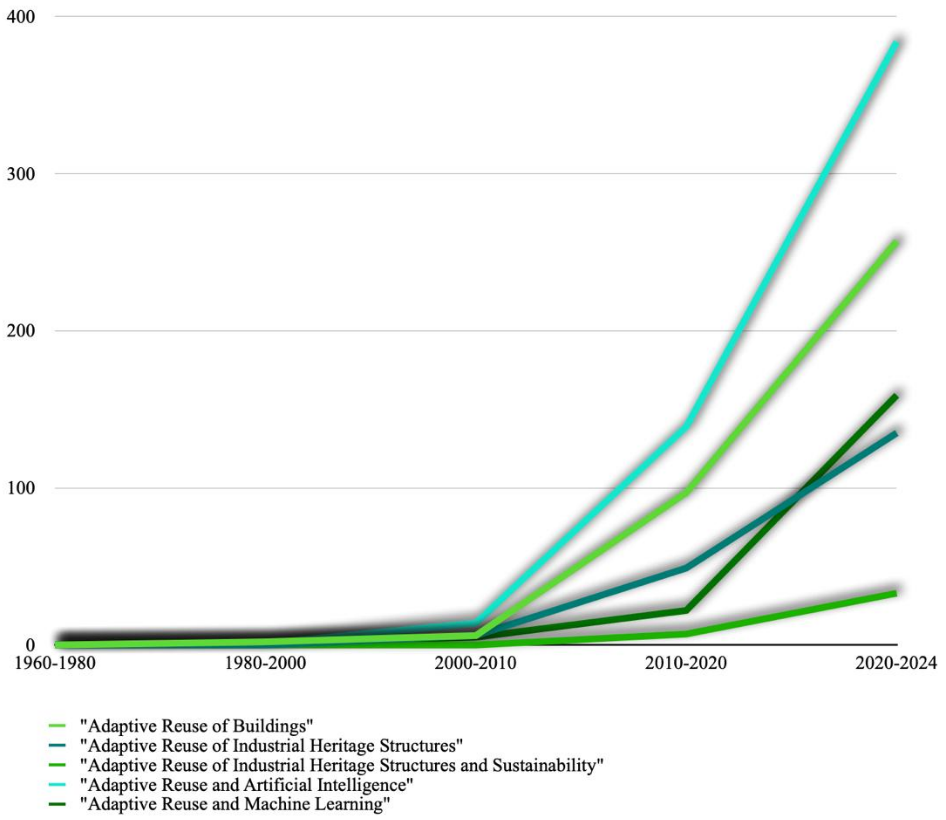
	1960-1980	1980-2000	2000-2010	2010-2020	2020-2024
"Adaptive Reuse of Buildings"	6	49	163	651	635
"Adaptive Reuse of Industrial Heritage Structures"	0	1	17	248	334
"Adaptive Reuse of Industrial Heritage Structures" "and" "Sustainability"	0	1	6	145	283
"Adaptive Reuse" "and" "Artificial Intelligence"	0	0	57	299	851
"Adaptive Reuse" "and" "Machine Learning"	1	6	19	139	515



Graph 1. Number of searches in Google Scholar of keywords between specified dates

Table 2. Number of studies in Scopus within the specified date ranges

	1960-1980	1980-2000	2000-2010	2010-2020	2020-2024
"Adaptive Reuse of Buildings"	0	2	6	97	257
"Adaptive Reuse of Industrial Heritage Structures"	0	0	6	49	135
"Adaptive Reuse of Industrial Heritage Structures" and "Sustainability"	0	0	0	7	33
"Adaptive Reuse" and "Artificial Intelligence"	0	1	14	139	384
"Adaptive Reuse" and "Machine Learning"	0	1	5	22	159



Graph 2. Number of studies in Scopus within the specified date ranges

In conclusion, the comprehensive literature review conducted from 1960 to 2024 reveals significant trends in the study of adaptive reuse and its intersection with artificial intelligence. The analysis highlights important dates and events such as the establishment of global frameworks for industrial heritage conservation and the increasing integration of advanced technologies in adaptive reuse practices. The observed surge in research from 2020 onwards underscores the growing importance of this interdisciplinary field, emphasizing the need for further exploration. Based on these insights, the subsequent sections of this paper will delve into specific case studies and theoretical frameworks, aiming to provide deeper insights into the evolving landscape of adaptive reuse and its technological advancements.

3. Adaptive Reuse and Artificial Intelligence (AI)

3.1 Adaptive Reuse Buildings, Adaptive Reuse Industrial Heritage Structures, and Sustainability

The restoration process of historical buildings should be carried carefully to preserve the cultural identity as these buildings are a part of urban memory. Maintenance and repairs are required to preserve characteristics forming the identity and ensure the continuity of cultural assets.

The aim of restoration is to preserve historical documents, cultural heritage, and social identity with minimum intervention as possible to historical buildings. There are many methods for interventions in buildings in this way. These can be listed as consolidation, integration, renewal, adaptive reuse (renovation-rehabilitation), reconstruction, cleaning, and relocation (Kocabıyık, 2014).

Adaptive reuse involves modifying and adapting existing buildings to suit new requirements, thereby extending the life cycle of historic buildings while giving them new functions (Othman & Elsaay, 2018). By transforming heritage buildings into accessible and usable spaces, adaptive reuse not only conserves historical significance but also revitalizes urban areas in a sustainable manner (Bullen & Love, 2011) In the realm of sustainability, adaptive reuse is seen as a key approach to achieving sustainable urban development (Vardopoulos et al., 2021).

As defined in the previous section on literature survey, adaptive reuse in architecture is gaining global interest as a strategy for sustainable development and heritage conservation. Industrial building demolition damages the environment and the economy while also producing more structural waste. Reusing industrial buildings is a crucial strategy for both making use of available resources and preserving historical assets (Oral Aydın & Çömlekçioğlu Kartal, 2010). This practice involves redesigning existing buildings for new functions, thereby extending their lifespan and reducing environmental impacts. Studies have shown that adaptive reuse not only aligns with United Nations' (UN) sustainability goals but also contributes to economic development, environmental protection, and social welfare (Langston, Wong, Hui, & Shen, 2008). Besides these impacts, buildings preserved and reintegrated into society through adaptive reuse help society to maintain urban memory and cultural heritage along with their surroundings. This process ensures that historical buildings continue to serve as tangible reminders of societal evolution and cultural continuity, enriching the fabric of communities and fostering a sense of identity rooted in shared history and heritage. Therefore, adaptive reuse buildings are important for preserving architectural heritage and supporting sustainability (Bullen & Love 2009).

Architects, developers, and decision-making units play significant roles in the implementation of adaptive reuse projects (Hassanain & Hamida, 2023). The experiences and perspectives of those involved in these projects are crucial for understanding the challenges and opportunities related to the reuse of heritage buildings (P. A. Bullen & Love, 2011). The decision-making process in adaptive reuse projects and function selection is guided by criteria prioritizing sustainability, continuous building life cycles, and the prevention of building demolition (Mohamed & Alauddin, 2016).

Adaptive reuse is a versatile strategy applicable to buildings of different sizes and scales, with various building typologies. It has been applied in historic buildings in different regions, proving its effectiveness in creating sustainable environments (Gewirtzman, 2017). The flexibility in reusing buildings through adaptive reuse allows the transformation of old buildings without significant structural changes, making it a suitable option for the preservation of historic buildings (Farooq & Qureshi, 2020). The restoration and adaptive reuse in architecture provide a balance between preservation and innovation, acting as a bridge between past traditions and future needs (Kersting, 2006).

While adaptive reuse of buildings, their spatial configurations should be considered. Significant differences between the previous and new spatial configurations of the building may lead to negative outcomes. For example, a building previously functioning as a hotel may not be suitable for use as a cinema but could become a modern accommodation facility. Similarly, a church with a single spatial feature cannot be converted into a school by dividing it into classrooms but can easily be transformed into a car showroom or cinema with less spatial or structural intervention. If buildings are refunctioned with functions that do not fit their former uses, they will largely lose their identity (Altınoluk, 1998).

The adaptive reuse process should consider not only the building's interior but also its environmental and locational features. Environmental requirements are crucial at this point. For functional interaction, considering a bank function for structures worth preserving in commercial areas may be more effective than a library function (Kaşlı, 2008). It involves repurposing existing spaces for functions different from their original design, contributing to sustainability by preserving historical value and bringing social, economic, and environmental benefits (Lemos & Donoso, 2023).

Adaptive reuse is an important concept in urban design especially for industrial buildings. With the advancement of technology, machines have replaced human labor in production. Over time, changes in production methods and production areas have highlighted the need for change in industrial buildings. This also demonstrates how industrial structures lose their function over time (Mengüşoğlu & Boyacıoğlu, 2013). In addition to changes in production methods, as population density increases in cities, other uses needed for industrial buildings in significant locations have become more important. At this point, renewing buildings serves to protect old buildings from demolition (Ahunbay, 2010).

Adaptive reuse in industrial heritage structures involve redesigning these buildings for new functions while preserving their historical and architectural significance. This process generally requires making minimal changes to the original urban fabric which may have an authentic texture of the city to preserve the building's cultural value (Prihatmanti & Susan, 2017). When evaluating function selections in adaptive reuse, ensuring the building's sustainability over time is one of the most important considerations. Sustainability of industrial heritage plays a significant role in facilitating adaptive reuse projects for heritage buildings, allowing these buildings to adapt to changing built environments while preserving their historical integrity (Balta, 2022).

Adaptive reuse helps preserve heritage buildings and contributes to sustainable development by providing eco-friendly solutions and creating usable spaces that benefit society (Günçe and Misirlisoy, 2019). The reuse of industrial heritage buildings can contribute to sustainably, giving new life to these structures and their surroundings (Günçe & Mısırlısoy, 2015). Additionally, using buildings with a new function can be a valuable preservation approach for heritage structures, ensuring their conservation for future generations with efficient and suitable functions (Farjami & Türker, 2021).

3.2. Adaptive reuse, Artificial Intelligence (AI), Machine Learning (ML), and Decision Trees

The artificial intelligence (AI) -based adaptive reuse process offers numerous advantages to restoration experts and all related units (Li, Zhao, Huang, & Law, 2021a). These advantages include determining the most suitable potential functions, creating optimized designs, improving marketing strategies, and supporting sustainable management. According to literature review, from the graphs given in section 2, it is seen that, the integration of AI into adaptive reuse and usage applications is an area of increasing interest. AI technologies, such as computer vision, machine learning, deep learning, and decision trees have the potential to revolutionize the fields of architecture and construction (Yönder, Doğan, & Çavka, 2021).

By refunctioning underutilized historical buildings and abandoned urban areas, adaptive reuse contributes to urban regeneration, and sustainable development (Aigwi et al., 2019). However, with today's technology, different strategies are no longer necessary with the aid of AI. Technologies like Generative Adversarial Networks (GAN), Easy DL, and Natural Language Processing (NLP) can provide technical support in the redesign, adaptive reuse, restoration, and conservation processes of defunct structures and areas, from design to operation (Baduge et al., 2022). In a study, Duan et al. (2022) evaluated ten representative urban ruins in Guangzhou first with the Analytic Hierarchy Process and then combined AI methods such as generative adversarial networks and big data applications for a study on the reuse design of urban decays (Duan, Qi, Cao, & Si, 2022).

There are many subsets and application methods of AI, one of which is machine learning (ML). Machine learning is a sub-discipline of AI that enhances computer systems' capabilities to analyze data, identify patterns, make predictions, and make decisions (Mitchell, 1997). AI, particularly in the context of machine learning and Python language, has the potential to be used for adaptive reuse. Machine learning, a subset of AI, has been identified as a leading tool in various fields (Greenspan, Van Ginneken, & Summers, 2016). Python, one of the programming languages, has been emphasized in the context of adaptive reuse. It provides open access to Python applications, ensuring the accessibility and reproducibility of models. (Noroozbabaee, Blanco, Safaei, & Nickerson, 2023).

AI, machine learning, and Python's use in adaptive reuse present distinct differences from other applications. For example, AI-based systems present unique challenges such as the increasing importance of data quality and management, boundaries for complex models, and challenges in customizing and reusing AI/machine learning components (Bogner, Verdecchia, & Gerostathopoulos, 2021). In the field of machine learning, Python stands out as a prominent programming language. This is because Python's versatility, ease of handling, and comprehensive libraries makes it a preferred language among people (Virtanen et al., 2020). Similarly, Python's integration with machine learning infrastructures has been crucial for its dissemination.

The ease of use and extensive library support of the Python language offer significant advantages in the development and implementation of machine learning projects. Decision trees are algorithms that proceed in a tree structure in decision-making systems, following the branches of a tree (Mondal et al., 2023). In decision trees, decision-making is based on data characteristics. The decision tree model includes intermediate nodes, branches, and terminal nodes (Lee & Ham, 2022).

To sum up, artificial intelligence and machine learning has been increasingly integrated into architectural practices, with researchers exploring innovative applications of machine learning in architectural design and adaptive reuse (Dai, 2023). This method can facilitate many aspects, from optimizing building selection for adaptive reuse to project management. However, recognizing the challenges and considerations related to the use of these technologies in adaptive reuse is crucial. It has to be ensure that the design and implementation align with the specific requirements of the adaptive reuse context (Li, Zhao, Huang, & Law, 2021b).

Graph 3: Definition of the problem and offered solution chart

In summary, adaptive reuse is often the best solution for abandoned buildings if a suitable new function can be identified. However, if the chosen function is inappropriate, the building may become obsolete and ultimately be demolished. This can result in the loss of cultural and historical heritage. Therefore, selecting the most appropriate function for each abandoned building is crucial. Artificial Intelligence (AI) can help by suggesting the most viable new uses for these structures with minimal intervention (Graph 3).

4. CONCLUSION

Adaptive reuse contributes to sustainable development, preservation of cultural heritage, and the revitalization of society by reusing existing buildings, making it a valuable practice in contemporary architectural discourse (Ullah, Shah, & Nazir, 2022). The adaptive reuse of historical and industrial buildings is a pivotal strategy for achieving sustainable urban development. This approach not only preserves cultural heritage and architectural identity but also addresses environmental concerns by reducing the need for new construction and minimizing waste. As cities continue to grow and evolve, the adaptive reuse of existing structures becomes increasingly important in maintaining a balance between preserving the past and meeting contemporary needs.

The integration of advanced technologies, particularly artificial intelligence (AI) and machine learning (ML) and decision trees, into the adaptive reuse process offers significant potential to enhance efficiency, effectiveness, and sustainability. AI and ML can analyze extensive datasets, predict optimal design solutions, and support informed decision-making. Technologies such as computer vision, deep learning, and decision trees can identify suitable functions for refunctioned buildings, optimize structural modifications, and ensure alignment with sustainability objectives.

The findings of this paper discuss the transformative potential of AI and ML in the field of architecture and construction. In recent years, the number of studies on these technologies has increased, and their application is becoming more evident. These technologies can play a crucial role in the adaptive reuse of industrial heritage buildings. With the assistance of AI, optimal new functional offerings can be systematically determined, thereby potentially saving time for designers. AI-supported adaptive reuse strategies can effectively align with the specific requirements of physical environments and facilitate sustainable development.

In contrast to conventional approaches to adaptive reuse decision-making, AI can propose superior alternatives, thereby potentially sustainable heritage protection beneficial outcomes through the selection of the most suitable and viable functional options. Evidently, contemporary discussions and graphical representations highlight AI and new technologies as burgeoning subjects with profound implications across various domains. This study investigates the contemporary impact of artificial intelligence in adaptive reuse.

In conclusion, the adaptive reuse of buildings, particularly industrial heritage structures, represents a critical intersection with the development and application of AI in the field of adaptive reuse. The incorporation of AI and ML into this process not only enhances its feasibility and sustainability but also opens new avenues for preserving cultural heritage in a rapidly changing world as stated. As we move forward, embracing these advanced technologies in the adaptive reuse of buildings will be essential for creating resilient, sustainable, and vibrant urban environments.

Considering conservation concerns, digitalization was initially adopted in cases where accessing information and documents with traditional methods was challenging. With this digitalization and new technologies, much faster documentation, measurement, and other necessary research for conservation became easier. Today, the concept of protection has moved a step further beyond traditional and digital protection concepts, adopting a preservation approach entirely based on automation with AI.

According to the related literature given, the historical process should be tackled from the very beginning, starting with the history of architecture. This approach relates to sustainability because understanding historical contexts helps preserve architectural heritage while adapting it for modern use. Integrating AI and machine learning (ML) can enhance sustainability by optimizing the adaptive reuse practices of historical buildings, improving resource usability with new and the most proper function, and minimizing environmental impact. AI and ML can analyze historical data to propose viable new functions, predict long-term impacts, and ensure that adaptations align with sustainability goals.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work the author used Grammarly GO AI Writing Assistant and Chat GPT to improve proofreading like language and readability. After using this tool, the author reviewed and edited the content as needed and take full responsibility for the content of the publication.

REFERENCES

Abd El- Maksoud, N., & Ahmed, E. (2024). Artificial Intelligence Applications in Green Architecture. *Fayoum University Journal of Engineering*, 7(2), 317–337. Retrieved from https://doi.org/10.21608/fuje.2024.345049

Abraham, A., Pedregosa, F., Eickenberg, M., Gervais, P., Mueller, A., Kossaifi, J., … Varoquaux, G. (2014). Machine learning for neuroimaging with scikit-learn. *Frontiers in Neuroinformatics*, 8. Retrieved from https://doi.org/10.3389/fninf.2014.00014

Ahunbay, Z. (2010). *Tarihi Çevre Koruma ve Restorasyon*. İstanbul: Yem Yayınları.

Aigwi, I. E., Egbelakin, T., Ingham, J., Phipps, R., Rotimi, J., & Filippova, O. (2019). A performance-based framework to prioritise underutilised historical buildings for adaptive reuse interventions in New Zealand. *Sustainable Cities and Society*, 48, 101547. Retrieved 1 December 2023 from https://doi.org/10.1016/J.SCS.2019.101547

Altınoluk, Ü. (1998). *Binaların yeniden kullanımı: program, tasarım, uygulama, kullanım* (Vol. 1). Yapı-Endüstri Merkezi Yayınları.

Baduge, S. K., Thilakarathna, S., Perera, J. S., Arashpour, M., Sharafi, P., Teodosio, B., … Mendis, P. (2022). Artificial intelligence and smart vision for building and construction 4.0: Machine and deep learning methods and applications. *Automation in Construction*, 141, 104440. Retrieved from https://doi.org/10.1016/j.autcon.2022.104440

Balta, M. Ö. (2022). An AHP-Based Multi-Criteria Model for Adaptive Reuse of Heritage Buildings. *Geographies, Planning And Tourism Studios*, 2(1), 40–45. Retrieved from https://doi.org/10.5505/gpts.2022.36854

Biehler, R., Fleischer, Y., Budde, L., Frischemeier, D., Gerstenberger, D., Podworny, S., & Schulte, C. (2020). Data science education in secondary schools: teaching and learning decision trees with CODAP and jupyter notebooks as an example of integrating machine learning into statistics education. In *New Skills in the changing World of Statistics Education IASE Roundtable Conference*. International Association for Statistical Education. Retrieved from https://doi.org/10.52041/SRAP.20304

Bogner, J., Verdecchia, R., & Gerostathopoulos, I. (2021). Characterizing Technical Debt and Antipatterns in AI-Based Systems: A Systematic Mapping Study. *Proceedings - 2021 IEEE/ACM International Conference on Technical Debt, TechDebt 2021*, 64–73. Retrieved 5 December 2023 from https://doi.org/10.1109/TechDebt52882.2021.00016

Bredesen-Aa, B. A., & Rehmsmeier, M. (2022). Gnocis: An integrated system for interactive and reproducible analysis and modelling of cis-regulatory elements in Python 3. *PLOS ONE*, 17(9), e0274338. Retrieved from https://doi.org/10.1371/journal.pone.0274338

Bullen, P. A., & Love, P. E. D. (2009). Residential regeneration and adaptive reuse: learning from the experiences of Los Angeles. *Structural Survey*, 27(5), 351–360. Retrieved from https://doi.org/10.1108/02630800911002611

Bullen, P. A., & Love, P. E. D. (2011). Adaptive reuse of heritage buildings. *Structural Survey*, 29(5), 411–421. Retrieved 1 December 2023 from https://doi.org/10.1108/02630801111182439/FULL/XML

Bullen, P., & Love, P. (2011). A new future for the past: a model for adaptive reuse decision-making. *Built Environment Project and Asset Management*, 1(1), 32–44. Retrieved from https://doi.org/10.1108/20441241111143768

Dai, A. (2023). Co-creation: Space Reconfiguration by Architect and Agent Simulation Based Machine Learning (pp. 304–313). Retrieved from https://doi.org/10.1007/978-981-19-8637-6_27

Duan, Q., Qi, L., Cao, R., & Si, P. (2022). Research on Sustainable Reuse of Urban Ruins Based on Artificial Intelligence Technology: A Study of Guangzhou. *Sustainability*, 14(22), 14812. Retrieved from https://doi.org/10.3390/su142214812

Eren, Ş. G. (2021). An Analysis on Urbanism and Urban Growth Concepts in the Context of Sustainability. In *Architectural Sciences and Sustainability* (Vol. 2, pp. 197–264). Iksad .

Farjami, E., & Türker, Ö. O. (2021). The Extraction of Prerequisite Criteria for Environmentally Certified Adaptive Reuse of Heritage Buildings. *Sustainability*, 13(6), 3536. Retrieved from https://doi.org/10.3390/su13063536

Farooq, D. S., & Qureshi, A. K. (2020). Sustainable Viability for Restoration and Adaptive Reuse of Sikh Era Havelis in Lahore, Pakistan. *Sir Syed University Research Journal of Engineering & Technology*, 10(2). Retrieved from https://doi.org/10.33317/ssurj.162

Fufa, S. M., Flyen, C., & Flyen, A.-C. (2021). How Can Existing Buildings with Historic Values Contribute to Achieving Emission Reduction Ambitions? *Applied Sciences*, 11(13), 5978. Retrieved from https://doi.org/10.3390/app11135978

Gewirtzman, D. F. (2017). Adaptive Reuse Architecture Documentation and Analysis. *Journal of Architectural Engineering Technology*, 05(03). Retrieved from https://doi.org/10.4172/2168-9717.1000172

Greenspan, H., Van Ginneken, B., & Summers, R. M. (2016). Guest Editorial Deep Learning in Medical Imaging: Overview and Future Promise of an Exciting New Technique. *IEEE Transactions on Medical Imaging*, 35(5), 1153–1159. Retrieved 5 December 2023 from https://doi.org/10.1109/TMI.2016.2553401

Günçe, K., & Misirlisoy, D. (2019). Assessment of Adaptive Reuse Practices through User Experiences: Traditional Houses in the Walled City of Nicosia. *Sustainability 2019, Vol. 11, Page 540*, 11(2), 540. Retrieved 15 December 2023 from https://doi.org/10.3390/SU11020540

Günçe, K., & Mısırlısoy, D. (2015). Questioning the Adaptive Reuse of Industrial Heritage and Its Interventions in the Context of Sustainability. *Sociology Study*, 5(9). Retrieved from https://doi.org/10.17265/2159-5526/2015.09.004

Hassanain, M. A., & Hamida, M. B. (2023). AEC/FM performance in adaptive reuse projects: investigation of challenges and development of practical guidelines. *Facilities*, 41(7/8), 477–497. Retrieved from https://doi.org/10.1108/F-04-2022-0053

Hegazy, M., & Saleh, A. (2023). Evolution of AI role in architectural design: between parametric exploration and machine hallucination. *MSA Engineering Journal*, 2(2), 262–288. Retrieved from https://doi.org/10.21608/msaeng.2023.291873

Kaşlı, B. (2008). *İstanbul'da Yeniden İşlevlendirilen Korumaya Değer Endüstri Yapıları Ve İç Mekan Müdahaleleri: Santralistanbul Örneği*. İtü, İstanbul.

Kersting, J. M. (2006). Integratıng Past And Present: The Story Of A Buıldıng Through Adaptıve Reuse. Retrieved 22 July 2024 from http://rave.ohiolink.edu/etdc/view?acc_num=ucin1148308325

Kocabıyık, Y. (2014). *Yeniden İşlevlendirme Kavramı ve Bu Kapsamda İTÜ Taşkışla Binasının İncelenmesi*. Maltepe Üniversitesi, İstanbul.

Langston, C., Wong, F. K. W., Hui, E. C. M., & Shen, L.-Y. (2008). Strategic assessment of building adaptive reuse opportunities in Hong Kong. *Building and Environment*, 43(10), 1709–1718. Retrieved from https://doi.org/10.1016/j.buildenv.2007.10.017

Lee, K.-S., & Ham, B.-J. (2022). Machine Learning on Early Diagnosis of Depression. *Psychiatry Investigation*, 19(8), 597–605. Retrieved from https://doi.org/10.30773/pi.2022.0075

Lemos, C. B., & Donoso, M. D. (2023). Reduce, Reuse, Rethınk And Preserve: The Reuse Of Hıstorıcal Buıldıngs As A Strategy For Envıronmental Sustaınabılıty And Herıtage Apprecıatıon. *Scientific Journal Of Applied Social And Clinical Science*, 3(20), 2–9. Retrieved from https://doi.org/10.22533/at.ed.2163202314089

Li, Y., Zhao, L., Huang, J., & Law, A. (2021a). Research frameworks, methodologies, and assessment methods concerning the adaptive reuse of architectural heritage: a review. *Built Heritage*, 5(1), 6. Retrieved from https://doi.org/10.1186/s43238-021-00025-x

Li, Y., Zhao, L., Huang, J., & Law, A. (2021b). Research frameworks, methodologies, and assessment methods concerning the adaptive reuse of architectural heritage: a review. *Built Heritage*, 5(1), 6. Retrieved from https://doi.org/10.1186/s43238-021-00025-x

Mengüşoğlu, N., & Boyacıoğlu, E. (2013). Reuse Of Industrial Built Heritage For Residential Purposes In Manchester. *METU Journal Of The Faculty Of Archıtecture*, 30(01). Retrieved from https://doi.org/10.4305/METU.JFA.2013.1.7

Mitchell, T. M. (1997). Does Machine Learning Really Work? *AI Magazine*, 18(3), 11–11. Retrieved 8 May 2024 from https://doi.org/10.1609/AIMAG.V18I3.1303

Mohamed, N., & Alauddin, K. (2016). The Criteria For Decision Making In Adaptive Reuse Towards Sustainable Development. *MATEC Web of Conferences*, 66, 00092. Retrieved from https://doi.org/10.1051/matecconf/20166600092

Mondal, R., Do, M. D., Ahmed, N. U., Walke, D., Micheel, D., Broneske, D., … Heyer, R. (2023). Decision tree learning in Neo4j on homogeneous and unconnected graph nodes from biological and clinical datasets. *BMC Medical Informatics and Decision Making*, 22(S6), 347. Retrieved from https://doi.org/10.1186/s12911-023-02112-8

Noroozbabaee, L., Blanco, P. J., Safaei, S., & Nickerson, D. (2023). Reproducibility study of the modular and reusable model of epithelial transport in the proximal convoluted tubule. *Physiome*. Retrieved 5 December 2023 from https://doi.org/10.36903/PHYSIOME.23499258.V4

Oral Aydın, E. Ö., & Çömlekçioğlu Kartal, R. (2010). Kocaeli Seka I. Kağıt Fabrikası'nın Mimari Analizi Ve Yeniden Kullanım Önerileri. *Türkiye Bilimler Akademisi Kültür Envanteri Dergisi*, (8), 21–34. Retrieved from https://doi.org/10.22520/tubaked.2010.0002

Othman, A. A. E., & Elsaay, H. (2018). Adaptive reuse: an innovative approach for generating sustainable values for historic buildings in developing countries. *Organization, Technology and Management in Construction: An International Journal*, 10(1), 1704–1718. Retrieved from https://doi.org/10.2478/otmcj-2018-0002

Prihatmanti, R., & Susan, M. Y. (2017). Adaptive reuse of heritage building and the impact to the visual comfort: Assessed by the lighting quality. *IPTEK Journal of Proceedings Series*, 0(3). Retrieved from https://doi.org/10.12962/j23546026.y2017i3.2443

Ullah, U., Shah, S. M. A., & Nazir, H. (2022). Challenges and Opportunities for Revitalization of the Architectural Heritage of Saidu Sharif Swat. *Annals of Human and Social Sciences*, 3(III). Retrieved from https://doi.org/10.35484/ahss.2022(3-III)11

Vardopoulos, I., Tsilika, E., Sarantakou, E., Zorpas, A., Salvati, L., & Tsartas, P. (2021). An Integrated SWOT-PESTLE-AHP Model Assessing Sustainability in Adaptive Reuse Projects. *Applied Sciences*, 11(15), 7134. Retrieved from https://doi.org/10.3390/app11157134

Virtanen, P., Gommers, R., Oliphant, T. E., Haberland, M., Reddy, T., Cournapeau, D., … Vázquez-Baeza, Y. (2020). SciPy 1.0: fundamental algorithms for scientific computing in Python. *Nature Methods*, 17(3), 261–272. Retrieved from https://doi.org/10.1038/s41592-019-0686-2

Yönder, V. M., Doğan, F., & Çavka, H. B. (2021). Deciphering and Forecasting Characteristics of Bodrum Houses Using Artificial Intelligence (AI) Approaches. In *Blucher Design Proceedings* (pp. 241–252). São Paulo: Editora Blucher. Retrieved from https://doi.org/10.5151/sigradi2021-146