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Prof. Dr. E. Esra KASAPBAŞI
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Dear Readers,

We are pleased to present the second issue of the seventh volume of the Journal of Haliç University Natural and Applied Sciences to you. In this issue, one original articles related to the fields of Information Systems and two original article related to the fields of Architecture are included. We would like to thank all the authors of the articles for their scientific contributions, the reviewers for their valuable comments and our journal team for their help and efforts for preparing this issue for publication. We hope that this issue of our journal will be beneficial to you. Yours sincerely,

Prof. Dr. E. Esra KASAPBAŞI
Editor
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Harnessing Artificial Intelligence and Big Data for Proactive Disaster Management: Strategies, Challenges, and Future Directions

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Abstract

Disasters are events that significantly impact people's lives and living spaces globally. Natural disasters can arise from various causes, such as climate change, geological movements, weather events, and human factors. The damage caused by these disasters can affect millions of people and negatively impact societies economically, socially, and environmentally. Disaster management has emerged as a multidisciplinary field aimed at minimizing the damage caused by disasters and making communities more resilient to them. Traditional disaster management strategies include emergency planning, crisis management, pre-disaster preparation, and rapid response during disasters. However, these strategies generally reflect a reactive approach and rely on human resources and existing infrastructure. This article aims to examine the role and impact of innovative technologies such as artificial intelligence and big data in the field of disaster management. While artificial intelligence is known for its ability to analyze complex datasets, discover patterns and relationships, optimize decision-making processes, and predict future events, big data provides the ability to process large amounts of data quickly and efficiently, transforming them into meaningful information. These technologies play a significant role in pre-disaster preparation, crisis management during disasters, and post-disaster recovery processes. The article discusses how artificial intelligence and big data technologies can be used in disaster management, how these technologies can be integrated into disaster risk reduction strategies, and how their effectiveness can be assessed. It further aims to provide a guide to understanding the current state of disaster management and developing more effective strategies. In conclusion, the integration of artificial intelligence and big data technologies into disaster management offers a more effective and efficient approach to dealing with disasters and can make significant contributions to making communities more resilient to disasters.

Keywords: Disaster Management, Artificial Intelligence, Big Data, Risk Analysis, Pre-disaster Preparedness.

Yapay Zekâ ve Büyük Veriyi Proaktif Afet Yönetimi İçin Kullanma: Stratejiler, Zorluklar ve Gelecek Yönelimler

Öz

Afetler, dünya genelinde insanların yaşamını ve yaşam alanlarını ciddi şekilde etkileyen olaylardır. Doğal afetler; iklim değişikliği, jeolojik hareketler, hava olayları ve insan kaynaklı etmenler gibi çeşitli sebeplerden ortaya çıkabilir. Bu afetlerin yol açtığı zararlar, milyonlarca insanı etkileyebilir ve toplumları ekonomik, sosyal ve çevresel açıdan olumsuz yönde etkileyebilir. Afet yönetimi, afetlerin neden olduğu zararları en aza indirmek ve toplumları afetlere karşı daha dirençli hâle getirmek amacıyla multidisipliner bir alan olarak ortaya çıkmıştır. Geleneksel afet yönetimi stratejileri; acil durum planlaması, kriz yönetimi, afet öncesi hazırlık ve afet sırasında hızlı müdahale gibi süreçleri içermektedir. Ancak bu stratejiler genellikle reaktif bir yaklaşımı yansıtır ve insan kaynaklarına ve mevcut altyapıya dayanır. Bu makale, afet yönetimi alanında yapay zekâ ve büyük veri gibi yenilikçi teknolojilerin rolünü ve etkisini incelemeyi amaçlamaktadır. Yapay zekâ; karmaşık veri kümelerini analiz etme, desenler ve ilişkiler keşfetme, karar alma süreçlerini optimize etme ve gelecekteki olayları tahmin etme yeteneği ile bilinirken, büyük veri, büyük miktarda veriyi hızlı ve etkin bir şekilde işleyerek anlamlı bilgilere dönüştürme imkânı sağlar. Bu teknolojiler, afet öncesi hazırlık, afet sırasında kriz yönetimi ve afet sonrası iyileştirme süreçlerinde önemli bir rol oynamaktadır. Makalede, yapay zekâ ve büyük veri teknolojilerinin afet yönetiminde nasıl kullanılabileceği, bu teknolojilerin afet risklerini azaltma stratejilerine nasıl entegre edilebileceği ve etkinliğinin nasıl değerlendirilebileceği ele alınmaktadır. Sonuç olarak, yapay zekâ ve büyük veri teknolojilerinin afet yönetimine entegrasyonu, afetlerle başa çıkmada daha etkili ve verimli bir yaklaşım sunmakta olup toplumların afetlere karşı daha dirençli hâle gelmesine önemli katkılar sağlayabilir.

Anahtar Kelimeler: Afet Yönetimi, Yapay Zekâ, Büyük Veri, Risk Analizi, Afet Öncesi Hazırlık.

1. Introduction

Disasters are profound events that can severely disrupt human lives and transform living environments on a global scale (Smith, 2018: 210-225). These events may arise from natural phenomena such as earthquakes, floods, hurricanes, and volcanic eruptions; or be induced by human activities like deforestation, urbanization, and industrial accidents (Jones & Brown, 2020: 45-58). The damage resulting from such disasters extends beyond immediate destruction, often leading to widespread humanitarian crises, economic instability, and long-term environmental degradation (Garcia & Martinez, 2023: 512-527). Additionally, disasters can disrupt social structures and pose significant challenges, particularly in densely populated urban areas and developing nations where resilience to such shocks may be lower (Robinson & Nguyen, 2022: 156-170; Chen et al., 2020: 643-658).

Addressing the impact of disasters requires a multi-faceted approach aimed at minimizing damage, enhancing community resilience, and ensuring preparedness for future events. Traditional disaster management strategies typically involve processes such as emergency planning, crisis management, pre-disaster preparedness, and rapid response during and after a disaster (Brown & Lee, 2023). Even though these methods have been foundational, they often depend heavily on existing human resources and infrastructure, which can limit their effectiveness and adaptability. Traditional approaches tend to be reactive, addressing the aftermath of disasters rather than proactively preventing or mitigating their effects (Wang et al., 2024: 87-102).

Recent advancements in technology, particularly artificial intelligence (AI) and big data, have significantly transformed disaster management practices. AI, with its ability to analyze vast volumes of complex data, recognize patterns, and optimize decision-making processes, has emerged as a powerful tool for predicting and responding to disasters (Gupta et al., 2021: 89-104). AI's applications include early warning systems, automated response mechanisms, and predictive analytics, all of which provide critical insights that enhance the effectiveness of disaster management efforts.

Mathematical modeling, a component of AI, plays a pivotal role in disaster management by providing frameworks for simulating and predicting disaster scenarios. These models use algorithms to simulate the impacts of different disaster events based on historical data, real-time information, and predictive analytics. This simulation capability allows for the development of detailed risk assessments and the formulation of proactive strategies to mitigate potential impacts (Smith & Lee, 2018: 1-14). For example, mathematical models can predict flood patterns and potential damage based on weather data and historical flood records, enabling better planning and resource allocation.

Big data technologies facilitate the rapid processing and analysis of extensive datasets, transforming them into actionable intelligence for both pre-disaster preparedness and post-disaster recovery (Choi & Patel, 2022: 56-73). This includes leveraging data from social media, satellite imagery, and sensor networks to improve situational awareness and resource allocation. The integration of big data analytics with AI enhances the ability to monitor and respond to disasters in real-time, improving the overall effectiveness of disaster management systems.

The integration of AI, big data, and mathematical modeling into disaster management represents a significant shift from reactive to proactive and predictive approaches. These technologies enhance all phases of disaster management—from preparation and response to recovery—by providing more accurate predictions, optimizing resource allocation, and improving decision-making processes (Huang et al., 2023: 521-537). By harnessing these advanced technologies, disaster management practices can be significantly improved, leading to more resilient communities and a reduced impact of disasters.

This paper aims to explore the effective utilization of AI, big data, and mathematical modeling within disaster management. It will examine the integration of these technologies into existing disaster risk reduction strategies, evaluate their effectiveness, and identify potential areas for future research. Subsequent sections will delve into the practical applications of AI and big data in disaster management, their historical development, methods of integration, a comprehensive literature review, and an assessment of their effectiveness, through which the paper seeks to offer a comprehensive understanding of how these advanced technologies can enhance disaster management practices and contribute to building more resilient societies.

2. Artificial Intelligence and Big Data in Disaster Management: Key Concepts

Disaster management is a multidisciplinary field dedicated to the effective handling of natural or human-induced emergencies. Its primary objective is not only to minimize the damage caused by disasters but also to enhance the resilience of communities against such events, ensuring that they can recover swiftly and with minimal long-term consequences (Smith, 2018: 210-225; Johnson, 2021: 45-60). This complex process encompasses various stages, including risk analysis, emergency planning, crisis management, rescue operations, recovery, and reconstruction. Each of these stages plays a critical role in building a robust and adaptive disaster management system capable of responding to the unpredictable nature of disasters.

2.1. Risk Analysis and Forecasting

Risk analysis serves as the foundation of disaster management. It involves identifying potential disaster hazards and evaluating their likely impacts on communities and infrastructure (Jones and Brown, 2021: 210-225). Effective risk analysis requires a comprehensive understanding of environmental, social, and economic factors that contribute to vulnerability. For instance, in flood-prone areas, understanding historical weather patterns, topography, and urban development trends is crucial for predicting future risks.

However, traditional risk analysis methods often fall short due to the sheer volume and complexity of data that must be processed. This is where AI and big data technologies can make a transformative impact. AI algorithms can analyze vast datasets, identifying subtle patterns and correlations that might be missed by human analysts, thereby providing more accurate risk assessments. Additionally, big data enables the continuous updating of risk profiles as new data becomes available, ensuring that emergency plans remain relevant and effective. In this respect comparison of traditional vs. AI-enhanced risk analysis techniques are depicted in Table-1 (Jones & Brown, 2021: 210-225; Garcia & Martinez, 2023: 512-527).

Table 1: Comparison of Traditional vs. AI-Enhanced Risk Analysis Techniques

Aspect	Traditional Techniques	AI-Enhanced Techniques
Data Source	Historical data	Real-time, multi-source data
Model Type	Static models	Dynamic, adaptive models
Predictive Accuracy	Moderate	High
Response Time	Slower	Real-time
Adaptability	Limited	Highly adaptable

Moreover, the ability of AI to integrate various data sources, such as satellite imagery, social media feeds, and real-time sensor data, allows for a more dynamic and comprehensive risk analysis. For example, during a hurricane, AI models can analyze weather data alongside social media posts to provide a real-time assessment of the storm's impact, helping authorities to respond more effectively (Garcia and Martinez, 2023: 512-527). This real-time analysis is critical for ensuring that resources are allocated efficiently and that vulnerable populations receive the support they need.

2.2. Emergency Planning and Resource Allocation

Emergency planning is a proactive approach that ensures communities are prepared for potential disasters. This phase involves pre-planning interventions, allocating resources, and establishing communication protocols to be activated in the event of a disaster (Wang et al., 2024: 87-102). While traditional emergency planning relies heavily on historical data and expert judgment, integrating AI and big data into this process offers several advantages.

AI can simulate various disaster scenarios; thus, helping planners identify the most effective strategies for different types of emergencies. For example, AI models can simulate the spread of wildfires under different weather conditions, enabling planners to develop more effective evacuation plans and resource allocation strategies. Moreover, big data analytics can optimize resource allocation by analyzing factors such as population density, infrastructure robustness, and the availability of emergency services. For example, during the COVID-19 pandemic, AI-driven models helped in the optimal distribution of medical supplies and the planning of lockdown measures, demonstrating the potential of these technologies in emergency planning. So, some case studies of AI in Emergency Planning are showed in Table-2 (Wang & Zhang, (2024: 87-102; Brown et al., 2019: 118-125).

Table 2: Case Studies of AI in Emergency Planning

Case Study	Location	AI Application	Outcome
Wildfire Evacuation Planning	California, USA	AI-driven simulations for evacuation routes	Reduced evacuation time, optimized resource use
Flood Management	Netherlands	AI-enhanced flood prediction models	Improved accuracy in flood forecasting
COVID-19 Resource Allocation	Global	AI models for distribution of medical supplies	Efficient distribution, minimized shortages

Another significant advantage of AI and big data in emergency planning is the ability to predict secondary impacts of disasters, such as disease outbreaks or infrastructure failures. By analyzing historical data and real-time information, AI can forecast these secondary effects, allowing planners to take preemptive measures to mitigate their impact.

2.3. Crisis Management and Real-Time Response

Crisis management is the phase of disaster management that deals with the immediate aftermath of a disaster. It is crucial for coordinating and swiftly responding to minimize loss of life and damage (Li and Kim, 2023: 567-581). This stage often requires real-time data processing and rapid decision-making under pressure. AI and big data technologies are invaluable here, offering tools that can process large volumes of real-time data from multiple sources such as social media, satellite images, and sensor networks.

AI can support decision-makers by providing predictive analytics that suggest the most effective response strategies based on the evolving situation. For example, during a wildfire, AI can analyze wind patterns, vegetation types, and historical fire data to predict the fire's path and recommend evacuation routes. Big data plays a complementary role by ensuring that the vast amounts of data generated during a disaster are organized, processed, and presented in a way that is actionable for crisis managers. In this respect some examples of AI applications in crisis responses are depicted in Table-3 (Li & Kim, (2023: 567-571; Smith & Lee, 2018: 1-14).

Table 3: Examples of AI Applications in Crisis Response

Application	AI Technique Used	Impact on Crisis Response
Earthquake Impact Prediction	Machine Learning	Improved accuracy in predicting affected areas
Hurricane Evacuation Optimization	Reinforcement Learning	Reduced evacuation times, safer routes
Communication Enhancement	Natural Language Processing (NLP)	Streamlined information dissemination

Furthermore, AI-driven systems can enhance communication during crises by analyzing and prioritizing incoming data, helping to filter out noise and focus on critical information. This capability is particularly important when managing large-scale disasters where the volume of data can be overwhelming.

2.4. Post-Disaster Recovery

Following the immediate response, rescue operations are conducted to save lives and begin the process of recovery. This phase is often the most challenging, as it requires quick, coordinated efforts in often chaotic and hazardous conditions (Chen and Wang, 2020: 45-58). AI and big data can significantly enhance the efficiency and effectiveness of rescue operations.

For instance, AI-powered drones can quickly survey disaster zones, providing rescuers with real-time information on the most severely affected areas. This allows for the prioritization of resources and efforts, ensuring that help reaches those in need as quickly as possible. Big data analytics can further support these efforts by aggregating information from multiple sources, such as survivor reports, environmental sensors, and historical data, to guide rescue teams and optimize their operations. Examples regarding AI applications in post disaster recovery are summarized in Table-4 (Chen, & Wang,2020: 45-56; Robinson, & Nguyen, 2022: 156-170).

Table 4: AI Applications in Post-Disaster Recovery

AI Application	Recovery Phase	Benefits
Satellite Image Analysis	Damage Assessment	Faster, more accurate assessments
Predictive Modeling for Reconstruction	Reconstruction Planning	Optimized resource allocation, reduced costs
AI-Based Infrastructure Monitoring	Long-Term Recovery	Early detection of potential failures

AI can also assist in optimizing the logistics of rescue operations. By analyzing traffic patterns, road conditions, and resource availability, AI can help to plan the most efficient routes for rescue teams, ensuring that they can reach disaster sites quickly and safely.

3. Evaluation of AI and Big Data in Disaster Management

While the potential of AI and big data in disaster management is vast, their integration into existing systems presents several challenges. One significant issue is the quality and availability of data. For AI and big data to be effective, they require large volumes of accurate and up-to-date information. However, in many parts of the world, especially in developing countries, such data may not be readily available. Moreover, there are concerns about data privacy and security, particularly when dealing with sensitive information such as personal data from social media or health records. These challenges underscore the need for robust data governance frameworks that ensure the ethical use of AI and big data in disaster management.

Another challenge is the need for interdisciplinary collaboration. Disaster management is inherently multidisciplinary, involving experts from fields such as meteorology, engineering, public health, and social sciences. In order for AI and big data to be effectively integrated, there needs to be a collaborative effort that brings together these diverse fields. This requires not only technical expertise but also an understanding of the social and cultural contexts in which these technologies are deployed.

Moreover, the successful implementation of AI and big data in disaster management requires a commitment to continuous learning and adaptation. As these technologies evolve, disaster management professionals must stay informed about the latest developments and be willing to adopt new tools and methodologies.

Despite these challenges, the benefits of AI and big data in disaster management are undeniable. These technologies offer the potential to transform disaster management from a reactive to a proactive process, enabling communities to better prepare for, respond to, and recover from disasters. As these technologies continue to evolve, they will likely play an increasingly important role in building resilient communities and reducing the impact of disasters.

In conclusion, the integration of AI and big data into disaster management represents a significant advancement in the field. By enhancing risk analysis, emergency planning, crisis management, and rescue operations, these technologies can help minimize the impact of disasters and make communities more resilient. However, to fully realize their potential, it is essential to address the challenges of data quality, privacy, and interdisciplinary collaboration. With the right approach, AI and big data can be powerful tools in the ongoing effort to improve disaster management and protect vulnerable communities.

4. The History of Using Artificial Intelligence and Big Data in Disaster Management

The historical development of technology use in disaster management traces back to humanity's early efforts to respond to disasters. Throughout history, various technologies and methods have been developed to reduce the impacts of disasters and protect communities. However, the importance of technology in disaster management in a modern sense has significantly increased since the mid-20th century.

The use of technology in disaster management has been largely shaped by the development of computer technologies. The invention of computers enabled more systematic and effective disaster management processes. Since the mid-20th century, the increasing prevalence and usage of computer technologies marked a significant turning point in the field of disaster management.

In the 1960s and 1970s, early technologies such as emergency management systems and geographic information systems began to be used to address disasters. These systems played a crucial role in processes like pre-disaster preparedness, crisis management, and rescue operations. However, technology usage during this period was generally limited and localized.

In the 1980s and 1990s, the development of computer technologies and the spread of the internet enabled greater use of technology in disaster management. During this period, the increase in information sharing and communication provided more effective coordination in combating disasters. Additionally, various disaster simulation models and risk analysis tools were developed.

Since the early 2000s, the rise of big data technologies and the development of AI algorithms have offered new opportunities in disaster management. Big data analytics has been used in areas such as disaster risk analysis and real-time data analysis during disasters, improving disaster response processes. Moreover, AI algorithms have helped reduce the impacts of disasters by being used in areas such as disaster prediction and crisis management.

Today, the importance of technology use in disaster management is steadily increasing. Advanced technologies are used more effectively and efficiently in combating disasters, contributing to making communities more resilient. However, to fully harness the potential of technology in disaster management, strong infrastructure, effective resource management, long-term strategy development, and the integration of AI and big data technologies into disaster management processes are required.

5. Integration of Artificial Intelligence and Big Data Technologies into Disaster Management

The integration of artificial intelligence (AI) and big data technologies into disaster management is a critical aspect of effectively addressing disasters (Anderson and Brown, 2019: 45-56). These technologies provide significant tools to mitigate the impacts of disasters, prepare communities, and facilitate rapid response. This section will examine in more detail how AI and big data technologies are integrated into disaster management processes and utilized at each stage.

Disaster Prevention Phase: AI and big data technologies are often employed for disaster risk analysis and prediction (Jones and Lee, 2020: 279-298). Big data analytics can help identify potential disaster risks on a regional or local scale by analyzing data collected before and during disasters in detail (Smith, 2019: 589-607). For example, various parameters such as historical disaster data, climate conditions, local population density, and infrastructure status can be examined through big data analytics to create potential disaster scenarios. AI algorithms can analyze these data, identify patterns and relationships, and help predict future disasters (Zhang et al., 2021: 1608-1623). For instance, deep learning algorithms can identify complex patterns from large data sets and be used to determine future disaster risks.

Disaster Preparedness Phase: AI and big data technologies can be used for emergency planning and resource management (Anderson and Brown, 2019: 45-56). Big data analytics can process data collected before and during disasters in detail, aiding in the effective distribution of resources; e.g., emergency teams can use geographic data analytics to identify high-risk areas during the pre-disaster period and prepare emergency plans accordingly (Jones and Lee, 2020: 279-298). AI algorithms can contribute to the development of emergency plans by simulating disaster scenarios. For instance, machine learning algorithms can analyze past disaster scenarios and determine the most effective measures to take in similar situations (Wang et al., 2024: 87-102).

Disaster Response Phase: AI and big data technologies can be utilized for real-time data analysis and decision support systems during disaster response (Zhang et al., 2021: 1608-1623). Big data analytics can quickly process data collected during a disaster, helping to convey critical information to decision-makers. For example, data collected through geographic information systems (GIS) and sensor networks can be analyzed by big data analytics to identify changes in the disaster area and emergency needs (Smith, 2019: 589-607). AI algorithms can extract meaningful insights from these data and help optimize response strategies. For instance, machine learning algorithms can identify risks in the disaster area by extracting meaningful patterns from real-time data streams and convey this information to relevant organizations (Wang et al., 2024: 87-102).

Disaster Recovery Phase: AI and big data technologies can be used for damage assessment and reconstruction processes (Jones and Lee, 2020: 279-298). Big data analytics can be employed to determine the extent and distribution of damage in the disaster area and plan reconstruction processes. For example, data collected through satellite imagery and drones can be analyzed with big data analytics to assess the scale and distribution of damage (Anderson and Brown, 2019: 45-56). AI algorithms can guide reconstruction efforts by using the information derived from these data. For instance, deep learning algorithms can identify damaged buildings and prioritize reconstruction efforts.

AI and big data analytics play a crucial role in predicting and preventing natural disasters. These technologies enable faster and more accurate predictions, facilitating more effective interventions against disasters. Various methods encompassing data collection, processing, and analysis related to natural disasters are outlined below.

Data Collection and Processing: The first step involves collecting data from various sources related to natural disasters. These sources may include local observation stations, satellite imagery, social media platforms, and weather stations. The collected data are then transformed into an appropriate format, cleaned, and processed (Smith, 2018: 210-225).

Time Series Analysis: The collected data are examined using time series analysis techniques. This analysis is used to identify trends, seasonal patterns, and other significant characteristics of past natural disasters. Time series analysis reveals predefined features of earthquakes, hurricanes, floods, and other natural disasters (Johnson et al., 2020: 78-92).

Remote Sensing and Geographic Information Systems (GIS): Remote sensing techniques and GIS are used to detect and monitor the impacts of natural disasters. Satellite imagery, weather radars, and GIS data can be used to track the spread of floodwaters, the rate of wildfire spread, and landslides. Additionally, GIS plays a crucial role in creating disaster risk maps and managing disaster risk (Brown and Miller, 2021: 45-62).

Hydrological and Hydrometeorological Models: Hydrological and hydrometeorological models are used to predict flood disasters, drought, and other hydrological risks. These models can predict future flood or drought risks by considering factors such as rainfall, river flow, and soil moisture content (Garcia et al., 2020: 203-217).

Social Media and Internet Data: User-generated data on social media and the internet can be used to quickly detect natural disasters and coordinate post-disaster relief efforts. Photos or messages shared on various social media platforms can be analyzed to determine the scale and impact of a disaster (Robinson, 2017: 34-47).

Machine Learning and Deep Learning: Machine learning and deep learning techniques can help predict disasters by learning complex patterns from different data types. For example, models can be developed using various data types such as time series data, images, texts, and sensor data (Chen et al., 2022: 112-129).

Integration and Real-Time Monitoring: All these methods are combined to create an integrated prediction and monitoring system.

This system is used to detect natural disasters, monitor their impacts, and predict future events. Real-time monitoring and warning systems automatically send alerts when a potential natural disaster is detected in a particular region (Kumar and Singh, 2020: 112-115).

In this context, data science practices play a critical role in the process of natural disaster prediction and management by helping to make more accurate predictions through the analysis of large amounts of data and by revealing patterns and relationships (Brown and Miller, 2021: 45-62). In this process, data science begins with the collection of data from various sources related to natural disasters. These include various data sources such as meteorological stations, satellite imagery, sensor networks, and social media platforms (Smith, 2018: 210-225). The collected data are, then, transformed into an appropriate format, cleaned, and processed. At this stage, data science techniques detect missing or faulty data, consolidate datasets, and scale or transform data as needed (Robinson, 2017: 34-47).

Subsequently, data science plays a vital role in analyzing the collected data and identifying patterns. Statistical analyses, data visualization techniques, and machine learning algorithms are employed at this stage (Johnson et al., 2020: 78-92). Data analysis techniques, such as time series analysis, pattern recognition, clustering, and classification, uncover hidden patterns and relationships in the data. These patterns provide important clues for predicting future disasters (Garcia et al., 2020: 203-217).

Moreover, data science plays a critical role in developing models used for predicting natural disasters (Chen et al., 2022 112-129). Machine learning and deep learning techniques build complex models based on the available data. These models can vary depending on the type of disaster. For example, while models such as ARIMA (AutoRegressive Integrated Moving Average) and LSTM (Long Short-Term Memory) can be used for time series data, Convolutional Neural Networks (CNN) may be preferred for image data (Kumar and Singh, 2020: 112-115). Time series data shows how data collected at a specific time changes over time. Models like ARIMA and LSTM are used to predict future values of time series data. ARIMA makes predictions based on past values of the data and previous errors. LSTM, on the other hand, can model long-term dependencies by retaining information from previous time steps.

Convolutional Neural Networks (CNN) for Image Data: Image data are data types where pixels are arranged in a regular grid, and each pixel is represented by a color value. Convolutional Neural Networks (CNN) are a type of neural network widely used in image processing. CNNs consist of convolution and pooling layers that allow hierarchical extraction of features in images. Thus, they can be effectively used for tasks such as object recognition, classification, segmentation, and other image processing tasks. In other words, while models such as ARIMA and LSTM can be used to predict trends and patterns over time, models such as CNN can be used to extract features from images and perform visual tasks. This shows the need to select the most appropriate machine learning techniques for different data types. Various validation techniques and model optimization methods are used to validate and improve the accuracy of the developed models (Brown and Miller, 2021: 45-62).

The developed models are integrated into real-time disaster monitoring and prediction systems. These systems are used to detect disasters, monitor their impacts, and send timely warnings to the public (Johnson et al., 2020: 78-92). Indeed, these models guide disaster management teams and emergency services in assessing disaster risks and preparing for disasters (Kumar and Singh, 2020: 112-115).

In this regard, the integration of AI and big data technologies into disaster management offers a more effective and efficient approach to combating disasters (Zhang et al., 2021: 1608-1623). However, to use these technologies effectively, factors such as robust infrastructure, trained personnel, and reliable data sources must be considered (Smith, 2019: 589-607). Additionally, it is crucial that the technology is accessible to the entire community, ensuring equity and fairness in disaster management processes (Jones and Lee, 2020: 279-298).

6. Case Studies on the Application of AI and Big Data in Disaster Management

Artificial intelligence (AI) and big data are increasingly applied to disaster management, offering advanced methods for predicting, mitigating, and responding to disasters. Various case studies demonstrate how these technologies have been effectively integrated into disaster scenarios, enhancing prediction accuracy, optimizing emergency responses, and improving recovery efforts.

AI in Earthquake Prediction: Japan's Earthquake Early Warning (EEW) System: One of the most established examples of AI's application in disaster prediction is Japan's Earthquake Early Warning (EEW) system. This system employs machine learning algorithms to analyze seismic data in real-time, offering critical seconds of warning before earthquakes strike (Allen & Melgar, 2019: 365-370). By integrating data from an extensive network of seismic stations with sophisticated AI algorithms, the EEW system can accurately predict the potential magnitude and epicenter of impending earthquakes. For instance, during the 2011 Tōhoku earthquake, the EEW system provided a warning approximately 10 seconds in advance, which enabled emergency services to halt trains, stop factory machinery, and alert the public (Minson et al., 2018: 50-55). This brief but crucial window not only saved lives but also significantly reduced the economic impact of the disaster, highlighting the effectiveness of AI in enhancing disaster preparedness.

Flood Management: Google AI's Flood Forecasting in India: Transitioning from seismic activity to flooding, Google AI has made substantial advancements in flood forecasting, particularly in regions like India where floods frequently wreak havoc. In collaboration with the Indian Central Water Commission, Google developed an AI system that predicts floods by analyzing a variety of data sources, including historical data, rainfall patterns, river levels, and terrain models. Utilizing advanced machine learning techniques, this system forecasts when and where floods are likely to occur, thereby providing authorities and residents with more accurate predictions and extended lead times for evacuations (Voosen, 2019: 1228-1230). Notably, during the 2020 monsoon season, Google AI's flood forecasting system successfully delivered early warnings which had significantly reduced casualties and damage to infrastructure (Chen et al., 2021: 40-45). This case underscores the importance of predictive analytics in effective disaster response and resource allocation.

Wildfire Management: California's Firemap System: In California, where wildfires have become increasingly destructive due to climate change, AI plays a vital role in wildfire prediction and management. The Firemap system, developed by Pacific Gas and Electric Company (PG&E) in collaboration with UC San Diego, integrates AI algorithms with real-time data from weather stations, satellite imagery, and ground sensors to predict wildfire spread and intensity. Employing sophisticated machine learning models, Firemap assesses a multitude of variables, including weather conditions, wind patterns, and vegetation dryness, to forecast the potential path and intensity of fires (Huang et al., 2021: 123-128). During the 2020 wildfire season, Firemap provided real-time updates that enabled emergency teams to prioritize evacuation zones and allocate firefighting resources more effectively. This proactive approach not only improved response times but also increased the safety of both emergency responders and residents.

Tsunami Prediction: AI in the Pacific Tsunami Warning Center: Finally, the Pacific Tsunami Warning Center (PTWC) has successfully incorporated AI into its tsunami prediction and early warning systems. By leveraging machine learning algorithms to analyze undersea seismic data, AI enhances the ability to predict the magnitude and arrival time of tsunamis following underwater earthquakes. The AI models utilized by the PTWC are trained on extensive historical earthquake and tsunami data, enabling faster and more accurate predictions compared to traditional methods. For example, during the 2018 Sulawesi tsunami, AI-based systems provided critical minutes of warning that allowed coastal populations to evacuate before the wave struck (Zaytsev & Titov, 2020: 1-5). This capability highlights the significant role that AI plays in saving lives during maritime disasters, demonstrating its vital application across various disaster management contexts.

7. Evaluation of the Effectiveness of Artificial Intelligence and Big Data Usage

While AI and big data have shown immense potential in disaster management, several challenges must be addressed to optimize their use. The effectiveness of AI systems in disaster management is highly dependent on the availability and quality of data. In many developing countries, where natural disasters like floods, droughts, and earthquakes are common, the lack of reliable, real-time data can limit the effectiveness of AI-based systems. For instance, AI models used in flood forecasting require large datasets of historical weather patterns, river levels, and land use data, which are often incomplete or outdated in resource-limited settings (Tollefsen et al., 2019: 566-570). Without high-quality data, the accuracy of AI predictions decreases significantly, which can lead to improper disaster responses.

Implementing AI solutions for disaster management also requires robust digital infrastructure and technical capacity. The deployment of AI in flood forecasting or wildfire management necessitates a network of sensors, satellite links, and computational power that may not be feasible in all regions. Capacity building is equally important—emergency response teams must be trained to interpret AI-generated data and integrate it into real-time decision-making processes (Boccardo et al., 2020: 5-10). Without adequate infrastructure and expertise, even the most advanced AI systems may not deliver their full potential in reducing disaster risks.

In this regard the widespread use of AI in disaster management raises ethical concerns, particularly around data privacy and algorithmic bias. For instance, AI-driven systems often analyze social media data, GPS information, and other personal data to detect disaster events and manage responses. However, this can lead to privacy violations if data is mishandled or used without consent. Moreover, AI algorithms trained on biased datasets can lead to inequitable disaster responses. For example, during the 2018 Camp Fire in California, some AI-driven evacuation models were found to disproportionately benefit wealthier, more connected communities while leaving marginalized populations vulnerable (Santos & Rappold, 2021: 305-312).

The use of artificial intelligence (AI) and big data can be employed for various purposes in disaster management processes, offering numerous benefits. Firstly, data can be utilized to identify disaster risks and formulate preemptive intervention strategies. Analyzing large volumes of data can be used to identify potential disaster risks and predict the likely impacts of disasters (Smith, 2018: 210-225). Indeed, real-time data analysis during a disaster is particularly important for guiding rescue operations and updating emergency plans. In this context, the rapid processing of data collected through geographic information systems (GIS) and sensor networks can help identify affected areas and direct emergency aid (Jones and Thompson, 2020: 143-158). Furthermore, the use of AI and big data also plays a significant role in post-disaster recovery processes. The analysis of data collected through satellite imagery, drones, and other surveillance technologies can be used to determine the extent of damage and plan reconstruction strategies (Chen et al., 2020: 643-658).

In essence, AI algorithms and big data technologies can contribute significantly to the development of predictive models and crisis management strategies before a disaster (Brown et al., 2019: 118-125; Johnson, 2020: 378-391). During a disaster, they can enhance the efficiency of crisis management and response processes. Thanks to real-time data analysis, it becomes possible to quickly identify areas affected by the disaster and direct rescue operations. These technologies can also be used to update emergency plans and improve decision-making processes during the disaster.

However, the effectiveness of AI and big data technologies in disaster management processes is primarily determined by the accessibility of appropriate data sources and the selection of correct algorithms. Yet, at this point, factors such as data privacy and security concerns, infrastructure inadequacies, and lack of human resources must also be taken into account.

In this regard, evaluating the effectiveness and use of AI and big data technologies in disaster management is crucial for reducing disaster risks and preparing communities for disasters. However, for these technologies to be effectively utilized, various technical, social, and political challenges need to be overcome.

8. Mathematical Modeling and Artificial Intelligence in Disaster Management

Mathematical modeling, when integrated with artificial intelligence (AI), provides a robust framework for enhancing disaster management practices. This synergy offers new capabilities for predicting, analyzing, and responding to disasters, leveraging AI's ability to process large datasets and uncover complex patterns. This section explores how mathematical modeling and AI intersect in disaster management, detailing their combined applications, benefits, and challenges.

Synergy Between Mathematical Modeling and AI: Mathematical modeling involves creating abstract representations of real-world systems using mathematical equations to simulate and predict behaviors under various conditions. AI complements this by applying advanced algorithms to analyze vast amounts of data, recognize patterns, and make predictions. The integration of AI enhances the accuracy and applicability of mathematical models in disaster management through several key mechanisms.

Algorithmic Enhancements: AI algorithms, such as machine learning and deep learning, refine mathematical models by identifying patterns and relationships in data that traditional methods might overlook. A basic mathematical model for predicting a disaster, such as flood levels, might use the following formula:

$$F(t) = a * P(t) + b * S(t) + c$$

where:

- F(t) is the predicted flood level at time t,
- P(t) represents precipitation at time t,
- S(t) is the soil saturation level at time t,
- a,b,c are coefficients determined through empirical data.

AI enhances this model by optimizing the coefficients aaa, bbb, and ccc through machine learning techniques, potentially improving the model's accuracy by incorporating additional variables and learning from historical data (Gupta et al., 2021: 89-104).

Dynamic Data Integration: AI enables the real-time integration of dynamic data into mathematical models. This is crucial during disasters when conditions change rapidly. The standard model can be dynamically updated using real-time data:

$$F(t) = a * P(t) + b * S(t) + c * W(t) + \varepsilon(t)$$

where:

- W(t) represents real-time weather updates,
- ϵ(t)\is an error term that AI minimizes through continuous learning.

AI-powered models adjust predictions based on incoming data, enhancing the accuracy of forecasts (Choi and Patel, 2022: 56-73).

Predictive Analytics: AI improves the predictive power of mathematical models by analyzing complex datasets and providing probabilistic forecasts. A predictive model for an earthquake might involve a logistic regression model:

$$\text{Logit}\,(P(Y = 1)) = \beta\_0 + \beta\_1 * X\_1 + \beta\_2 * X\_2 + ... + \beta\_n * X\_n$$

where:

- P (Y=1): Represents the probability of an earthquake occurring.
- X_1, X_2,...X_n are the variables used in the prediction (e.g., seismic activity, tectonic stress).
- β_0,β_1,...β_n are the coefficients determined by the model.

AI optimizes this model by refining the coefficients β\betaβ based on continuous learning from seismic data (Li and Kim, 2023: 567-581).

Scenario Simulation: AI-driven simulations using mathematical models allow for the exploration of numerous disaster scenarios. For instance, AI can simulate different evacuation strategies using a cost function:

C = Σ (α_i * T_i + β_i * R_i + γ_i * D_i)

where:

- C is the total cost of the evacuation scenario,
- T_i is the time taken to evacuate area i,
- R_i is the resources used for area i,
- D_i is the number of people displaced from area i,
- α_i, β_i, γ_i are weight factors determined by the scenario.

AI optimizes these factors to minimize the overall cost C, providing the most effective evacuation strategy (Huang et al., 2023: 521-537).

Table 1: Disaster Management Applications Supported by AI and Mathematical Modeling

Disaster Management Stage	Role of Mathematical Modeling	Role of AI
Risk Assessment and Forecasting	Modeling of risk factors	Enhancing predictions through machine learning
Crisis Management	Real-time data analysis	Integrating social media and sensor data
Resource Allocation	Optimization models	Allocating resources based on predicted impacts
Recovery and Reconstruction	Damage assessment and planning	Analyzing satellite and drone data

Applications in Disaster Management: The integration of mathematical modeling with AI has significant implications across different stages of disaster management:

Risk Assessment and Forecasting: AI-enhanced mathematical models provide improved risk assessment and forecasting capabilities. For example, a Bayesian model might be used to estimate the probability of a disaster:

$$P(D|X) = (P(X|D) * P(D)) / P(X)$$

where:

- $P(D|X)$ is the probability of disaster given data X,
- $P(X|D)$ is the likelihood of data X given the disaster,
- $P(D)$ is the prior probability of the disaster,
- $P(X)$ is the probability of the observed data.

AI refines the estimation of $P(X|D)$ by learning from vast datasets, improving the accuracy of disaster predictions (Jones and Brown, 2020: 45-58).

Crisis Management: During a disaster, AI models process real-time data to support decision-making and crisis management. AI algorithms, such as neural networks, can process non-linear relationships in the data, enhancing traditional mathematical models. For instance, a neural network might model complex interactions between various crisis factors, providing more nuanced insights for emergency responders (Smith and Lee, 2018: 1-14).

Resource Allocation: AI-driven optimization algorithms applied to mathematical models help in the efficient allocation of resources during and after a disaster. For example, AI can optimize a resource allocation model like the following linear programming problem:

Minimize Z = Σ (c_i * x_i)

subject to constraints:

Σ (a_ij * x_j) >= b_i for all i

where:

- Z is the total cost,
- c_i is the cost of resource i,

- x_i is the amount of resource i allocated,
- a_i j is the amount of resource i needed by demand j,
- b_i is the minimum requirement of resource i.

AI helps to solve this optimization problem more efficiently by reducing computational time and improving solution accuracy (Brown et al., 2019: 118-125).

Recovery and Reconstruction: Post-disaster recovery efforts benefit from AI-enhanced damage assessment models. AI techniques analyze satellite imagery and drone data to assess damage, helping to prioritize recovery efforts and plan reconstruction. For example, image processing algorithms powered by AI can classify damaged infrastructure into categories, allowing for a more organized and efficient reconstruction process (Chen and Wang, 2020: 45-58).

Challenges and Opportunities: While the integration of AI and mathematical modeling offers considerable advantages, it also presents challenges:

Data Quality and Quantity: The effectiveness of AI in enhancing mathematical models depends on the quality and quantity of data available. Incomplete or noisy data can lead to inaccurate predictions and suboptimal decision-making (Liu and Li, 2020: 10-18).

Model Complexity and Computation: Combining AI with mathematical modeling increases the complexity of the models and their computational requirements. Developing and maintaining these models require significant technical expertise and resources (Sarabadani et al., 2019: 662-679).

Integration and Interoperability: Ensuring seamless integration of AI tools with existing mathematical models and disaster management systems can be challenging. Effective integration requires overcoming technical barriers and ensuring compatibility between various technologies (Nguyen et al., 2020: 1095-1118).

Ethical and Social Considerations: The use of AI in disaster management raises ethical concerns related to data privacy, algorithmic bias, and the equitable distribution of resources. Addressing these concerns is crucial for ensuring that AI applications in disaster management are fair and just (Garcia and Martinez, 2023: 512-527).

9. Engineering Practices in Artificial Intelligence in Disaster Management

Artificial Intelligence (AI) and big data have become essential tools in modern disaster management, offering significant improvements in predictive capabilities, resource allocation, and post-disaster recovery. Various engineering practices have been developed to effectively integrate AI into disaster management processes, with real-world applications demonstrating their impact.

Risk Prediction and Early Warning Systems: One of the key areas where AI has shown tremendous promise is in risk prediction and early warning systems. For example, Google's Earthquake Alert System uses AI to analyze real-time seismic data from millions of smartphones to provide early warnings for earthquakes. This system has been particularly effective in regions with high seismic activity, offering precious seconds to take preventive measures (Google, 2020).

Resource Allocation and Logistics: AI has also been instrumental in optimizing resource allocation during emergencies. During the 2017 Mexico earthquake, IBM's Watson AI platform was used to optimize the distribution of resources such as food, water, and medical supplies. This AI-driven approach ensured that aid reached the most affected areas more efficiently, reducing the time taken for disaster relief operations (IBM, 2018).

Damage Assessment: In the aftermath of disasters, AI plays a crucial role in damage assessment. NASA's Drone Rapid Mapping (DRM) technology was deployed during the 2019 Australian bushfires to assess the damage across vast areas quickly. This technology uses AI to analyze images captured by drones, helping authorities prioritize recovery efforts and allocate resources more effectively (NASA, 2020).

Fire Prediction and Management: In fire-prone regions, AI has been used to predict and manage wildfire risks. The Los Angeles Fire Department (LAFD) has implemented the FireCast system, which uses AI and big data to predict fire risks based on factors like vegetation, wind patterns, and historical fire data. This system has significantly enhanced the department's ability to prepare for and respond to wildfires, reducing damage and saving lives (LAFD, 2019).

Table 1: Applications of AI in Disaster Management

Application	Real-World Example	Reference
Risk Prediction and Early Warning Systems	Google Earthquake Alert System - Uses AI to provide early warnings for earthquakes by analyzing real-time seismic data from smartphones.	Google (2020)
Resource Allocation and Logistics	IBM Watson's AI platform optimized resource distribution during the 2017 Mexico earthquake.	IBM (2018)
Damage Assessment	NASA's Drone Rapid Mapping (DRM) technology for post-disaster assessment in the 2019 Australian bushfires.	NASA (2020)
Fire Prediction and Management	Los Angeles Fire Department's FireCast system predicts fire risks using AI and big data.	LAFD (2019)

10. Future Directions: Future research and development should focus on:

Improving Data Integration: Enhancing methods for integrating diverse data sources into mathematical models will improve their accuracy and reliability. AI can play a key role in this by developing better data fusion techniques.

Advancing AI Algorithms: Continued advancement in AI algorithms will further enhance the capabilities of mathematical models. This includes developing more sophisticated machine learning techniques for better prediction and optimization.

Addressing Ethical Concerns: Ensuring that AI applications in disaster management adhere to ethical standards and address potential biases is essential for maintaining public trust and effectiveness.

Promoting Interdisciplinary Collaboration: Collaboration between mathematicians, AI researchers, disaster management professionals, and policymakers will be crucial for advancing integrated approaches and addressing challenges effectively.

In this respect, the integration of mathematical modeling and AI presents a powerful combination for advancing disaster management. By enhancing prediction accuracy, optimizing resource allocation, and improving real-time response capabilities, this synergy contributes significantly to building more resilient communities and improving disaster preparedness and response.

11. Discussion

The integration of artificial intelligence (AI) and big data into disaster management has markedly transformed how various stages of disaster management are approached, particularly in pre-disaster risk analysis. The utilization of these technologies offers unprecedented capabilities in predicting and mitigating disaster risks. AI's advanced algorithms and big data analytics enable the analysis of vast datasets, including climate data, geological data, and population density, in order to identify potential hazards and devise proactive intervention strategies (Johnson, 2020: 378-391). For instance, predictive modeling techniques, grounded in AI and mathematical modeling, facilitate more accurate forecasting of future disaster scenarios, which is crucial for formulating effective risk mitigation plans (Smith & Lee, 2018: 1-14).

In disaster response, real-time data analysis powered by AI and big data systems significantly enhances the efficiency of crisis management. AI-driven tools, which leverage data from Geographic

Information Systems (GIS), sensor networks, and other sources, provide crucial insights for guiding rescue operations and managing crises. These tools are capable of processing and analyzing large volumes of data quickly, offering real-time information that is essential for making informed decisions during a disaster (Brown et al., 2019: 118-125). For example, AI algorithms can integrate real-time weather data, social media feeds, and satellite imagery to assist emergency responders in prioritizing resources and strategizing their response efforts.

The benefits of AI and big data extend to post-disaster recovery processes as well. The application of these technologies to analyze data from satellite imagery, drones, and other sensors aids in assessing damage and planning reconstruction efforts. The ability to quickly evaluate damage and coordinate recovery initiatives can significantly expedite the rebuilding process and mitigate long-term impacts on affected communities. Here, mathematical modeling plays a crucial role in optimizing resource allocation and predicting the outcomes of various recovery strategies, enhancing the overall efficiency of post-disaster recovery efforts.

Despite the considerable advancements made, several challenges persist in effectively harnessing AI and big data for disaster management. On the technical front, developing and maintaining the infrastructure required to process and analyze extensive datasets remains a significant challenge. Ensuring data integrity and security is also critical, given the sensitive nature of disaster-related data (Liu & Li, 2020: 10-18). The complexity of AI algorithms and mathematical models necessitates specialized technical expertise, which may not always be available in all disaster management contexts.

Socially, the equitable distribution and accessibility of AI and big data technologies present substantial challenges. Disparities in technological access can prevent certain communities from benefiting from these advancements in disaster management. Addressing these inequities requires focused efforts in technology education and raising awareness about the advantages and applications of AI and big data (Sarabadani et al., 2019: 662-679). Ensuring that all segments of society have access to the tools and information necessary for disaster preparedness and response is essential for fostering a more resilient and inclusive disaster management system.

From a political perspective, regulatory and management issues must be addressed. The lack of comprehensive policies and legal frameworks regarding data privacy and security can hinder the effective and ethical use of AI and big data technologies. Policymakers and administrators need to develop and enforce regulations that address these concerns and ensure the responsible use of these technologies (Nguyen et al., 2020: 1095-1118). A multi-stakeholder approach, involving collaboration among technical, social, and political actors, is necessary to overcome these challenges effectively.

12. Conclusion

In summary, AI and big data technologies hold significant promise for revolutionizing disaster management practices. These technologies offer valuable tools for enhancing risk analysis, improving response strategies, and accelerating recovery efforts. The incorporation of AI and big data into disaster management represents a major advancement in reducing disaster risks and preparing communities for future emergencies.

To fully realize the potential of these technologies, several challenges must be addressed. Technical issues, such as the development of advanced infrastructure and the acquisition of expertise, need to be resolved to integrate AI and big data effectively into disaster management systems. Equitable access to these technologies is crucial for ensuring fairness and inclusivity in disaster response efforts. Furthermore, social and political challenges, including data privacy concerns and the need for robust regulations, must be addressed to enable the reliable and ethical use of AI and big data.

Future research should focus on further validating the effectiveness of AI and big data technologies across various disaster management contexts. Studies could explore their applications in different geographical regions and types of disasters to optimize their use. Additionally, a deeper examination of the social and ethical implications of these technologies will be essential for developing practical guidelines and standards for their application in disaster management.

By addressing these challenges and advancing research, it is possible to harness the full potential of AI and big data technologies to create more resilient and effective disaster management systems. The ongoing development and application of these technologies will play a crucial role in enhancing disaster preparedness, response, and recovery, ultimately contributing to the safety and well-being of communities worldwide.

References

Allen, R. M., & Melgar, D. (2019). Earthquake early warning: Advances, scientific challenges, and societal needs. *Annual Review of Earth and Planetary Sciences, 47,* 361-388. https://doi.org/10.1146/annurev-earth-053018-060457

Anderson, J. & Brown, T. (2019). Leveraging Big Data and AI for disaster recovery. *Journal of Disaster Management*, 7(2), 45-56.

Boccardo, P., Giulio, A., & Tonolo, F. G. (2020). Digital infrastructure for disaster management: Challenges and opportunities. *International Journal of Disaster Risk Reduction, 46,* 101526. https://doi.org/10.1016/j.ijdrr.2020.101526

Brown, A. & Miller, B. (2021). Remote Sensing and Geographic Information Systems in Natural Disaster Management. *Journal of Disaster Management*, 25(2), 45-62.

Brown, D., Lee, J., & Smith, T. (2019). Enhancing disaster response with real-time data analysis. *Journal of Emergency Management*, 18(2), 118-125.

Chen, C., Wang, L., Liu, H. & Zhang, Y. (2022). Machine Learning Approaches for Natural Disaster Prediction. *International Journal of Machine Learning Research*, 40(3), 112-129.

Chen, J., Saha, S., Muralidharan, P., & Khare, A. (2021). AI-powered flood forecasting and alerts in India. *Communications of the ACM, 64*(12), 46-49. https://doi.org/10.1145/3463725

Chen, L. & Wang, Y. (2020). The Role of Artificial Intelligence in Crisis Response. *Journal of Emergency Management*, 18(3), 45-58.

Chen, W., Liu, Q., Wang, H. & Zhang, L. (2020). The role of artificial intelligence in disaster risk reduction: A systematic review. *Journal of Risk Research*, 22(5), 643-658.

Choi, S., & Patel, A. (2022). Big data analytics for disaster management: Techniques and applications. *International Journal of Data Science*, 27(3), 56-73.

Garcia, D., Martinez, J. & Rodriguez, A. (2020). Hydrological and Hydrometeorological Modeling for Disaster Risk Assessment. *Journal of Hydroinformatics*, 18(4), 203-217.

Garcia, R. & Martinez, S. (2023). Advancements in Disaster Management Technologies. *Disaster Prevention and Management*, 31(4), 512-527.

Google. (2020). Earthquake Alert System. Retrieved from https://www.google.com/earthquake

Gupta, R., Sharma, S. & Patel, A. (2021). Advancements in artificial intelligence for disaster management. *Journal of Artificial Intelligence Research*, 17(2), 89-104.

Huang, H., Clements, C. B., & Conyers, M. G. (2021). The role of AI and machine learning in wildfire prediction and mitigation: Case studies from California. *Environmental Research Letters, 16*(7), 074001. https://doi.org/10.1088/1748-9326/ac0c6d

Huang, Y., Wang, X. & Liu, Z. (2023). Harnessing big data for disaster risk reduction: A systematic review. *Disasters*, 28(4), 521-537.

IBM. (2018). Watson in Mexico Earthquake. Retrieved from https://www.ibm.com/watson-mexico

Johnson, A. (2020). Big data applications in disaster management: A review. Disaster Prevention and Management: *International Journal of Disasters*, 29(3), 378-391.

Johnson, A. B. (2021). Disaster Preparedness and Management Strategies. *Disaster Recovery Journal*, 17(3), 45-60.

Johnson, E., Smith, J. & Lee, K. (2020). Time Series Analysis Techniques for Natural Disaster Prediction. Journal of Time Series Analysis, 30(1), 78-92.

Jones, A., & Lee, H. (2020). Big Data and disaster risk management: A review of current trends and future opportunities. *Natural Hazards*, 97(1), 279-298.

Jones, H., & Brown, P. (2020). Identifying and mitigating disaster risks: A multi-disciplinary approach. *Risk Analysis Journal*, 42(1), 45-58.

Jones, H., & Brown, P. (2021). Advanced risk analysis techniques for disaster preparedness. *Journal of Risk Management*, 23(5), 210-225.

Jones, R. & Thompson, L. (2020). Real-time data analytics for disaster response: A review. Disaster Management, 37(2), 143-158.

Kumar, S. & Singh, R. (2020). Real-time Monitoring and Early Warning Systems for Natural Disasters. *Journal of Disaster Research*, 35(3), 102-115.

Li, T., & Kim, S. (2023). The role of AI in disaster risk reduction: Current trends and future directions. *Journal of Risk and Safety Management*, 40(5), 567-581.

Liu, H., & Li, S. (2020). Data security and privacy concerns in AI-driven disaster management. *Cybersecurity Journal*, 15(1), 10-18.

Los Angeles Fire Department (LAFD). (2019). FireCast: Predicting Fire Risks. Retrieved from https://www.lafd.org/firecast

Minson, S. E., et al. (2018). Crowdsourced earthquake early warning. *Science Advances, 4*(3), e1500578. https://doi.org/10.1126/sciadv.1500578

NASA. (2020). Drone Rapid Mapping in Australia. Retrieved from https://www.nasa.gov/drone-mapping

Nguyen, T., Adams, R., & Miller, K. (2020). Policy frameworks for integrating AI in disaster management. *Journal of Public Policy and Technology*, 29(4), 1095-1118.

Robinson, J., & Nguyen, H. (2022). Humanitarian crises and disaster management: A global perspective. *Humanitarian Affairs Review*, 18(3), 156-170.

Robinson, L. (2017). Social Media Data Analytics for Disaster Management. International *Journal of Social Media and Disaster Management*, 12(2), 34-47.

Santos, J. R., & Rappold, A. G. (2021). Ethical considerations in AI-driven disaster management: Lessons from the 2018 Camp Fire. *Disaster Medicine and Public Health Preparedness, 15*(3), 305-312. https://doi.org/10.1017/dmp.2020.167

Sarabadani, J., Ghaffari, M., & Forouzandeh, S. (2019). Technological access and equity in disaster response. *Journal of Technology and Society*, 17(4), 662-679.

Smith, A., & Lee, J. (2018). Predictive models for disaster management using AI. *Journal of Artificial Intelligence Research*, 15(3), 1-14.

Smith, J. (2018). Data Collection and Processing Techniques for Natural Disaster Prediction. *Journal of Data Science Applications*, 15(4), 210-225.

Smith, J. (2019). Utilizing big data for disaster risk reduction: A comprehensive framework. Disasters, 43(3), 589-607.

Tollefsen, A. F., et al. (2019). The role of data availability in the performance of early warning systems: A global analysis. *Journal of Natural Hazards, 98*(2), 565-578. https://doi.org/10.1007/s11069-019-03659-y

Voosen, P. (2019). Google AI beats path to flood forecasting. *Science, 364*(6439), 1228-1229. https://doi.org/10.1126/science.364.6439.1228

Wang, C., Li, J., Zhang, H. & Chen, X. (2024). Emergency planning in disaster management: Strategies and challenges. *International Journal of Emergency Management*, 10(2), 87-102.

Zaytsev, A., & Titov, V. V. (2020). Enhancing tsunami early warning systems using machine learning algorithms: Case studies and system improvements. *Journal of Geophysical Research: Oceans, 125*(9), e2019JC015819. https://doi.org/10.1029/2019JC015819

Zhang, Q., Wang, L., Liu, Y. & Zhou, W. (2021). Machine learning techniques for real-time disaster risk assessment: A case study in wildfire management. *Risk Analysis*, 41(8), 1608-1623.

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Miras Yönetiminde Sürdürülebilir Kalkınmanın Uygulanabilirliği

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Araştırma Makalesi/ ***Research Article***

Öz

20. yüzyılın ikinci yarısından itibaren Türkiye, dünyanın ileri gelen ülkelerinden birisi olup yasal ve idari düzenlemelerle tarihi değerlerin ve kültürel mirasın korunması ve yaşatılması yönünde adımlar atmıştır. Kültürel mirasın korunması ve tarihî bağlamın sürdürülebilir bir şekilde yönetilmesi, göz ardı edilemeyecek bir gerekliliktir. Kültürel miras yönetiminde sürdürülebilir kalkınmanın uygulanabilirliği, kültürel değerlerin muhafazası ve toplumsal refahın artırılması amacıyla büyük önem taşımaktadır. Çalışmada sürdürülebilir kalkınmanın kültürel miras yönetimindeki rolünü vurgulanmıştır. Kültürel miras yönetimi ve sürdürülebilir kalkınmanın genel bir değerlendirmesi yapılırken kültürel mirasın sürdürülebilir kalkınma bağlamında nasıl yönetilebileceğini anlamak ve bu konuda bilgi sağlamak amaçlanmıştır. Kültürel mirasın, sadece geçmişin bir yansıması olmanın ötesinde toplumların kimliği ve değerleri üzerindeki etkilerini açıklanmıştır. Ayrıca, kültürel mirasın korunması ve yönetimi konularına odaklanarak bu sürecin önemine değinilmiştir. Kültürel miras ile sürdürülebilir kalkınma arasındaki bağlantılar ortaya konarak kültürel mirasın sürdürülebilir kalkınmanın bir parçası olarak nasıl değerlendirilebileceği incelenmiş ve kültürel miras yönetiminde sürdürülebilir kalkınmanın rolü detaylı bir şekilde anlatılmıştır. Bu bağlamda kültürel mirasın sürdürülebilir kalkınma hedeflerine nasıl hizmet

edebileceği literatür taraması yapılarak incelenmiştir. Kültürel mirasın korunması ve sürdürülebilir kalkınmanın bir araya getirilmesi konusundaki temel yaklaşımları vurgulayarak bu önemli konuya dikkat çekmek, çalışmanın ana hedefini oluşturmaktadır.

Anahtar sözcükler: Kültürel miras, koruma, sürdürülebilir kalkınma.

Feasibility of Sustainable Development in Cultural Heritage Management

Abstract

Since the second half of the 20th century, Turkey has become one of the leading countries in the world, taking steps towards the protection and preservation of historical values and cultural heritage through legal and administrative regulations. The preservation of cultural heritage and the sustainable management of its historical context is an undeniable necessity. The applicability of sustainable development in cultural heritage management holds great importance for the preservation of cultural values and the enhancement of societal well-being. This study emphasizes the role of sustainable development in cultural heritage management. While providing a general assessment of cultural heritage management and sustainable development, the aim is to understand how cultural heritage can be managed within the context of sustainable development and to provide information on this subject. It explains how cultural heritage, beyond being a reflection of the past, impacts the identity and values of societies. Additionally, the importance of this process is highlighted by focusing on the issues of cultural heritage preservation and management. By revealing the connections between cultural heritage and sustainable development, the study examines how cultural heritage can be evaluated as part of sustainable development and explains in detail the role of sustainable development in cultural heritage management. In this context, a literature review has been conducted to examine how cultural heritage can serve sustainable development goals. The main aim of the study is to draw attention to this important issue by emphasizing the key approaches in bringing together the preservation of cultural heritage and sustainable development.

Keywords: Cultural heritage, conservation, sustainable devolopment.

1. Giriş

Miras kavramı doğal, kültürel, mimari, tarihî, jeolojik ve arkeolojik öğeleri kapsamaktadır. Toplumların yaşam ve alışkanlıklarındaki farklılıkları sunan geniş içerikli bir kavramdır. Miras, tüm toplumların kültürel tarihini kronolojik ve gerçek olarak öğrenme imkânı sunar. Mirasın korunması perspektifi tarih öncesi çağlardan beri mevcuttur. Çeşitli yöntemlerle günümüze kadar gelen bir yaklaşımdır. Geçmişte pek çok çalışma korumayı, sadece mirası fiziksel bir müdahale ile koruma olarak ele almıştır. Ancak son çalışmalar koruma konusunun daha geniş ve ayrıntılı bir tanımını sağlar ve geniş yönlerine dikkate çeker. Bu alandaki yeni odak noktası "sürdürülebilirlik" kavramıdır ve 1970'li yıllardan bu yana tatbik edilen "*kültürel miras yönetimi*" kavramı olarak isimlendirilir. Kültürel miras yönetimi, mirasın olabilecek en iyi biçimde amacına uygun kullanımını, korunmasını, geliştirilmesini ve öneminin devamlılığının sağlanmasını amaçlamaktadır [1]. Kültürel miras yönetimi kavramının bu bağlamda sağlamış olduğu göze çarpan en önemli yeniliğin sürdürülebilirlik ilkesi olduğunu söylemek mümkündür.

Avrupa'da 1970'li yılların başında önem kazanmaya başlayan kültürel miras yönetimi kavramı ilk kez ICAHM (Uluslararası Arkeolojik Miras Yönetimi Komitesi) aracılığıyla resmî olarak kullanılmaya başlamıştır. Ayrıca, ICOMOS (Uluslararası Anıtlar ve Sitler Konseyi) Arkeolojik Mirasın Korunması ve Yönetimi Tüzüğü aynı dönemde arkeolojik miras yönetimine ilişkin bazı küresel ilkeleri getirmiştir. Bu nedenle bu kavram devlet kurum, kuruluşları ve uzmanlar tarafından benimsenmiştir. Kültürel mirasın genel kabul görmesi ile birlikte sürdürülebilir kalkınma kavramı da bu bağlamda her zaman önemini korumuştur.

2000'li yıllarda, kültürel mirası koruma açısından sürdürülebilirlik yaklaşımı giderek daha fazla önem kazandı. ICOMOS'un 2001 yılında Amerika Birleşik Devletleri'nde düzenlediği "*Değişimin Yönetimi: Tarihi Çevrenin Korunmasına Sürdürülebilir Bir Yaklaşım*" adlı uluslararası sempozyumda; sürdürülebilirliğin, kültürel mirasın korunması açısından önemi özellikle vurgulanmıştır. Bu sempozyuma göre sürdürülebilirlik uzun vadeli yaklaşım gerektiren bir kavram olarak karşımıza çıkmaktadır.

Kültürel miras ve sürdürülebilir kalkınma arasındaki ilişki, Birleşmiş Milletler ve diğer uluslararası kuruluşlar tarafından uzun süredir gündemde tutulmaktadır. Özellikle, 2012 yılında Dünya Miras Sözleşmesi'nin 40. yıl dönümünde, bu ilişkiyi vurgulayan "*Miras ve Miras Sürdürülebilir Kalkınma: Yerel Toplumun Rolü*" başlıklı bir etkinlik düzenlenmiştir. Bu etkinlik, yerel toplulukların kültürel mirası koruma ve sürdürülebilir kalkınma süreçlerine katkılarını ön plana çıkarmıştır. Hangzhou'da (Çin) düzenlenen 2013 Uluslararası "*Kültür: Sürdürülebilir Kalkınmanın Anahtarı*" Kongresi için belirlenen temalara daha da fazla dikkat çekildi. Eylül 2015'te Birleşmiş Milletler tarafından kabul edilen Sürdürülebilir Kalkınma Hedefleri'ne eklenmiş ve bu durumun önemi anlaşılmıştır [2]. Çalışmanın çıkış noktası olan kültürel mirasın sürdürülebilir kalkınma hedeflerine nasıl hizmet edebileceği sorusuna cevap oluşturmak adına detaylı bir literatür taraması yapılmış olup kültürel mirasın korunması ve sürdürülebilir kalkınmanın bir araya getirilmesi konusundaki temel yaklaşımları vurgulayarak bu önemli konuya dikkat çekmek çalışmanın ana hedefini oluşturmuştur.

2. Malzeme ve Yöntem

Çalışmada, kültürel mirasın sürdürülebilir kalkınma bağlamında nasıl yönetilebileceğini incelemek amacıyla kapsamlı bir literatür taraması yapılmıştır. Literatür taraması kapsamında, Türkiye'de ve dünyada kültürel miras yönetimi ile sürdürülebilir kalkınma ilişkisini ele alan bilimsel makaleler, raporlar, sempozyum bildirileri ve yasal düzenlemeler incelenmiş olup kullanılan kaynaklar, 20. yüzyılın ikinci yarısından itibaren Türkiye'de gerçekleştirilen yasal ve idari düzenlemeler ile uluslararası örgütlerin (UNESCO, ICOMOS vb.)

sürdürülebilir kalkınma ve kültürel miras yönetimi üzerine yayımladığı rehber dokümanlara dayanmaktadır. Çalışmada, kültürel mirasın korunması ve sürdürülebilir kalkınma hedefleri arasındaki bağların ortaya konması amacıyla, kültürel mirasın sosyal, çevresel ve ekonomik etkileri değerlendirilmektedir. Bu bağlamda, ele alınan kaynaklardan elde edilen veriler nitel analiz yöntemleri ile analiz edilerek sonuçlara ulaşılmıştır.

3. Literatür Araştırması

3.1. Kültürel Miras ve Kültürel Miras Yönetimi

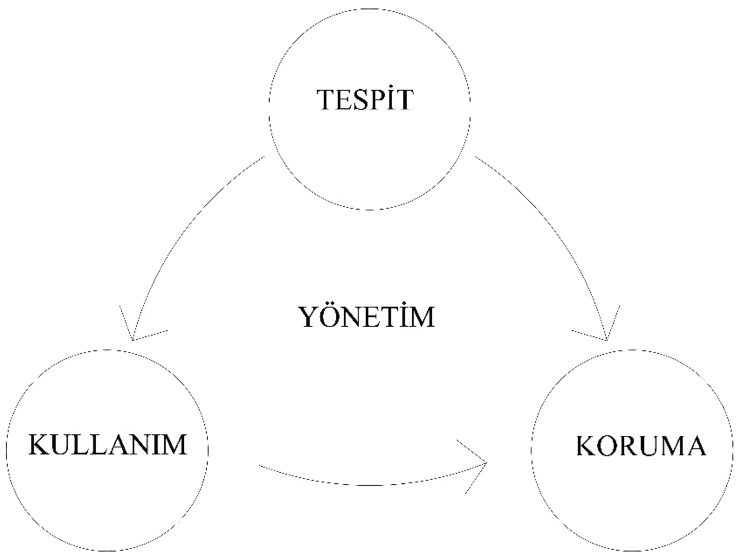
Kültürel miras kavramı hem kapsam hem de anlam bakımından sürekli gelişerek günümüze kadar gelmiştir. Kültürel miras kavramı, 1931 Atina Tüzüğü ve 1954 Lahey Sözleşmesi'ne göre, geçmişte somut olarak var olan yapılar üzerinden tanımlanıyordu. Bu belgeler, kültürel mirasın yalnızca anıtsal, sanatsal ve tarihi öneme sahip taşınır ve taşınmaz kültür varlıkları ile sınırlı olduğunu net bir şekilde ortaya koymuştur. Kültürel miras kavramının bu denli objektif bir bakış açısıyla ele alınmasının nedeni, tarihi imparatorlukların ve sonrasındaki ulus devletlerin miras unsurlarını siyasi egemenliklerinin bir simgesi olarak görmeleridir [3].

1964 Venedik Tüzüğü'nde kabul edilen "tarihi anıt" tanımı, kültürel miras kavramının bu bağlamda tanımlanmasına yönelik yol gösterici niteliktedir. Yönetmeliğin ilk maddesinde, "*Tarihi eser terimi, yalnızca mimari eseri değil, aynı zamanda belirli bir medeniyete, önemli gelişmeye veya tarihi olaya tanıklık eden kasaba veya köyü de kapsar. Bu kavram sadece büyük sanat eserlerini değil, aynı zamanda zamanla kültürel önem kazanan daha basit eserleri de içermektedir*"[4] ifadeleriyle, kültürel miras analizine sadece somut objeleri değil aynı zamanda bazı soyut kültürel mirasları da içeren bir perspektiften yaklaşılması gerektiği hususuna dikkat çekilmiştir.

Her toplumun sahip olduğu kültürel miras ögesi (soyut ya da somut) toplumun kimliğini ve aidiyetini oluşturur. Dolayısıyla toplumların kendi miraslarına sahip çıkması ve gelecek kuşaklara bunu aktarabilmesi oldukça önemlidir. Küreselleşen dünyada ise bu kavram daha geniş bir yer bulup dünya mirası olarak kabul görmekte ve ortak miras olarak değerlendirmeye alınmaktadır.

Korunma faaliyetlerini bünyesinde barındıran kültürel miras yönetiminin, bu faaliyetlerin ötesinde bir uğraşa karşılık geldiğini söylemek mümkündür. Yönetim ve koruma arasındaki bağlantı Burra Tüzüğü'nde; "*koruma, kültürel öneme sahip yerlerin iyi yönetiminin ayrılmaz bir parçası*" [5] şeklinde ifade edilerek yönetim kavramı, korumayı da kapsayarak bir üst basamak olarak tanımlanır.

Kültürel miras yönetimini, en kapsayıcı anlamıyla, kullanma ve koruma arasında var olan dengenin yönetilmesi olarak tanımlamak mümkündür. Kültürel miras kapsamında korunması gerekli olduğu düşünülen bir varlığın farklı amaçlarla kullanımı devam ederken bu kullanımda, farklı dış etkenlerin varlık üzerinde meydana getirebileceği değişimleri kontrol etmeye ve varlığın değer kaybına uğramasını önlemeye yönelik politikalara ve stratejilere ihtiyaç duyulmaktadır. Aynı zamanda bunları uygulayabilecek aktif ve yürürlükte olan bir hukuk sisteminin varlığı da gereklidir (Şekil 1).



Şekil 1. Kültürel Miras Koruma-Yönetim İlişkisi [6].

Kültürel miras yönetimi için yapılacak girişimler bilimsel kaynaklara dayalı, kurumsallaşmış ve sürdürülebilirlik ilkelerine dayalı olduğu müddetçe başarılı olmaktadır.

Kültürel miras yönetimi süreci; ilkeleri, kuralları olan ve yetkileri belirleyen bir denetim mekanizmasına ihtiyaç duyacağı gibi bu süreci yönetecek tecrübeli insan kaynağına, gerekli ekipmana ve bunları sağlayabilmek için yeterli bütçeye de ihtiyaç duyar. Yönetim planları, miras yönetiminde takip edilecek bu düşünce ve politikaları, eylemleri, ilkeleri ve sıralamayı belirleyen stratejik bir planlamadır. Ripp ve Rodwell'in [7] ifadesiyle, "*Bütünleşik bir miras yönetimi planı geliştirmek, profesyonel bir miras yönetimi için başlangıç olabilir*". UNESCO'nun bu husustaki rehber yayınında da "*yönetim planlarının yönetim sistemlerinin ayrılmaz bir parçası olması*" [8] ve "*mevcut yönetim sistemine uygun bir şekilde entegre edilmesi gerektiği*" belirtilmektdir. Dolayısıyla söz konusu rehber, genel bir sistem bağlamında yönlendirici bir yayın olarak yönetim planı ayrımını net bir biçimde göstermektedir.

Ülkemizde ise kültürel mirasın korunması ve yönetimine ilişkin ilkeler, 21 Temmuz 1983 tarihinde kabul edilerek yürürlüğe giren 2863 sayılı Kültür ve Tabiat Varlıklarını Koruma Kanunu çerçevesinde belirlenmiştir. Bu mirasın korunmasında iki ana kamu kuruluşu olan Kültür ve Turizm Bakanlığı ile Vakıflar Genel Müdürlüğü sorumluluk üstlenmektedir. Bu kuruluşlar, merkezî ve yerel düzeyde merkezden yönetim prensibi doğrultusunda organize olarak, kültürel mirasın korunmasına yönelik çeşitli faaliyetler yürütmektedir [9].

Türkiye, 2003 yılında kabul edilen UNESCO Somut Olmayan Kültürel Mirasın Korunması Sözleşmesi'ne, 5448 sayılı kanunla dâhil olmuş ve bu sözleşmeye 27 Mart 2006 tarihinde resmen taraf olmuştur. Her ne kadar 2006 yılında sözleşmeye taraf olsa da koruma alanındaki ulusal yasal düzenlemelerde bütüncül bir yaklaşım eksikliği mevcuttur. Kültür ve Turizm Bakanlığına bağlı Araştırma ve Eğitim Genel Müdürlüğü ise, somut olmayan kültürel mirasın belgelenmesi yönündeki çalışmalarını sürdürmektedir [9].

3.2. Sürdürülebilir Kalkınma

Sürdürülebilirlik, yaşam kalitesini düşürmeden, bakış açısını farklı yöne çekmeyi gerektiren bir olgu olarak ortaya çıkmaktadır. Bu farklılık ise temelinde, tüketim toplumu olmaktan çıkıp küresel anlamda dayanışma toplumu olabilmek amacıyla çevre yönetimi, sosyal sorumluluk ve ekonomik çözümleri hedeflemektir [10]. Bu bağlamda gelişen sürdürülebilir kalkınma kavramı, küresel ilişkiler dâhilinde artan farkındalık ile ekonomik ve sosyal sorunlar, artmakta olan çevre sorunları, insanlığın eşitsizlik ve sağlıklı gelecek kaygısından ileri gelmektedir [7]. BM Küresel Çevre ve Kalkınma Komisyonu tarafından 1987 yılında yayımlanan "*Ortak Geleceğimiz*" başlıklı Bruthland Raporu olarak da bilinen raporda "*çok boyutlu bir tema*" olarak ileri sürülen sürdürülebilir kalkınma kavramı, "*bugünün gerekliliklerini, gelecek nesillerin kendi gereksinimlerini karşılama olanaklarını riske atmadan yerine getiren bir kalkınma şekli"* olarak tanımlandıktan sonra herkesin gündeminde yer aldı [11]. Brundthland Raporu'nda kalkınma ve çevre korunması arasındaki ilişkinin altı çizilirken değişimin ve yeni bir küresel etik anlayışının gerekliliği vurgulanmış ve aynı zamanda bu ihtiyacın günümüz şartlarında bulunan insan kaynağı, teknoloji ve kaynaklarla karşılanabileceği belirtilmiştir [12].

Rio de Janeiro'da, 1992 senesinde düzenlenen Birleşmiş Milletler Kalkınma ve Çevre Konferansında "kalkınma" kavramı, tartışılan en önemli konuydu. Kalkınma kavramının bu kadar ön planda tutulmasının altında yatan nedenlerden bazıları; ekonomik ve çevresel problemleri çözmekte yaşanan sıkıntılar, doğayı koruma endişesi ve üçüncü dünya ülkelerinin yoksunluğu şeklinde sıralanabilir [13].

Sürdürülebilir kalkınma, insanlığın karşı karşıya olduğu çevresel, ekonomik ve sosyal problemlere çözüm üretme çabasında olan çeşitli siyasi, hukuki ve ekonomik girişimleri motive etmek için kullanılır [14]. Sürdürülebilir kalkınmanın bir değişim süreci olduğunu söylemek mümkündür. Bu bağlamda sürecin; kaynakların kullanımında, teknolojik gelişme ve kurumsal değişimlerin yönünün uyumlu bir şekilde belirlenmesinde ve mevcut ve gelecekteki ihtiyaçlarla beklentileri karşılama potansiyelinin önünün açılmasında gerekliliğinden söz edilebilir [15].

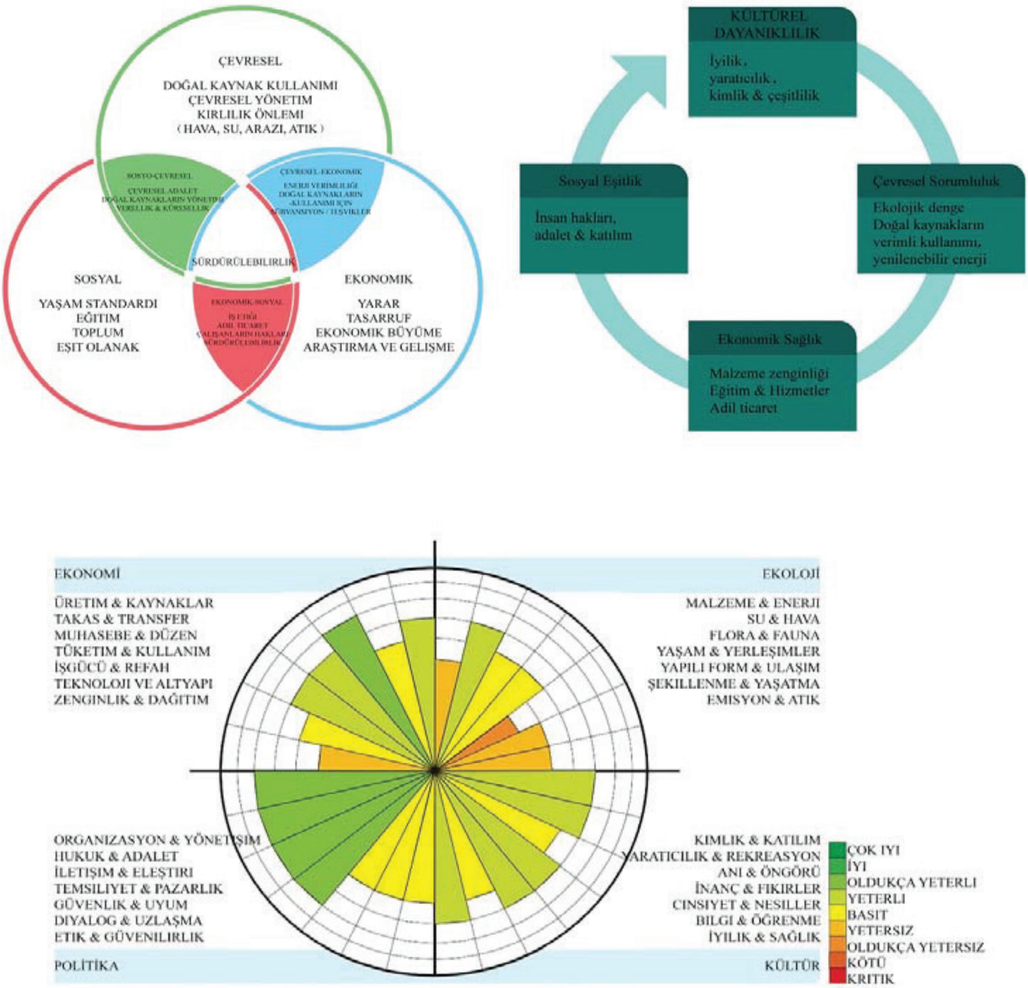
Tablo 1. Sürdürülebilir Kalkınmanın Yapı Taşları [16].

UYARLANABİLİRLİK Geri bildirim döngüsüne göre sürekli düzenlemeler yapma		
ÇEVRE Yenilenebilir kaynakları kullanmak ve çevreyi korumak ve muhafaza etmek arasındaki denge	**TOPLUM** Eşitliğe ve sosyo-kültürel sistem ve değerlere yönelik sorumlu yaklaşımları desteklemek	**EKONOMİ** Etik temelde eşitlikçi fakat geçerli ekonomik sistemler yaratmak

Tablo 1'de ifade edildiği gibi sürdürülebilir kalkınma, çevresel denge için korumacı bir yaklaşım sergilenmesini, eşitlik ilkesine sahip ekonomik sistemler oluşturulmasını ve toplumsal değerlere duyarlı bir yaklaşımın desteklenmesi ve sistemlerin oluşturulması yoluyla sürekli bir gelişim süreciyle beraber düzenlemeler gerçekleştirmeyi esas almaktadır. Sürdürülebilir kalkınmanın tanımlanması konusunda fikir birliği olmamasına rağmen sürdürülebilir kalkınmanın ilkeleri yol gösterici olmaya devam etmektedir. Tablo 1'de belirtilen ilkeler; çevresel, ekonomik ve sosyal sürdürülebilirlik prensipleridir. Bu üç ilkeyi birleştiren ve sürdürülebilir kalkınmanın sürekli bir dinamik denge süreci olduğunu vurgulayan ise uyarlanabilirlik ilkesidir [16].

4. Kültürel Miras ve Sürdürülebilir Kalkınmanın İlişkisi

İlk etapta sürdürülebilirlik, üç ayrı ilkeye dayandırılmaktaydı. Zamanla, kültürün, yaratıcılığın ve bilginin önemine dair uluslararası tartışmaların sonucunda bütünsel ve daha karmaşık bir vizyon ortaya çıktı. Kültür, Johannesburg'daki 2002 Yeryüzü Zirvesinde sürdürülebilir kalkınmanın dördüncü dayanağı olarak sunuldu; 2010 yılında Dünya Yerel ve Bölgesel Liderler Zirvesinde tanındı. Burada sürdürülebilirliğin kültürel bir anlayış olmasının yanı sıra, ana hedefi olan "sürdürülebilir kalkınmanın dördüncü basamağı olarak kültürün tanıtılması" programları ve politikaları oluşturulmuştur. Sürdürülebilirliğin üç temel ilkesi ekonomik, çevresel ve sosyal bileşenlerden oluşmaktadır. Bu ilkeler, sürdürülebilirliği, esnekliği ve dayanıklılığı değerlendirmek için nicel ve nitel göstergelerle bir araya getiren Sürdürülebilirlik Çemberleri adlı yöntem çerçevesinde yeniden yapılandırılmıştır. Bu yapı, çevresel sürdürülebilirliği sağlamak için kritik öneme sahiptir. Bu bağlamda sürdürülebilirlik kavramının gelişimi Şekil 2'de gösterilmektedir [2].



Şekil 2. Sürdürülebilirlik kavramının evrimi [2].

Atalan'a göre, kültürel miras ve koruma kültürü, sosyal ve tarihsel gelişim süreci içerisinde oluşturulan materyalleri ve sahip olunan manevi değerleri temsil eden ögelerin tümü olarak tanımlanmaktadır [18]. Dolayısıyla kültürel miras; bireyin sosyal ve doğal çevresinin baskınlığının içeriği ile ilgili fikir verirken, sonraki nesillere aktarılmak için kullanılan ögeleri bünyesinde barındırır. Kültür, kuşaktan kuşağa aktarılır ve bu yüzden kültürlerin korunması temelde bu aktarıma bağlıdır. Kuşaktan kuşağa yapılan bu aktarım miras olarak ifade edilir ve onu önemli hâle getiren de budur. Kültürel miras koruma yöneticileri, doğal veya yapılı çevrenin somut veya somut olmayan ögelerine odaklanır.

Günümüzde de miras yöneticileri mirasa dâhil olan kaynakları seçer, yönetir ve korur. Bu aktiviteler çoğunlukla kamu sektörü aracılığı ile yönetilir. Kentsel ve kültürel peyzajların korunmasını içeren miras planlaması, daha bağımsız bir şekilde yapılmamalıdır. Miras planlamasının, kültürel, sosyal, ekonomik ve çevresel etkileri hedefleyen Sürdürülebilir Kalkınma Amaçları'na ulaşabilmek için kentleşmeyle ilgili tüm birimleri kapsayan ve sektörler arası bir yaklaşımla gerçekleştirilmesi gerekmektedir.

Sonuçlar

Son yıllarda yaşanan çevresel felaketler, ekonomik eşitsizlikler ve toplumsal huzursuzluklar, insanlığın geleceğinin çözümü olarak görülen sürdürülebilir kalkınmanın yalnızca ekonomik kalkınmayla sağlanamayacağını ortaya koymuştur. Sürdürülebilir kalkınma ancak doğaya, insana ve kültürel mirasa saygılı kalkınmayla sağlanabilir.

Soyut ve somut kültürel miras yüzyıllar boyunca doğal olarak ve içinde bulunduğu fiziki bağlam sayesinde yaratılmış, aktarılmış ve nesilden nesle gelişmiştir. Toplumların sürdürülebilir kültürel, ekonomik ve sosyal gelişiminde sadece doğal kaynaklar değil, kültürel kaynaklar da önemli rol oynar ve bu sayede onların yaradılışlarını etkileyen fiziksel doku da korunmuş olur.

Kültür, sürdürülebilir kalkınmanın geleneksel söylemini genişleten dördüncü faktör olarak destekleyici bir rol oynamaktadır. Kültürün sosyal, ekolojik ve ekonomik istekler ile sürdürülebilirlik gereklilikleriyle birlikte dikkate alınması gerekir. Bu daha etkili rol, kültürü, üç sütunu dengeleyebilen ve sosyal, ekolojik ve ekonomik baskılar ve ihtiyaçlar arasında sürdürülebilir kalkınmaya rehberlik edebilen bir çerçeve, içselleştirme ve arabulucu konumuna getirmektedir. Geleceğe yönelik tüm kalkınma planlarında kültürün diğer tüm sektörlerle bağlantıları, ilişkileri, birbirlerine olan etkileri ve katkıları dikkate alınmalıdır. Miras planlamasının; kültürel, sosyal, çevresel ve ekonomik etkileri hedefleyen Sürdürülebilir Kalkınma Amaçları'na ulaşmak için kentleşmeyle alakalı birimlerin tümünü kapsayacak şekilde ve sektörler arası yapılması gerekmektedir.

Kültürel mirasın sadece geçmişin bir yansıması olmanın ötesinde toplumların kimliği ve değerleri üzerindeki etkileri göz önünde bulundurulmalı, bu bağlamda kültürel mirasın korunması ve yönetimi sürecinin her zaman göz önünde tutulması gerekmektedir.

Referanslar

[1] Ünver, E. (2006). Sustainability of Cultural Heritage Management: Keklik Street and Its Surrounding Conservation and Development Project, Master's Thesis, The Graduate School of Natural And Applied Sciences of Middle East Technical University, Ankara.

[2] Hoskara, S., Lombardi, A., & Doganer, S. (2021). Sürdürülebilir Kalkınma Amaçlarına Ulaşmada Kültürel Mirasın Korunması ve Yönetiminin Rolü: Disiplinlerarası Bir Yaklaşım. Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 36(4), 1963-1976. Https://Doi.Org/10.17341/Gazimmfd.800950

[3] Aksoy, A. vd. (2012). Kültürel Miras Yönetimi, 1. Baskı, Eskişehir: Anadolu Üniversitesi Web-Ofset.

[4] url-1 http://www.icomos.org.tr/?Sayfa=Tuzukler1&dil=tr, Erişim Tarihi: 27.07.2016

[5] url-2 ICOMOS Avustralya. (1999). The Burra charter: the Australia ICOMOS charter for places of cultural significance. Burwood: Australia ICOMOS. http://australia.icomos.org/wp-content/uploads/BURRA-CHARTER- 1999_charter-only.pdf.

[6] Ulusan E., (2023). Kültürel Miras Yönetim Planlaması Kavramsal Çerçevesi ve İlgili Lisansüstü Araştırmalar Üzerine Bir İnceleme. *Planlama Dergisi*, *33*(1), 40-57.

[7] Ripp M. ve Rodwell, D. (2016) The governance of urban heritage, The Historic Environment: Policy & Practice, 7:1, 81-108, DOI: 10.1080/17567505.2016.1142699.

[8] UNESCO, ICCROM, ICOMOS ve IUCN. (2013). Managing cultural world heritage. Paris: UNESCO.

[9] Ö. Karakul ve T. Yıldız, *Kültürel Mirasın Korunmasında Yerel Yönetimlerin Rolü*. Bursa: UCLG-MEWA, 2020. Erişim: 02 Eylül 2024. [Çevrimiçi]. Erişim adresi: https://uclg-mewa.org/wp-content/uploads/2022/05/Kulturel_Mirasin_Korunmasinda_Yerel_Yonetimlerin_Rolu-Turkiye.pdf

[10] Özmehmet E., (2012). "Dünyada ve Türkiye'de Sürdürülebilir Kalkınma Yaklaşımları", Journal of Yaşar University, 3(12), s. 1-23.

[11] Bodosca S., Diaconescu M. D. (2015). "Tourism Development After the Implementation of Sustainable Strategies in Neamt County", Procedia, 188, s. 230-236.

[12] Çakılcıoğlu M. (2013). "Turizm Odaklı Sürdürülebilir Kalkınma İçin Bir Yöntem Önerisi", Tasarım+Kuram, 9(16), s. 27-42

[13] Bazyar A. (2014). "Social Sustainable Development and Economic Transformation", OIDA International Journal of Sustainable Development, 7(5), s. 40-50

[14] Bebbington J. (2000). "Sustainable Development: A review of the international development, business and accounting literatüre", Aberdeen Papers in Accountancy, Finance & Management, Working paper.

[15] Dünya Çevre ve Kalkınma Komisyonu, WCED (1987). Our Common Future: The Brundland Report, New York: Oxford University Press.

[16] Plessis D. Cristina (1999). "Sustainable Development Demands Dialogue Between Developed and Developing Worlds", Building Research & Information, 27(6), s. 378-389.

[17] James, P., Circles of sustainability, Urban Sustainability in Theory and Practice, New York: Outletçe, 2014.

[18] Atalan O., Importance of cultural heritage and conservation concept in the 'architectural education'. International Journal of Human Secince, 15, 3, 2018.

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Exploring Architectural Tools for Oculus Quest 2

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Araştırma Makalesi/ *Research Article*

Abstract

Virtual Reality (VR) has emerged as a transformative technology in architectural design, providing immersive and interactive experiences that surpass traditional methods. This article explores the diverse applications of VR in architecture, with a particular focus on the Oculus Quest 2 due to its accessibility, dedicated user platform, and specialized software. The study thoroughly examines both stand-alone and computer-connected VR tools and platforms, detailing how they can be utilized in architectural workflows. Stand-alone software such as Gravity Sketch, Arkio, and SketchUp Viewer run directly on the Oculus Quest 2, offering intuitive design and visualization capabilities without the need for a computer. On the other hand, the software requiring computer connectivity like Blender, Rhino, Unity, and Enscape leverage the processing power of a PC to provide advanced features and detailed visualizations through platforms like SteamVR or Meta Quest Link.

The article also provides a comparative analysis of these tools, highlighting their strengths and limitations, focusing on their usability, accessibility, and relevance to architectural practice. Additionally, the integration of VR with Building Information Modeling (BIM) is identified as a significant innovation that enhances collaboration and information synchronization throughout the design and construction process. While the primary focus is on practical applications for architects and designers, the article also briefly touches on the educational implications of VR software, offering insights into how these tools can be used to enable students engage with complex spatial concepts in an intuitive manner.

The findings of this study emphasize VR's critical role in fostering creativity, improving design accuracy, and enhancing the overall architectural workflow. The analysis reveals that tools like Gravity Sketch excel in freeform modeling, while Arkio stands out for its BIM compatibility and cross-platform availability. These insights provide a foundation for future research, development, and innovation, positioning VR as a pioneer technology in the future of architecture.

Keywords: Architecture, Virtual Reality, Oculus Quest 2, 3D Visualization, BIM, Architectural Education

Oculus Quest 2 için Mimari Araçların Keşfi

Öz

Sanal Gerçeklik (VR), mimari tasarımda geleneksel yöntemleri aşan, sürükleyici ve etkileşimli deneyimler sunan dönüştürücü bir teknoloji olarak ortaya çıkmıştır. Bu makale, erişilebilirliği, belirli bir kullanıcı platformuna sahip olması ve özel uygulamaları nedeniyle Oculus Quest 2'ye odaklanarak, VR'ın mimarlıkta çeşitli uygulamalarını incelemektedir. Çalışma, hem bağımsız hem de bilgisayar bağlantılı VR araçlarını ve platformlarını detaylı bir şekilde ele alarak mimari iş akışlarında nasıl kullanılabileceklerini açıklamaktadır. Gravity Sketch, Arkio ve SketchUp Viewer gibi bağımsız uygulamalar, Oculus Quest 2 üzerinde doğrudan çalışarak bilgisayara ihtiyaç duymadan sezgisel tasarım ve görselleştirme yetenekleri sunar. Öte yandan, Blender, Rhino, Unity ve Enscape gibi bilgisayar bağlantısı gerektiren uygulamalar, SteamVR veya Meta Quest Link gibi platformlar aracılığıyla PC'nin işlem gücünden yararlanarak gelişmiş özellikler ve detaylı görselleştirmeler sağlar.

Makale ayrıca bu araçların güçlü ve zayıf yönlerini vurgulayan karşılaştırmalı bir analiz sunarak, kullanılabilirlik, erişilebilirlik ve mimari uygulamalara uygunluklarına odaklanmaktadır. Ayrıca, VR'ın Bina Bilgi Modellemesi (BIM) ile entegrasyonu, tasarım ve inşaat süreci boyunca iş birliğini ve bilgi senkronizasyonunu artıran önemli bir yenilik olarak tanımlanmaktadır. Ana odak, mimarlar ve tasarımcılar için pratik uygulamalar üzerinde olsa da, makale aynı zamanda VR yazılımlarının eğitimsel etkilerine de kısaca değinerek bu araçların karmaşık mekansal kavramlarla sezgisel bir şekilde etkileşim kurmak için nasıl kullanılabileceğine dair içgörüler sunmaktadır.

Bu makale, mimarideki VR yazılımlarının mevcut durumuna kapsamlı bir bakış sunarak, gelecekteki eğilimler ve potansiyel gelişmeler hakkında bilgiler sağlamaktadır. Bulgular, VR'ın yaratıcılığı teşvik etmede, tasarım doğruluğunu artırmada ve genel mimari iş akışını iyileştirmede kritik bir rol oynadığını vurgulamakta ve VR'ı geleceğin mimarisinde temel bir teknoloji olarak konumlandırmaktadır.

Anahtar Kelimeler: Mimarlık, Sanal Gerçeklik, Oculus Quest 2, 3D Görselleştirme, BIM, Mimarlık Eğitimi

1. Introduction

Virtual Reality (VR) has transformed a variety of disciplines, such as architecture, engineering, education, and the humanities. VR, a technology that simulates a three-dimensional environment, provides immersive experiences that have the potential to revolutionize the way we interact with objects and spaces, as well as envision and design them. VR has emerged as a potent tool that surpasses conventional two-dimensional representations from the screens in the context of architectural design and visualization, allowing architects, designers, and students to interact with spatial concepts in a more intuitive manner.

The integration of VR into architectural design enables a more thorough comprehension of the human interaction, lighting, materials, and spatial relationships within a designed environment. The design process is further improved by the integration of VR with Building Information Modeling (BIM), which provides a collaborative platform that synchronizes information across various stages of a project, from conceptualization to construction [1].

VR has been implemented in the educational sector to enhance the learning and teaching experiences [2]. It enables students to innovatively recognize good design practices and visualize complex systems. Additionally, VR and AR's potential for research, dissemination, and mediation in the humanities is illustrated by its use in the recreation of historical sites and events [3]. The potential of VR to manage intricate spatial configurations and continuous updates in accordance with new standards and healing techniques is emphasized by its use in complex architectures, such as soundscape design [4].

The Oculus Quest was chosen for this study due to its wireless capabilities, user-friendly interface, and high-resolution display, dedicated app market which make it an ideal platform for architectural design and education. Its economic accessibility, portability and extensive application support provide architects and students with an accessible and effective VR experience, enhancing the overall usability and integration of VR in architectural workflows.

The architectural design process is a structured sequence of stages that guide the development of a project from initial concept to final construction. VR technology can significantly enhance each of these stages, particularly in the following areas:

In the conceptual design phase, architects brainstorm and develop the basic idea or concept for the project. VR allows for the creation of immersive 3D sketches, enabling designers and stakeholders to explore and refine ideas in a virtual space. This enhances creativity and helps in visualizing the potential of the design early on like physical models but much faster.

Throughout in the whole design process, VR serves as a powerful tool for real-time visualization. It allows architects to create detailed virtual models that can be explored and modified at any stage of the design. This continuous visualization helps in identifying potential issues, making necessary adjustments, and ensuring that the design evolves in line with the project goals.

VR is particularly effective for client presentations and demonstrations. It provides clients with an immersive experience, allowing them to walk through the virtual model of the project. This helps in conveying design concepts more effectively and facilitates better communication and feedback. Clients can experience the space as if it were already built, leading to more informed decision-making.

By integrating VR technology at these critical stages of the architectural design process, architects can enhance visualization, improve collaboration, and streamline workflows. The Oculus Quest 2, with its accessibility and advanced capabilities, serves as an effective tool for implementing VR in these various phases, thereby transforming traditional architectural practices.

2. Literature Review

The history of VR is extensive and multifaceted, encompassing a variety of fields and applications. Schroeder [5] offers a comprehensive account of the evolution of interactive computer graphics, examining the socio-technical influences that have influenced the development of multi-user VR systems. Brooks [6] contemplates the early stages of VR technology, exploring its potential as a novel form of expression. The evolution and diversification of VR applications are further characterized by the integration of VR in various sectors, including air traffic control [7], surgical education [8], or public education [9].

The integration of VR into the architectural design process has garnered substantial attention. Aydın and Aktaş [10] investigate the function of VR-based architectural design education, which encompasses real-time rendering and 3D form-finding. The Eindhoven Perspective by Achten et al. [11] delineates the context and history of VR in architectural education, examining the use of VR in student projects since 1991. Zhang [12] presents a methodology for the integration of VR-BIM into the construction management undergraduate program, addressing obstacles and suggesting potential solutions.

VR's role in architectural visualization is significant, providing enhanced spatial understanding and interactive design environments. Giailorenzo et al. [13] have investigated the potential of VR in intricate architectures, including hospital design. They developed a methodology that integrates BIM models with high-end immersive VR systems. The efficiency of VR in an urban planning context was emphasized by Imottesjo and Kain [14], who investigated the usability of online VR technology for 3D urban planning and design. Lau et al. [15] conducted a cross-sectional study to compare VR visualization with 3D printed heart models in congenital heart disease.

In various contexts, the collaborative and immersive aspects of VR have been investigated. The application of a VR-based workflow in a real project was examined by Zaker and Coloma [16], who assessed the advanced features of VR software. Walmsley and Kersten [17] detailed the creation of an immersive VR application for the Imperial Cathedral in Königslutter that incorporates 360° panoramic photographs into the virtual environment.

The application of VR in the construction industry has shown significant promise in enhancing various aspects of project management and execution. VR allows for immersive 3D walkthroughs of building designs, providing a more intuitive understanding of spatial relationships and potential challenges within a project. VR can also be used for construction training and education, offering safer and more effective training environments [18,19]. Additionally, VR aids in optimizing site planning and improving quality control and inspection processes by allowing for detailed simulations and real-time adjustments [20].

Numerous studies have illustrated the utilization of VR in the preservation of cultural heritage and historical recreation. Soto-Martín et al. [21] present a method for the reconstruction and restoration of historic buildings and mural paintings through the use of digital models. This approach demonstrates the effectiveness of VR in preserving and presenting historical artifacts and sites. The use of VR in the production process, particularly in complex architectural projects, has shown significant potential. François et al. [22] describe the VESPACE project, which employs VR to recreate 18th-century theater. This project highlights the use of VR for detailed production planning and execution in historical recreations.

In conclusion, the integration of VR technology within these domains not only enhances current practices but also paves the way for future innovations. The ongoing advancements in VR are likely to further revolutionize how we approach education, project management, and preservation efforts. As VR continues to evolve, its potential to transform and improve various aspects of architecture and construction will undoubtedly expand, making it an indispensable tool for professionals in these fields. Future research should continue to explore and document these developments, ensuring that the full spectrum of VR's capabilities is realized and effectively utilized.

3. Methodology

The methodology employed in this study aims to provide a comprehensive analysis of the applications of virtual reality in architectural modeling and visualization. A thorough literature review was performed to identify relevant studies, articles, and case studies concerning the applications of virtual reality in architectural design, education, construction, historical recreation, technology comparison, collaboration.

A comparative analysis was performed to evaluate the characteristics, usability, integration with other tools, and specific applications in architectural design of different VR modeling and visualization applications. This analysis was guided by prior research comparing VR with alternative technologies [23] and examining the collaborative and immersive dimensions of VR [24].

The VR applications were classified into three primary categories according to their operational prerequisites and intended users: standalone applications, applications necessitating computer connectivity, and entry-level applications. Standalone applications operate directly on the Oculus Quest 2 without requiring a computer, encompassing both visualization and design tools. Applications necessitating computer connectivity generally function via plugins and platforms such as SteamVR or Meta Quest Link, encompassing both visualization and design tools. Entry-level applications are accessible tools designed for pre-architectural education at the secondary school level or for non-professional users.

Each application was assessed according to its capacity to import and export diverse file formats, essential for interoperability and integration into current architectural workflows. This encompassed formats including OBJ, FBX, SKP, and others. The potential influence of VR tools on architectural education was evaluated, emphasizing their capacity to improve pedagogical methods, spatial comprehension, and student involvement. This entailed assessing the accessibility, usability, and pertinence of VR tools in educational environments.

The results from the literature review, comparative analysis, categorization, and evaluations were integrated to present a thorough overview of the present status of VR applications in architecture. This synthesis emphasized the advantages, drawbacks, and prospective future developments of VR technology in the domain.

4. Examination of Applications

This section is segmented into three parts to thoroughly examine the diverse applications of virtual reality in architecture utilizing the Oculus Quest 2. The Oculus Quest 2's distinctive advantage over platforms such as the HTC Vive is its capability to function autonomously without requiring a computer. This independent functionality is utilized by various applications, which will be examined in the initial section. The subsequent section will concentrate on techniques necessitating computer connectivity, usually via plugins and platforms such as SteamVR or Meta Quest Link. The third section will address entry-level applications appropriate for pre-architectural education at the secondary school level or for non-professional users.

This section is segmented into three parts to thoroughly examine the diverse applications of virtual reality in architecture utilizing the Oculus Quest 2. The Oculus Quest 2's distinct advantage over platforms such as the HTC Vive is its capacity for standalone operation without reliance on a computer. This independent functionality is utilized by various applications, which will be examined in the initial section. The subsequent section will concentrate on techniques necessitating computer connectivity, generally via plugins and platforms such as SteamVR or Meta Quest Link. The third section will address entry-level applications appropriate for pre-architectural education at the secondary school level or for non-professional users.

4.1 Standalone Applications

Standalone applications operate directly on the Oculus Quest 2, eliminating the necessity for a computer, thereby enhancing accessibility and convenience for professional and educational applications in the studio. These applications utilize the Oculus Quest 2's features to deliver immersive experiences without requiring supplementary hardware makes them more accessible in many situations.

4.1.1 Independent Visualization Applications

Standalone visualization applications are specifically intended for the observation and interaction with 3D models within a virtual setting. These applications utilize the Oculus Quest 2's functionalities to deliver immersive experiences independently of a computer. They are especially beneficial for client presentations, design evaluations, and virtual tours, providing intricate visualizations that improve comprehension of architectural projects. Although these applications emphasize visualization, they also incorporate fundamental interaction features that enable users to navigate and examine the models more intuitively.

Resolve is a robust virtual reality application intended for immersive visualization. It enables architects and designers to investigate 3D models within a completely immersive environment, offering an authentic perception of scale and space. Resolve facilitates the exportation of annotations in BCF (BIM Collaboration Format) and XML formats, thereby ensuring compatibility with other applications such as Revizto and Navisworks.

AutodeskXR provides an extensive array of tools for visualizing architectural designs in virtual reality. This standalone application allows users to engage with intricate 3D models and environments, thereby improving comprehension of complex architectural projects (Figure 1). AutodeskXR facilitates the importation of models from Revit and other Autodesk applications, generally utilizing formats such as FBX, DWG, and DWF.

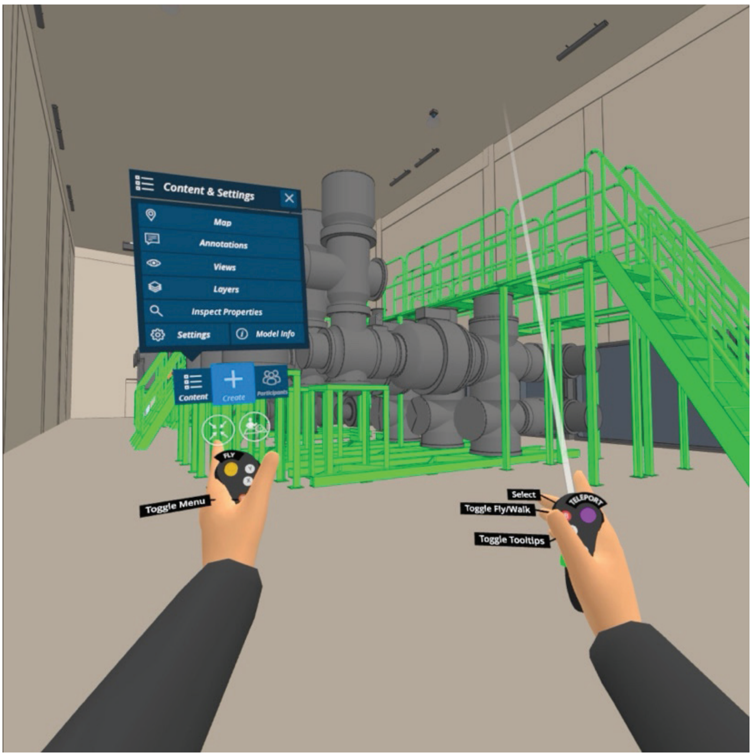

Figure 1. AutodeskXR's interface.

3D Vista VR is a multifaceted application for the creation and observation of virtual tours. It enables architects to showcase their designs interactively, offering clients a virtual tour of the project (Figure 2). 3D Vista VR facilitates the importation of image formats including JPG, PNG, BMP, TIFF, and GIF, and enables the exportation of virtual tours in web-compatible formats as well as standalone executable files (EXE for PC and tar.bz2 for Mac).

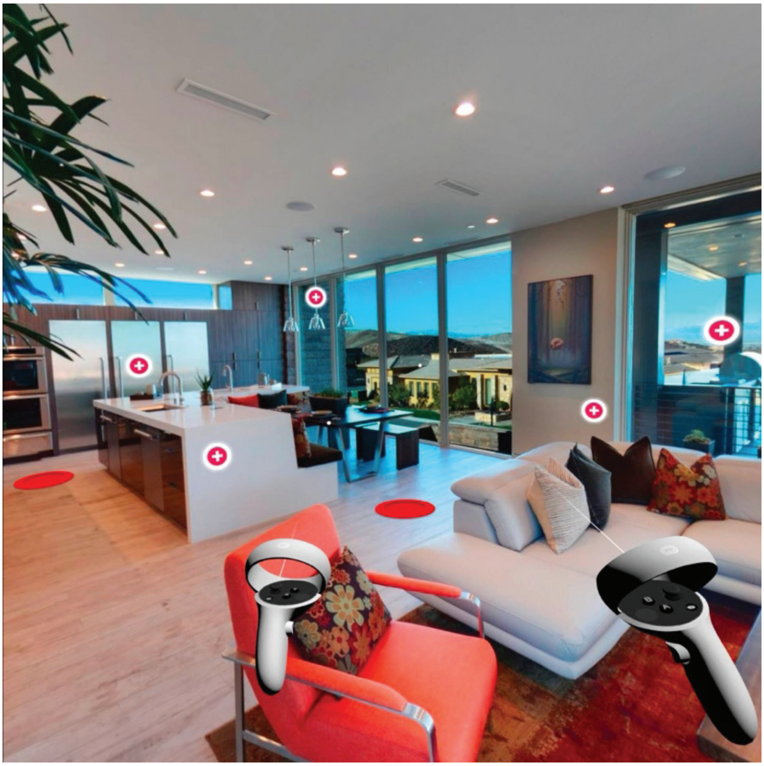

Figure 2. 3D Vista VR's interface.

4.1.2 Standalone Design Applications

Standalone design applications transcend basic visualization by allowing users to create, alter, and engage with 3D models directly within the VR environment. These applications are specifically designed for the Oculus Quest 2, offering a seamless and immersive design experience independent of a computer. They facilitate various design activities, including sketching, modeling, and collaborative on site or online design sessions, rendering them suitable for both professional architects and students. Although visualization is essential to these applications, their main emphasis is on enhancing the design process via intuitive and interactive tools.

Gravity Sketch is a virtual reality design tool enabling users to construct three-dimensional models within a virtual setting. It facilitates intuitive sketching and modeling, rendering it an invaluable instrument mainly for industial designers and architects to conceptualize and refine their freeform designs in real-time. Gravity Sketch facilitates the importation of models in OBJ and FBX formats, and the exportation of models in OBJ, FBX, and IGES formats. Gravity Sketch excels in creating curvilinear forms, making it popular in automotive and industrial design for its ability to model complex, freeform shapes. This same capability is valuable in architecture, where it allows architects to explore innovative, fluid designs. By enabling real-time adjustments and immersive visualization, Gravity Sketch enhances the architectural design process, fostering creativity and precision in developing unique, high-quality projects. Additionally, it offers Rhinoceros T-spline-like modification of surfaces, providing architects with advanced tools for refining and perfecting their designs (Figure 3).

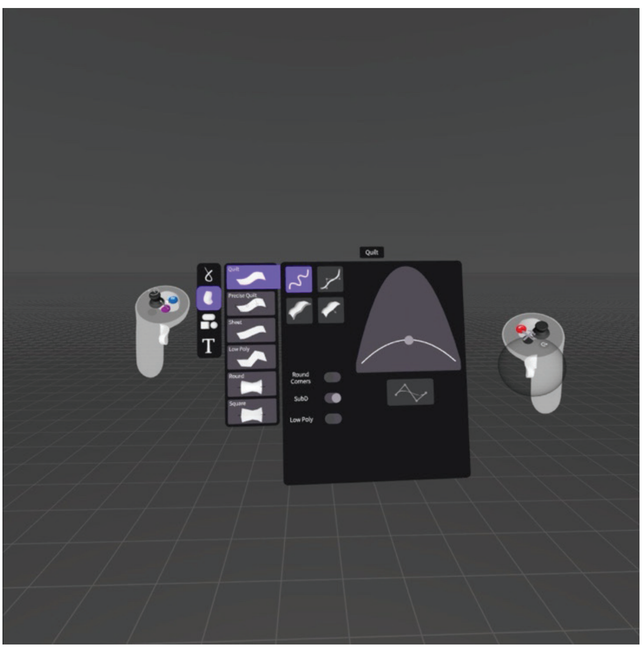

Figure 3. Gravity Sketch’s freeform surface interface.

Arkio is a collaborative design application that allows users to sketch, model, and create in virtual reality. Arkio, as an independent application on Oculus Quest 2, is ideally suited for architectural design courses and professional applications, fostering creativity and collaboration in design processes (Figure 4). Arkio facilitates the importation of models in OBJ and FBX formats, as well as the exportation of models in the same formats. The most important feature of Arkio is its execution in most of the operating systems like Windows, OSX, Android and IOS.

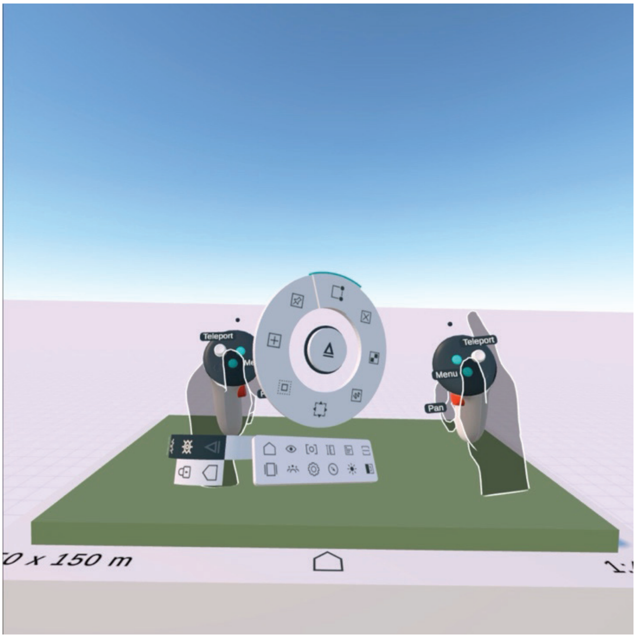

Figure 4. Arkio's interface.

Shapes XR is intended for the creation and presentation of immersive 3D models. It enables architects to visualize their designs in virtual reality, offering an interactive method for spatial planning and design with vast amount of assets (Figure 5). This independent application is especially beneficial for initial design and concept formulation my enabling custom animations in VR. Shapes XR facilitates the importation of models in prevalent 3D formats, including OBJ and FBX, and the exportation of models in OBJ and FBX formats.

Figure 5. ShapeXR's asset library.

SketchUp Viewer: SketchUp Viewer is a virtual reality extension of the popular 3D modeling software SketchUp. It allows users to display and modify 3D models in virtual reality directly on the Oculus Quest 2, offering an immersive experience for both designers and clients. This independent application improves the visualization and evaluation process in architectural projects (Figure 6). SketchUp Viewer facilitates the importation of models in the SKP format, which is native to SketchUp.

Figure 6. SketchUp Viever's interface.

4.2 Applications Requiring Computer Connectivity

4.2.1 Visualization Applications

Applications for visualization in this category are chiefly employed for the examination and interaction with 3D models within a detailed and immersive setting. These applications typically necessitate the processing of models on a computer, which are subsequently streamed to the Oculus Quest 2 through SteamVR or Meta Quest Link. This configuration facilitates intricate and comprehensive visualizations, which are crucial for professional architectural presentations and design evaluations.

Rhinoceros - Simlab: Rhinoceros, often referred to as Rhino, is a potent 3D modeling software that, in conjunction with Simlab, offers advanced VR visualization functionalities. Simlab accommodates a diverse array of import and export formats, such as 3D PDF, FBX, OBJ, STL, among others. This adaptability enables architects to utilize diverse file formats and effortlessly incorporate their models into virtual reality settings. The integration of Rhino and Simlab improves spatial comprehension and client presentations through the provision of intricate and interactive visualizations.

Enscape is a real-time rendering and virtual reality plugin that integrates effortlessly with widely used architectural design software, including SketchUp, Revit, ArchiCAD, and Rhino. Enscape facilitates export in formats such as EXE standalone files, Web Standalone, and multiple image formats (PNG, JPG, EXR, TGA). This facilitates superior visualizations and immersive walkthroughs, rendering it an indispensable instrument for design evaluations and client presentations in 2D. Enscape's capability to export VR scenes as standalone executables is especially advantageous for disseminating interactive experiences without necessitating supplementary software.

Unreal Engine and Twinmotion provide sophisticated real-time rendering and virtual reality functionalities. Twinmotion accommodates import formats like FBX, C4D, OBJ, and SKP, and export formats such as EXE standalone files and Datasmith files for Unreal Engine 3. This formidable pair enables architects to produce intricate and interactive visualizations. The models are processed on a computer and subsequently experienced in virtual reality via the Oculus Quest 2, facilitating a realistic and immersive design review process. The integration with Datasmith guarantees the precise transfer of all geometry, materials, and lighting configurations to Unreal Engine for additional refinement.

4.2.2 Design Applications

Applications in this category allow users to create, modify, and engage with 3D models within a virtual environment. These applications generally necessitate a computer to manage the processing power essential for intricate design tasks, with the VR experience enabled via SteamVR or Meta Quest Link. This configuration facilitates more intricate and engaging design processes, rendering these tools indispensable for professional architects and designers.

MindeskVR is a virtual reality design tool that integrates with widely used CAD software, including Rhino and SolidWorks. It accommodates import formats such as Rhino (.3dm), SolidWorks (.sldprt, .sldasm), and export formats including FBX and OBJ4. MindeskVR enables architects to construct and alter 3D models instantaneously within a virtual setting. The processing occurs on a computer, with the VR experience transmitted to the Oculus Quest 2, facilitating a seamless and immersive design workflow. The live-link functionality guarantees that modifications executed in the CAD software are immediately manifested in the VR environment.

Unity and Pixyz together provide a robust platform for developing interactive 3D content and virtual reality applications. Pixyz accommodates a diverse array of import formats, such as CATIA, NX, SolidWorks, STEP, IGES, FBX, OBJ, among others. Export formats encompass FBX, OBJ, glTF, and USDZ6. This configuration enables architects to design and visualize their projects within an immersive virtual reality environment. The computer manages the processing, while the Oculus Quest 2 enables the VR experience. Pixyz's capability to manage intricate CAD models and enhance them for real-time rendering in Unity renders it an indispensable instrument for comprehensive and interactive architectural design.

4.3. Entry Level Applications

Entry-level applications are crafted to be intuitive and accessible, rendering them appropriate for pre-architectural education at the secondary school level or for non-professional users. These applications offer a streamlined introduction to virtual reality and architectural design, enabling users to investigate fundamental concepts and cultivate essential skills. Although they may lack the sophisticated functionalities of professional tools, they are beneficial for educational purposes and for novices in the field of architecture.

Open Brush is an open-source virtual reality painting application that originated from Google's Tilt Brush. It enables users to generate 3D artwork within a virtual environment, serving as an exceptional instrument for examining spatial concepts and artistic expression. Open Brush facilitates the import and export of models in formats like OBJ and GLB, allowing users to share their creations with various 3D applications.

Home Design 3D VR is an intuitive application enabling users to design and visualize residential layouts within a virtual setting. It is especially appropriate for novices and enthusiasts seeking to explore interior design and spatial arrangement. The application facilitates the importation of models in formats such as OBJ and the exportation of designs in both 2D and 3D formats, thereby simplifying project sharing and further development.

These introductory applications offer an accessible entry point to virtual reality and architectural design, assisting users in developing confidence and foundational skills prior to advancing to more sophisticated tools. They are optimal for educational contexts and for individuals seeking to investigate the fundamentals of architectural design in a virtual setting.

5. Results

The examination and comparative evaluation of various VR tools in architectural design, visualization, and education have uncovered a dynamic and intricate landscape. The primary insights, implications, challenges, and opportunities that result from this analysis are synthesized in this section.

5.1 Functionality and Features

Insights into the capabilities, strengths, and weaknesses of various VR tools in architectural design and visualization are gained through the comparative evaluation of features and functionality. This section compares and evaluates the features and functionality of professional 3D modeling tools, architectural visualization tools, educational and entry-level tools, and open-source and customizable tools. The selection of a tool is contingent upon the specific requirements, objectives, and contexts, which can range from professional 3D modeling and architectural visualization to educational engagement and open-source customization. The ongoing development of these tools [25], in conjunction with the increasing integration of VR technology [26], presents exciting opportunities for further innovation and exploration in the field of architecture and beyond.

5.2 Accessibility and Usability

The effectiveness and adoption of VR tools in architectural practice, education, and visualization are significantly influenced by their usability and accessibility. This section evaluates and contrasts the accessibility and usability of a variety of VR tools, taking into account factors such as user-friendliness, learning curve, customization, collaboration, and integration with other tools [27]. The comparative assessment of accessibility and usability reveals a wide variety of VR tools, each of which is tailored to the unique requirements, levels of expertise, and applications of its users. Professional tools may provide advanced capabilities; however, they may also necessitate more rigorous training. In contrast, educational and entry-level tools emphasize accessibility and user-friendliness. Open-source and customizable tools provide adaptability; however, they may necessitate particular technical abilities.

5.3 Relevance to Architectural Education

The integration of VR tools in architectural education has emerged as a transformative approach to the teaching and learning of design principles, spatial understanding, collaboration, and creativity. This section evaluates the potential of a variety of VR tools to improve pedagogical practices and student engagement in architectural education. The multifaceted landscape of VR tools is revealed through the comparative evaluation of features and functionality, usability and accessibility, and relevance to architectural education. Each tool is tailored to meet the specific requirements of various educational contexts, expertise levels, and needs, and offers a variety of applications and capabilities [28]. The incorporation of VR into architectural education offers thrilling prospects for exploration, collaboration, and innovation [29–31].

When selecting a tool, it is crucial to ensure that the features, usability, accessibility, and relevance are in accordance with the desired outcomes, user expertise, and educational objectives. Further advancements in the accessibility to opportunities in education, and beyond are anticipated as a result of the ongoing evolution of VR technology and the increasing interest in immersive experiences in various education disciplines [32,33].

5.4 Summary of Applications

The following table provides a summary of the various applications available for Oculus Quest 2, including their categories and supported import/export formats:

Table 1. Overview of VR Applications for Oculus Quest 2 in Architectural Design.

App Name	Category	Import Formats	Export Formats	Operating Systems
Resolve	Standalone Visualization Apps	-	BCF, XML	Oculus Quest 2
AutodeskXR	Standalone Visualization Apps	FBX, DWG, DWF	-	Oculus Quest 2
3D Vista VR	Standalone Visualization Apps	JPG, PNG, BMP, TIFF, GIF	EXE (PC), tar.bz2 (Mac)	Oculus Quest 2, Windows, Mac
Gravity Sketch	Standalone Design Apps	OBJ, FBX	OBJ, FBX, IGES	Oculus Quest 2, Windows, Mac
Arkio	Standalone Design Apps	OBJ, FBX	OBJ, FBX	Oculus Quest 2, Windows, Mac, iOS, Android
Shapes XR	Standalone Design Apps	OBJ, FBX	OBJ, FBX	Oculus Quest 2
SketchUp Viewer	Standalone Design Apps	SKP	-	Oculus Quest 2, Windows, Mac
Rhinoceros - Simlab	Visualization Apps Requiring Computer Connectivity	3D PDF, FBX, OBJ, STL	-	Windows, Mac
Enscape	Visualization Apps Requiring Computer Connectivity	-	-	Windows
Unreal Engine	Visualization Apps Requiring Computer Connectivity	FBX, C4D, OBJ, SKP	EXE standalone files, Datasmith files	Windows, Mac
MindeskVR	Design Apps Requiring Computer Connectivity	.3dm, .sldprt, .sldasm	FBX, OBJ	Windows
Unity - Pixyz	Design Apps Requiring Computer Connectivity	CATIA, NX, SolidWorks, STEP, IGES, FBX, OBJ	FBX, OBJ, glTF, USDZ	Windows, Mac
Open Brush	Entry Level Apps	OBJ, GLB	-	Oculus Quest 2
Home Design 3D VR	Entry Level Apps	OBJ	-	Oculus Quest 2, Windows, Mac, iOS, Android

6. Discussion

The analysis and comparative assessment of various VR tools in architectural design, visualization, and education have revealed a complex and evolving landscape. This discussion synthesizes the primary insights, implications, challenges, and opportunities derived from the analysis.

Gravity Sketch excels in freeform modeling, facilitating intuitive sketching and real-time iteration. This tool is especially beneficial for architects requiring rapid conceptualization and refinement of their designs within a virtual setting. Conversely, Arkio demonstrates superior BIM compatibility and is accessible on all operating systems, rendering it a versatile instrument for collaborative design and educational applications. Arkio's integration with BIM improves collaboration and information synchronization during the design and construction phases, facilitating a seamless workflow for architects and designers.

The capacity to enhance pedagogical methods, spatial comprehension, and student involvement is apparent in the significance of VR tools within architectural education. New tools offer accessible and user-friendly platforms for instructing design principles, fostering collaboration, and enhancing creativity [11,34]. The incorporation of virtual reality in architectural education enhances experiential learning, thus closing the divide between theory and practice. Applications such as Gravity Sketch and Arkio provide distinct benefits in educational environments, with Gravity Sketch facilitating tactile, imaginative exploration and Arkio enhancing collaborative, BIM-integrated learning experiences.

Ongoing advancements and opportunities are expected as VR technology evolves, alongside a growing interest and investment. The exploration of new tools, methodologies, and applications may yield novel insights and innovations in architectural design, visualization, and education. Collaborations between industry and academia, interdisciplinary involvement, and joint research could significantly augment the potential and influence of virtual reality in architecture.

7. Conclusion

This analysis has examined a wide range of solutions, including architectural visualization platforms, professional 3D modeling tools, educational and entry-level applications, and open-source and customizable options. The incorporation of VR into architectural practice is a substantial advancement in innovation, as it improves communication, collaboration, creativity, and spatial comprehension. The way architects and designers interact with their work has been revolutionized by the emergence of powerful platforms for real-time rendering and immersive experiences.

A versatile and adaptable toolkit for a variety of needs and contexts is provided by the diversity of VR tools, which exhibit varying levels of complexity, usability, and accessibility. Although there are obstacles and constraints, the ongoing development of technology and the increasing popularity of immersive experiences indicate that there will be additional advancements and opportunities.

This analysis contributes to a more comprehensive understanding of the potential and function of VR in the field of architecture. It provides a foundation for the exploration, innovation, and collaboration of architects, designers, educators, students, and researchers, thereby influencing the future of architectural practice and education. The implications and insights that result from this investigation are not limited to the field of architecture; they are also compatible with more general themes such as educational transformation, technological innovation, and interdisciplinary collaboration. They encourage further research, development, and reflection, thereby contributing to the ongoing dialogue and discovery in the dynamic and ever-evolving field of VR.

References

[1] Rocha, L. S.; Krassmann, A. L.; Notare, M. R.; Vidotto, K. N. S.: BIM associated with virtual and augmented reality resources in an educational context: a systematic literature review. Interactive Learning Environments, , 1–14 (2024). http://doi:10.1080/10494820.2024.2350647.

[2] Alvarado, R. G.; Maver, T.: Virtual Reality in Architectural Education: Defining Possibilities. ACADIA Quarterly, **18**, 97–99 (1999).

[3] Zoellner, M.; Keil, J.; Drevensek, T.; Wuest, H.: Cultural heritage layers: Integrating historic media in augmented reality. In *VSMM 2009 - Proceedings of the 15th International Conference on Virtual Systems and Multimedia*; IEEE, (2009); pp. 193–196.

[4] Rudi, J.: Designing Soundscapes for Presence in Virtual Reality Exhibitions: A Study of Visitor Experiences. Visitor Studies, **24**, 121–136 (2021). http://doi:10.1080/10645578.2021.1907151.

[5] Schroeder, R.: Networked Worlds: Social Aspects of Multi-User Virtual Reality Technology. Sociological Research Online, **2**, 89–99 (1997).

[6] Brooks, F. P.: What's Real About Virtual Reality? In *Proceedings IEEE Virtual Reality*; Houston, (1999); p. Cat. No. 99CB36316.

[7] Akselsson, R. ; Källqvist, C. ; Bednarek, V. ; Cepciansky, M. ; Trollås, A. ; Davies, R. ; Eriksson, J. ; Olsson, R. ;; Johansson, G.: Virtual Reality in Air Traffic Control. In *Proceedings of the IEA 2000/HFES 2000 Congress*; APA: San Diego, (2000); Vol. 6, pp. 273–275.

[8] Klasen, J. R. S.; Thatcher, G. P.; Bleedorn, J. A.; Soukup, J. W.: Virtual surgical planning and 3D printing: Methodology and applications in veterinary oromaxillofacial surgery. Frontiers in Veterinary Science, **9** (2022). http://doi:10.3389/FVETS.2022.971318/FULL.

[9] Kamińska, D.; Sapiński, T.; Wiak, S.; Tikk, T.; Haamer, R. E.; Avots, E.; Helmi, A.; Ozcinar, C.; Anbarjafari, G.: Virtual reality and its applications in education: Survey. Information (Switzerland), **10**, 1–20 (2019). http://doi:10.3390/info10100318.

[10] Aydin, S.; Aktaş, B.: Developing an Integrated VR Infrastructure in Architectural Design Education. Frontiers in Robotics and AI, **7** (2020). http://doi:10.3389/frobt.2020.495468.

[11] Achten, H.; Vries, B. DE; Jessurun, A.: DDDOOLZ A Virtual Reality Sketch Tool for Early Design. In *CAADRIA 2000: Proceedings of the Fifth Conference on Computer Aided Architectural Design*; Singapore, (2000); pp. 451–460.

[12] Zhang, B.: Research on visual design method and application of architecture based on BIM + VR. In *IOP Conference Series: Materials Science and Engineering*; (2020); Vol. 750, p. 012110.

[13] Giailorenzo, V.; Banerjee, P.; Conroy, L.; Franke, J.: Application of Virtual Reality in Hospital Facilities Design. Virtual Reality, **4**, 223–234 (1999).

[14] Imottesjo, H.; Kain, J. H.: The Urban CoCreation Lab—An Integrated Platform for Remote and Simultaneous Collaborative Urban Planning and Design through Web-Based Desktop 3D Modeling, Head-Mounted Virtual Reality and Mobile Augmented Reality: Prototyping a Minimum Viable Product and Developing Specifications for a Minimum Marketable Product. Applied Sciences (Switzerland), **12**, 1–28 (2022). http://doi:10.3390/app12020797.

[15] Lau, I.; Gupta, A.; Sun, Z.: Clinical value of virtual reality versus 3d printing in congenital heart disease. Biomolecules, **11** (2021). http://doi:10.3390/biom11060884.

[16] Zaker, R.; Coloma, E.: Virtual reality-integrated workflow in BIM-enabled projects collaboration and design review: a case study. Visualization in Engineering, **6** (2018). http://doi:10.1186/s40327-018-0065-6.

[17] Walmsley, A. P.; Kersten, T. P.: The imperial cathedral in Königslutter (Germany) as an immersive experience in virtual reality with integrated 360° panoramic photography. Applied Sciences (Switzerland), **10** (2020). http://doi:10.3390/app10041517.

[18] Whyte, J.: Innovation and users: Virtual reality in the construction sector. Construction Management and Economics, **21**, 565–572 (2003). http://doi:10.1080/0144619032000113690.

[19] Li, X.; Yi, W.; Chi, H. L.; Wang, X.; Chan, A. P. C.: A critical review of virtual and augmented reality (VR/AR) applications in construction safety. Automation in Construction, **86**, 150–162 (2018). http://doi:10.1016/j.autcon.2017.11.003.

[20] Davila Delgado, J. M.; Oyedele, L.; Demian, P.; Beach, T.: A research agenda for augmented and virtual reality in architecture, engineering and construction. Advanced Engineering Informatics, **45** (2020). http://doi:10.1016/j.aei.2020.101122.

[21] Soto-Martin, O.; Fuentes-Porto, A.; Martin-Gutierrez, J.: A digital reconstruction of a historical building and virtual reintegration of mural paintings to create an interactive and immersive experience in virtual reality. Applied Sciences (Switzerland), **10** (2020). http://doi:10.3390/app10020597.

[22] François, P.; Leichman, J.; Laroche, F.; Rubellin, F.: Virtual reality as a versatile tool for research, dissemination and mediation in the humanities. Virtual Archaeology Review, **12**, 2021 (2021). http://doi:10.4995/var.2021.14880ï.

[23] Paes, D.; Arantes, E.; Irizarry, J.: Immersive environment for improving the understanding of architectural 3D models: Comparing user spatial perception between immersive and traditional virtual reality systems. Automation in Construction, **84**, 292–303 (2017). http://doi:10.1016/j.autcon.2017.09.016.

[24] Ehab, A.; Burnett, G.; Heath, T.: Enhancing Public Engagement in Architectural Design: A Comparative Analysis of Advanced Virtual Reality Approaches in Building Information Modeling and Gamification Techniques. Buildings, **13** (2023). http://doi:10.3390/buildings13051262.

[25] Hajirasouli, A.; Banihashemi, S.; Sanders, P.; Rahimian, F.: BIM-enabled virtual reality (VR)-based pedagogical framework in architectural design studios. Smart and Sustainable Built Environment, (2023). http://doi:10.1108/SASBE-07-2022-0149.

[26] Zoleykani, M. J.; Abbasianjahromi, H.; Banihashemi, S.; Tabadkani, S. A.; Hajirasouli, A.: Extended reality (XR) technologies in the construction safety: systematic review and analysis. Construction Innovation, **24**, 1137–1164 (2024). http://doi:10.1108/CI-05-2022-0131.

[27] Zhang, Q.; Wang, K.; Zhou, S.: Application and practice of vr virtual education platform in improving the quality and ability of college students. IEEE Access, **8**, 162830–162837 (2020). http://doi:10.1109/ACCESS.2020.3019262.

[28] Bartosh, A.; Anzalone, P.: Experimental Applications of Virtual Reality in Design Education. In *ACADIA proceedings*; Austin, (2019); pp. 458–467.

[29] Ibrahim, A.; Al-Rababah, A. I.; Bani Baker, Q.: Integrating virtual reality technology into architecture education: the case of architectural history courses. Open House International, **46**, 498–509 (2021). http://doi:10.1108/OHI-12-2020-0190.

[30] Rauf, H. L.; Shareef, S. S.; Othman, N. N.: Innovation in Architecture Education: Collaborative Learning Method Through Virtual Reality. Journal of Higher Education Theory and Practice, **21**, 33–40 (2021). http://doi:10.33423/jhetp.v21i16.4909.

[31] Rodriguez, C.; Hudson, R.; Niblock, C.: Collaborative learning in architectural education: Benefits of combining conventional studio, virtual design studio and live projects. British Journal of Educational Technology, **49**, 337–353 (2018). http://doi:10.1111/bjet.12535.

[32] Kumar, K. L.; Owston, R.: Evaluating e-learning accessibility by automated and student-centered methods. Educational Technology Research and Development, **64**, 263–283 (2016). http://doi:10.1007/s11423-015-9413-6.

[33] Nersesian, E.; Spryszynski, A.; Thompson, U.; Lee, M.: Encompassing english language learners in virtual reality. In *Proceedings - 2018 IEEE International Conference on Artificial Intelligence and Virtual Reality, AIVR 2018*; Institute of Electrical and Electronics Engineers Inc.: Taichung, (2018); pp. 200–203.

[34] Kamath, R. S.; Dongale, T. D.; Kamat, R. K.: Development of Virtual Reality Tool for Creative Learning in Architectural Education. Int. J. Qual. Assur. Eng. Technol. Educ., **2**, 16–24 (2012).

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Çalışmanın Türkçe İsmi Her Kelimenin İlk Harfi Büyük (Bağlaçlar Hariç) ve "Times New Roman" Fontunda 14 Punto Olacak Şekilde

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Çalışmanın İngilizce İsmi Her Kelimenin İlk Harfi Büyük (Bağlaçlar Hariç) ve "Times New Roman" Fontunda 14Punto Olacak Şekilde

Abstract

Bu Microsoft Word belgesi Haliç Üniversitesi Fen Bilimleri Enstitüsü Müdürlüğü tarafından yayınlanan Fen Bilimleri Dergisi'ne gönderilecek olan makaleler için örnek olması amacıyla hazırlanmıştır. Dergimizde yayınlanmak üzere gönderilen makalelerin bu şablona göre düzenlenmeleri gerekmektedir. Özet kısmında çalışmanın yenilikleri ve temel bulguları vurgulanmalıdır. Türkçe ve İngilizce özet kısımları Times New Roman yazı tipi ile yazılmalı ve 10 punto büyüklüğü seçilmelidir. Yazım metni iki tarafa yaslanmalıdır. Abstract bölümünün yazımında tek satır aralığı seçilmelidir. Makale özetinin 100 ila 200 kelime arasında olmasına dikkat edilmelidir. Türkçe ve İngilizce özetlerin 1 (bir) sayfayı geçmemesi gerekmektedir. Makalenin İngilizce olarak sunulmak istenmesi durumunda başlık, özet ve anahtar kelimelerin önce İngilizcelerinin sonra Türkçelerinin verilmesi gerekmektedir. Anahtar kelime sayısı en az 3 en fazla 6 olmalıdır.

Keywords: Keywords 1 , Keywords 2 , Keywords 3.

1. Giriş

Ana metin, A4 kağıt boyutuna 2 cm kenar boşlukları ile 12 punto yazı büyüklüğünde Times New Roman yazı tipi ile 1 satır aralığı ve her iki yana yaslı şekilde yazılmalıdır. Ana bölüm başlıkları numaralandırılmalı, kelimelerin ilk harfleri büyük olmalı ve **koyu (bold)** karakterde yazılmalıdır. Ana bölüm başlığından sonra 1,5 satır aralıklı boşluk bırakılarak metne geçilmelidir. Başlıkla üst metin arasında da bir satır boşluk bırakılmalıdır. Paragraflar arasında boşluk bırakılmamalıdır. Çalışmanın İngilizce olarak sunulmak istenmesi durumunda bölüm başlığı "**Introduction**" olarak verilmelidir.

Bu bölümde çalışmayla ilgili yeterli literatür bilgisi verilmeli ve çalışmanın gerekçesi belirtildikten sonra amacı vurgulanmalıdır. Ancak konu ile ilgisi olmayan ve gereğinden fazla literatür bilgisi vermekten kaçınılmalıdır.

2. Materyal ve Metot

Bu bölümde, uygulanan yöntemler ve teknikler anlaşılır bir şekilde verilmeli ve metin "Times New Roman" yazı tipinde 12 punto büyüklüğünde ve tek satır aralıkla yazılmalıdır. Metinle ilgili olarak Giriş bölümünde yapılan açıklamalar bu bölüm için de geçerlidir. Başlıkta bağlaç haricindeki tüm kelimelerde ilk harf büyük yazılmalıdır.

Çalışmanın İngilizce olarak sunulmak istenmesi durumunda bölüm başlığı "**Material and Method**" olarak verilmelidir. Bölüm içerisinde alt bölüm başlıkları açılması mümkündür.

2.1. Materyal ve metot alt başlığı

Materyal ve metot bölümünde alt başlık altında bilgi verilmek istenmesi durumunda alt başlık "Times New Roman" yazı tipi, 12 punto ve kalın olarak yazılmalıdır. Alt başlığın ilk kelimesinin ilk harfi büyük, geri kalan kısmı ise küçük harflerle yazılmalıdır.

2.2. Şekiller, Tablolar ve Denklemler

Şekiller grafik, diyagram, fotoğraf, resim ve harita şeklinde olabilir. Şekil yazısı şeklin alt kısmına yazılmalıdır. Hem şekil hem de şekil yazısı sayfaya ortalanmalıdır. Şekil yazıları okunaklı olmalıdır. Şekil ile üst metin arasında 1 satır boşluk bırakılmalıdır. Şekil yazısı ile alt metin arasında da 1 satır boşluk bırakılmalıdır. Şekil yazısı 11 punto olarak yazılmalı ve aşağıdaki örnekte (Şekil 1) olduğu gibi verilmelidir. Metin içerisinde şekillere atıfta bulunulmalıdır.

Şekil 1. Örnek Resim

Tablolar açık çerçeveli tercih edilebilir. Tablo yazısı tablonun üst kısmına yazılmalıdır. Hem tablo hem de tablo yazısı sayfanın soluna hizalanmalıdır. Tablo yazısı ile üst metin arasında 1 satır boşluk bırakılmalıdır. Tablo ile alt metin arasında 1 satır boşluk bırakılmalıdır. Tablo yazıları tercihen 11 punto ile yazılmalı ve tek satır aralığı seçilmelidir. Metin içerisinde tablolara atıfta bulunulmalıdır.

Tablo 1. Tablo Başlığı

Sütun Başlığı	Sütun Başlığı	Sütun Başlığı
Bilgi satırı	Bilgi satırı	Bilgi satırı
Bilgi satırı	Bilgi satırı	Bilgi satırı
Bilgi satırı	Bilgi satırı	Bilgi satırı
Bilgi satırı	Bilgi satırı	Bilgi satırı

Denklemler sırasıyla 1'den başlanarak numaralandırılmalıdır. Denklem sola yaslanarak yazılmalı ve denklem numarası sağ kenara yerleştirilmelidir. Denklem ile metin arasında üstten ve alttan birer satır boşluk bırakılmalıdır. Denklemler resim formatında olmamalıdır. Word denklem düzenleyicisi tercih edilebilir.

$$E=mc^2 \tag{1}$$

3. Bulgular

Bu bölümde çalışma sonucunda elde edilen bulgular çalışma sırasına göre sunulmalıdır. Çalışmanın İngilizce olarak sunulmak istenmesi durumunda bölüm başlığı "**Results**" olarak verilmelidir.

4. Tartışma

Bu bölümde, yapılan çalışmadan elde edilen bulgular bilimsel ilkelerin ışığı altında önceki verilerle karşılaştırılarak irdelenmelidir. İstenilmesi halinde, elde edilen bulgular ve bunların irdelenmesi **Bulgular ve Tartışma** başlığı altında da verilebilir.

5. Sonuçlar

Bu bölümde çalışmadan elde edilen özgün sonuçlar bir sıra dâhilinde sunulmalıdır. Çalışmanın İngilizce olarak sunulmak istenmesi durumunda bölüm başlığı “**Conclusions”** olarak verilmelidir.

Teşekkür

Bu bölümde, çalışmada yardım ya da destekleri bulunan kişi veya kişilere ya da kurum yetkililerine teşekkür edilebilir. Çalışmanın İngilizce olarak sunulmak istenmesi durumunda bu bölümün başlığı “**Acknowledgment**” olarak verilmelidir.

Kaynaklar

Çalışmada yararlanılan kaynaklar kullanım sırasına göre numaralandırılarak verilmelidir. Ancak Özet bölümünde kaynak gösterilmez. Kaynak numaraları köşeli parantez içerisinde gösterilmelidir. Kaynakların tamamı çalışmanın son sayfasındaki “Kaynaklar” başlığı altında, makale içerisindeki kullanım sırasına göre aşağıdaki örneklere uygun biçimde verilmelidir. Kaynaklar “Times New Roman” fontunda 10 punto olarak yazılmalıdır. Kaynak numaraları otomatik numaralandırma ile eklenmelidir ve her referans arasında 6 punto boşluk olmalıdır. Çalışmanın İngilizce olarak sunulmak istenmesi durumunda bölüm başlığı “**References**“ olarak verilmelidir.

Periyodik yayınlar:

[1] Soyadı, A., Soyadı, B. B., ve Soyadı, C.,. Yayınlanan makalenin adı, Makalenin yayınlandığı dergi adı, Cilt ve sayı numarası 7(1), (yıl) sayfa numarası aralığı 1-12. Doi:

Kitaplar:

[2] Soyadı, A. A., Kitap adı, Yayınevi, Kitabın basıldığı yer, (yıl).

Sempozyum, Kongre, Bildiri:

[3] Soyadı, A., Soyadı, B. B., ve Soyadı, C., Yayınlanan bildirinin adı, Bildirinin yayınlandığı sempozyum kongre, toplantı ya da konferans adı (s. 1-12), (yıl, Ay), Şehir, Varsa üniversite veya kuruluş.

Tez:

[4] Soyadı, A. A., Yüksek Lisans veya Doktora tezinin adı, Tezin türü, Üniversite, Enstitü, (yıl).

Web sitesi:

[5] http://www.halic.edu.tr, (Erişim tarihi:).

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