

# International Journal of Urban Management and Energy Sustainability (JUMES)

Homepage: <http://www.ijumes.com>



## ORIGINAL RESEARCH PAPER

### The evolution of Iranian architectural technology with regard to modern technology in the use of building materials

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#### ARTICLE INFO

*Article History:*

Received 2025-04-02

Revised 2025-06-10

Accepted 2025-07-24

*Keywords:*

Architecture, construction materials, innovative design, Iranian architecture, modern technology, sustainable architecture

DOI: [10.22034/ijumes.2025.2066593.1318](https://doi.org/10.22034/ijumes.2025.2066593.1318)

#### ABSTRACT

In this study, the challenges and opportunities for technological development in Iranian architecture have been examined. Major obstacles include economic limitations, lack of technical infrastructure, deficiencies in workforce training, and the absence of cohesive standards, which slow down the progress of modern technologies in construction. Conversely, rich cultural heritage, climatic diversity, digital technologies, and international collaborations offer significant opportunities to overcome these barriers. The current research is analytical in nature and aimed at practical application. Data collection was conducted through documentary and library sources, utilizing recent reports and resources on Iranian architecture. Initially, the study employing content analysis explores fundamental concepts, and through inductive reasoning, examines and scrutinizes composite concepts. Findings indicate that utilizing indigenous construction materials, innovative designs, and technologies such as BIM and parametric design can reduce costs and enhance cultural identity. Consequently, to effectively support this process, developing a comprehensive national program with standardization, financial policies, promoting specialized education, and establishing research and development institutions are essential. Regional and international collaborations and the development of a competitive environment also play a crucial role in accelerating technology and elevating architectural projects. The integration of these policies and actions paves the way for achieving sustainable, innovative, and identity-driven architecture, outlining a sustainable and progressive future for Iranian architectural art.

Running Title: Iranian architectural technology with regard to modern technology in the use of building materials



NUMBER OF REFERENCES

24



NUMBER OF FIGURES

04



NUMBER OF TABLES

03

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## **INTRODUCTION**

The history of technological transformation in Iranian architecture reflects the history, culture, and technologies of each era, demonstrating how architectural art has adapted to tools and materials over time. From prehistoric times to the contemporary era, the use of construction materials and modern technologies has played a significant role in shaping and developing Iranian architectural spaces (Akbari and Mohseni, 2020). In ancient times, materials such as bricks, stone, and plaster were the primary substances used, and construction technologies were largely limited to traditional achievements. However, over time, especially during the Islamic period, art and technology in Iranian architecture flourished with the adoption of new materials; examples include magnificent palaces and mosques with intricate decorations and resilient structures (Behzad and Nazari, 2019). During the Middle Ages, Iranian architecture benefited from advanced technologies such as qanats, water features, and arches, which exemplified the blend of technology and art. The use of materials like tiles, adobe, and bricks alongside modern technologies in interior and exterior designs contributed to architectural progress (Farahani et al., 2018). In the Qajar era, the development of industrial technology and the import of new materials like iron and glass created new opportunities in architecture. Buildings in Tehran and other major cities exemplify the successful integration of modern materials with traditional architecture (Hosseini and Ebadi, 2017). Technological advancements during the Pahlavi era, with the introduction of modern materials such as concrete and steel, enabled the construction of tall structures and modern buildings. These developments contributed to urban modernization and innovative architectural designs (Akbari and Mohseni, 2020). After the Islamic Revolution, modern technologies continued to influence the materials used and the construction of buildings, especially in tower projects, housing, and administrative structures.

Innovative construction technologies, such as the use of sustainable materials and modern insulation systems, have gained importance (Hosseini and Ebadi, 2017). Today, modern technologies in Iranian architecture include the use of green materials, smart building systems, and digital construction technologies, which play a vital role in reducing costs and environmental pollution. These technologies are employed to address climatic needs and promote sustainable development (Javadi and Rezaei, 2022). The development of technology in Iranian architecture reflects the alignment of global innovations with indigenous needs; in such a way that modern materials and technologies have helped to design durable, beautiful, and efficient buildings. This process indicates a continuous and evolutionary path in the use of materials and technologies (Hosseini and Ebadi, 2017). Consequently, the trajectory of technological and material evolution in Iranian architecture embodies the cultural and technological development of this land and holds significant importance for understanding the future of Iranian architecture. The progress of modern technologies offers new opportunities for architects and engineers to create better and more sustainable architectural spaces (Akbari and Mohseni, 2020). The advancement of technology and the application of modern materials in Iranian architecture have always been critical and sensitive issues, requiring deep understanding and precise analysis. In contemporary history, technological changes in civil and architectural fields have been influenced by global technologies, continually playing an important role in the development of buildings and urban spaces (Kamal and Mousavi, 2019). In modern times, many high-rise buildings, green structures, and public spaces have been constructed utilizing modern technologies and advanced materials. However, challenges such as the unsustainable use of materials, discontinuity between traditional and modern technologies, and the mismatch of new technologies with indigenous needs persist (Lotfi and

Malki, 2020). This topic is important in various respects because any transformation in technology and materials directly impacts the lifespan, efficiency, and sustainability of buildings. Consequently, a lack of accurate and up-to-date understanding of technological trends can lead to the construction of inefficient or unsustainable buildings, causing significant economic and environmental damages (Ghasemi and Kiani, 2021). On the other hand, Iranian architectural culture, considering its long history and climatic and cultural diversity, requires the adaptation and integration of modern technologies to preserve architectural authenticity and values alongside technological efficiency. Therefore, careful examination and analysis of transformation trends are necessary so that architects and engineers can make informed practical decisions. Additionally, the absence of comprehensive and documented studies in the field of the compatibility of modern technologies and materials in Iranian architecture highlights the need for further research in this area. The lack of scientific standards and indigenous technologies has hindered the development of innovative and sustainable architecture in the country. Successful examples of proper utilization of new technologies and materials exist in other countries, but Iran has yet to fully benefit from these experiences or develop its own native technologies. This gap underscores the importance of reviewing the history, present, and future trends of technology and materials in the country's architecture (Mahdavi and Takoli, 2018). In this context, addressing this topic is vital because an in-depth understanding of the evolution of technology and materials can play a significant role in urban development, heritage preservation, and responding to environmental crises. This topic helps architects and policymakers to present suitable strategies for the future of the country's architecture (Nemati and Farrokhzad, 2021). On the other hand, global trends towards green architecture, smart buildings, and sustainable materials have also compelled Iran to

pursue technologies aligned with the country's climatic and cultural conditions. Understanding past and current trends offers a pathway toward progress and innovation in the future. Therefore, the necessity of this research lies not only in collecting and analyzing historical trends but also in providing practical solutions for developing new technologies and materials to meet urban, economic, and environmental development needs. This research aims to strengthen the process of developing indigenous technologies and transfer experiences from successful countries (Ostadrahimi and Hosseini, 2019)

### **MATERIALS AND METHODS**

Technology in architecture is a set of technologies and methods used in the process of designing, constructing, and operating buildings. In Iranian architecture, these technologies have been an important part of the development and maintenance of cultural, religious, and residential spaces. Since ancient times, Iranian architects, based on their knowledge of local materials and technologies, have designed resilient, beautiful, and efficient structures. The relationship between technology and architecture has always been a dynamic and symbiotic one; indigenous technologies in each era have inspired the architectural structures characteristic of that time (Parvizi & Azizi, 2022). In this context, understanding the technological processes and architectural design processes in Iran reflects the cultural and technological development of this land.

#### *History of Technology in Iranian Architecture*

In ancient times, materials and construction technologies in Iran were developed based on ecological knowledge, ethics, and climatic needs. Materials such as bricks, adobe, stone, and plaster were developed through traditional methods and numerous experiments to construct buildings resistant to the country's different climates (Qasemian and Salarian, 2017). In the Islamic period, construction technologies such as Iranian arches, domes, and fountains were combined with modern technologies,

reflecting engineering and technological advances. In addition to their strengthening role, these technologies acquired an aesthetic and cultural aspect (Ramazani and Khalili, 2020). In the Qajar period, buildings and public spaces were developed with the import of new materials and industrial technologies such as iron and glass. These developments created high-rise structures and neoclassical and modern Iranian buildings (Safavi and Miri, 2019). Technological advances in the contemporary era, including the use of concrete, steel, and digital technologies, have transformed urban structures and architecture. Therefore, technologies in Iran have gradually changed from traditional technologies to advanced and modern technologies (Tabrizi and Hedayati, 2021). Technology also plays an important role in the field of conservation and restoration of Iranian architectural monuments. Modern technologies such as 3D imaging, digital modeling, and new restoration materials have made it possible to reconstruct and maintain historical monuments in a more accurate manner (Vahidi and Farahmand, 2018). At the same time, indigenous technologies such as the use of traditional tiles, natural materials, and traditional construction technologies play a role in preserving the authenticity and identity of Iranian architecture. Combining modern and traditional technology can be sustainable and efficient solutions in the management of historical monuments (Yazdani and Kordestani, 2022). With the advancement of technology, it has become possible to build more resistant and efficient examples in Iranian architecture against earthquakes, wind, and rain. These technologies, while preserving cultural values, help in better monitoring and maintaining buildings (Zare and Esfahani, 2017)

#### *Architectural design technology and process in Iran*

Technology plays a fundamental role in the process of Iranian architectural design. Today, virtual design technologies, building information modeling, and virtual reality are powerful tools that Iranian architects use in the design and

evaluation process of projects (Azerbaijani and Mofidi, 2012). These technologies have enabled accurate simulation, building performance evaluation, and reduction of design errors. At the same time, understanding construction technologies helps architects and engineers to present innovative, resilient designs that are in line with cultural and climatic needs. In some examples of traditional and contemporary architecture, we witness the use of technologies such as digital mapping, structural analysis, and climate simulation, which play an important role in improving the performance of architectural spaces. Also, technology in the development of environmental parameters and energy efficiency in architectural design in Iran has created new approaches that play an important role in the development of green and sustainable architecture (Foroutan, 2011). In the construction process, new technologies such as digital manufacturing technologies, 3D printing, and automated technologies have practically played a transformative role in Iranian architectural projects. These technologies have greatly increased the speed of implementation, accuracy, and reduced construction costs (Balikhani, 2010). Also, modern construction technologies provide the possibility of producing complex structures, unique shapes, and organic architecture that in the past, the possibility of constructing them was very limited or impossible. In restoration and preservation projects of historical monuments, imaging technologies and 3D scans have provided new possibilities for documenting and analyzing the existing condition of buildings, which can lead to better methods of restoration. Technology is also very efficient in designing surfaces and decorative elements (Jahanes, 2010). With the advancement of implementation technologies, new methods have been developed in the manufacture of materials, coatings, and reinforcement systems that are much more resistant to salinity, earthquakes, and other climatic hazards, reducing economic and environmental consequences.

#### *Technology in building maintenance and operation*

Technology plays an important role in the maintenance and operation of buildings. Smart systems, biosensors, and online monitoring systems have enabled better management of buildings (Foroutan, 2011). In Iranian architecture, new technologies, including smart control systems, can improve energy consumption, the performance of cooling and heating systems, and the health of structures. These technologies, in addition to reducing costs, also increase the useful life of buildings. In addition, by using adaptive technologies, the level of satisfaction of residents and users can be increased and the interior and exterior space of the building can be adapted to new needs (Gorji Mahlabani, 2015). Also, digitalization and smart management methods play a vital role in the process of warehousing, preventive maintenance, and building renovation, which have a great contribution to the development of smart buildings in Iran. Laser scanning, multi-beam imaging, and 3D classification are important tools in the documentation, analysis, and restoration of ancient monuments. These technologies have enabled the accurate restoration, reinforcement, and reconstruction of historical monuments (Foroutan, 2011). Especially in Iran, with its rich history and unique cultural heritage, digital scanning and modeling technology plays a key role in preserving the authenticity and identity of historical monuments. Another technology used is nanotechnology in restoration and reconstruction, with the aim of strengthening materials and preventing environmental degradation (Golabchi and Nagizadeh, 2011). In addition to these technologies, recovery and restoration methods based on modern technologies have improved the conservation conditions for damaged monuments. These technologies enable damage analysis in the shortest possible time and have shortened and made the restoration process, which was long and expensive in the past, short and economical. As a result, technology in the protection of Iranian cultural heritage works, in addition to protection, deep-

ens the process of documentation, knowledge, and scientific analysis, and leads to the development of scientific and reasoned protection and restoration policies. Despite technological advances, there are many challenges in the field of technology in Iranian architecture. One of the most important challenges is the scalability of modern technologies with local and cultural needs (Gorji Mahlabani, 2015). Many of the technologies used require adaptation to Iranian climatic and cultural conditions. On the other hand, high costs, lack of specialized personnel, and the absence of specific standards limit the development of technology. At the same time, dependence on foreign technologies may put the domestic construction and architecture industry at risk and hinder the development of indigenous technologies. On the other hand, there are many opportunities for the development of Iranian technologies. The potential of using indigenous materials and traditional technologies, alongside modern technologies, can be a solution. Utilizing digital and modern technologies, along with preserving cultural values, are innovative solutions in Iranian architecture (Farahani et al., 2018).

#### *Technological Challenges in Iranian Architecture*

One of the main challenges is the lack of infrastructure necessary for the development and expansion of advanced technologies. These deficiencies include the lack of modern equipment, the lack of specialized personnel, and the lack of unified standards in the field of technology and construction (Foroutan, 2011). In many cases, technologies imported from abroad do not meet local needs, which leads to a gap between technology and practical application. Another issue is the instability and compatibility of new technologies with the climate and environmental conditions of Iran. Many of today's technologies are exposed to environmental damage and require localization and modification to make them more reliable. Also, high initial costs and the lack of strong support from the government and the private sector limit the implementation of new technologies. Another challenge is

the conservative outlook in society, especially in the field of architecture and construction in Iran, which causes resistance to the acceptance of new technologies. This trend, along with the lack of attention to the importance of education and research, slows down the development of technology in the construction industry. It can be concluded that in different periods, the role of technology in the protection, restoration, development, and exploitation of historical monuments has always been a topic of attention. Modern technologies, with features such as digital construction, modeling, 3D scans, and new materials, have been able to play a fundamental role in the evolution of modern architecture in

Iran. At the same time, challenges such as the shortage of specialized human resources, the lack of complete standards, and high costs are common and require continuous policymaking, financial support, and specialized training. Opportunities for localizing traditional technologies and combining them with modern technologies are the key to developing sustainable and identity-oriented Iranian architecture. Progress in this area requires cooperation between government institutions, universities, and the private sector, so that they can properly apply new technologies in the country's construction and architecture industry and bring brilliant results at the regional and global levels. (Tab. 1)

Table 1: Table of technological challenges in Iranian architecture

Concepts	Key Points	Explanations	Related Examples	Advantages / Opportunities	Challenges and Limitations
History of Technology in Iranian Architecture	Development of materials, traditional and modern technologies	The evolution process of technology from ancient times to the modern era	Use of brick, plaster, dome and arch technologies in historic buildings	Strong cultural heritage, progress in restoration and preservation	Lack of indigenous technology and dependence on foreign technology
Role of Technology in Heritage Preservation	Documentation technologies, digital scanning, and modeling	Preserving authenticity and restoring historic artifacts	Laser scanning, 3D modeling of historic buildings	More precise conservation, reduction of restoration costs and time	High costs, need for advanced and specialized equipment
Technology in the Design Process	Digital tools, BIM, virtual reality	Improving the design and evaluation process of buildings	Revit software, climate simulation, 3D modeling	Increased accuracy, error reduction, rapid modeling	Need for specialized training, high software costs
Construction and Implementation Technologies	Digital technologies, 3D printing, modern construction	Fast and accurate execution of architectural projects	Construction of complex structures, decorative elements, earthquake-resistant structures	Reduced time, lowered costs, development of resilient and innovative structures	Need for skilled workforce, high initial costs
Technology in Operation and Maintenance	Smart systems, biosensors, online monitoring	Managing energy consumption, improving building performance	Smart control systems, IoT technology in buildings	Reduced maintenance costs, longer building lifespan	Need for maintaining sensitive equipment, data security
Technology in Education and Research	Virtual tools, augmented reality, online education	Enhancing scientific knowledge, facilitating education and research	Online courses, virtual laboratories, design educational software	Rapid advancement, training specialized workforce, developing innovative technologies	Financial limitations, lack of technological infrastructure in some centers
Opportunities and Strategies for Technology Development	Indigenous zing traditional technologies, developing green and modern technologies	Using local materials, indigenous technologies, reducing foreign dependence	Nanotechnology in materials, updated traditional construction methods, local materials	Increased competitiveness, identity focus, sustainable development	Lack of financial support, need for cohesive science and technology policies

### *New building materials in Iranian architecture*

In contemporary Iranian architecture, the role of new materials and new technologies in improving efficiency, increasing durability, reducing costs, and improving the quality of buildings has been given great attention. New materials, which are generally made from advanced technologies, are replacing traditional materials that have been used throughout Iranian history to construct various buildings. These materials have technical, economic, environmental, and artistic advantages and can revolutionize the way buildings are constructed, renovated, and operated. The purpose of this article is to examine the theoretical foundations of new materials in Iranian architecture, their advantages and challenges, practical examples, and future prospects in this field. New building materials are materials that are manufactured and developed based on modern technologies, with different characteristics from traditional materials. These materials may include composite materials, materials resistant to harsh environmental conditions, green and environmentally friendly materials, and smart materials. In Iranian architecture, which is known for its thousands of years of history and rich cultural heritage, the integration of modern materials with traditional materials can lead to the construction of buildings that are highly efficient, earthquake-resistant, energy-efficient, and in line with cultural values. Throughout history, traditional materials such as brick, plaster, adobe, stone, and wood have played a fundamental role in the construction of Iranian buildings. These materials have always been used due to their easy accessibility, strength, and natural beauty. However, with the advancement of technology and modern needs, modern materials have replaced old materials. In recent decades, examples such as green concrete, advanced thermal insulation materials, lightweight and earthquake-resistant materials, and smart materials have been developed in Iranian architecture, which indicates the technological evolution in construction. The main advantages of modern

materials include reduced energy consumption, increased earthquake resistance, resistance to moisture and pollution, better integration with the environment, and reduced maintenance costs. For example, modern thermal insulation materials reduce energy consumption for heating and cooling, which is particularly important due to Iran's dry and humid climate. Lightweight materials, such as polymer composites, facilitate construction and reduce the weight of the structure, and therefore play a key role in designing durable and resilient buildings. In addition to the advantages, challenges such as high initial cost, lack of technical knowledge, lack of national standards, and weakness in the education and technology transfer process prevent the widespread development of modern materials in Iranian architecture. Also, environmental concerns, cultural resistance to change, and lack of supportive policies are limiting factors in this area. One of the most important parts in the development of new materials is the formulation of national standards, assessment of useful life, and adaptation to the country's different climates. Iran needs foundational research and development of localized materials so that the role of modern materials reaches its highest level and, along with it, the cultural identity of Iranian architecture is preserved. Localization of technology reduces costs and better adapts to the needs of Iran's diverse climates.

### *New technologies in materials production*

In the last few decades, new technologies have been developed in the field of building materials production that play a significant role in the evolution of architecture. Technologies such as nanotechnology, bio-styling technologies, polymeric materials, smart composites, and green materials are among the prominent examples. These technologies change the physical and chemical properties of materials in such a way that they can meet the specific needs of modern structures. Nanotechnology, one of the most advanced technologies, helps in making materials more resistant and smarter. For exam-

ple, examples of this type of materials include nano-mesh, waterproof and anti-pollution nano-coating, and nano-isokits that improve insulation and reduce environmental pollution (Foroutan, 2011). As a result, new technologies provide more possibilities for designing and constructing high-performance buildings, better protection against pollution and climate change, and the development of localized materials. Given the climate and natural resources in Iran, the development of green and energy-efficient materials plays an important role in realizing sustainable buildings. In this regard, technology-oriented companies and researchers in the country are engaged in the development of materials such as green concrete, new insulation, and composite materials. These new materials reduce the need for high energy-consuming processes, reduce maintenance costs, and increase the life of structures. Growing public awareness and government policies can play a significant role in promoting the use of these types of materials (Golabchi and Taghizadeh, 2011).

#### *The function of modern materials in Iran*

In recent years, valuable successful projects in the field of new materials have been implemented in Iranian architecture, a clear example of which can be a guide for future projects. For example, in the Mesha Villa project in Damavand, nano-concretes and materials resistant to moisture and pollution have been utilized. In the Qazvin Grand Mosque projects, the use of smart materials for insulation systems and anti-pollution tiles are examples of the integration of Iranian technology and culture. Also, in high-rise construction in Tehran, new lightweight and durable materials, such as polymer composites, have been utilized, which help reduce the weight of the structure and increase earthquake resistance. The use of green and localized materials in residential and office projects has reduced construction and maintenance costs and increased the durability of buildings. In addition, projects in the field of restoration of historical structures have benefited from

low-impact, high-tech materials that ensure the preservation of cultural identity alongside modern technology. In the field of developing new materials, the role of the government and government policies is very important. Correct policies and the creation of the necessary infrastructure can pave the way for the growth of innovative technologies in the field of building materials. For example, countries such as Japan and Germany, with financial support and incentive laws, have been able to develop new material technologies in large national projects and reduce dependence on traditional materials. In Iran, sustainable development policies and the use of green technologies in urban design and construction can play an important role. Paying attention to environmental needs and reducing the negative effects of the construction process by using new and localized materials are among the policy priorities that must be defined and pursued at the national and regional levels. In addition, establishing national standards, developing technical guidelines, and promoting specialized training in the field of new materials are other important measures that will build public and industrial trust and acceptance. In addition, encouraging investment in the field of new material technologies and supporting technology companies and applied research play a vital role in the development of this industry. In implementing policies for the development of new materials, the government needs to expand multilateral cooperation with the private sector, universities, and research centers so that new technologies can be developed and exploited in the domestic market. Supportive policies can pave the way for economic and technological development in the country's construction industry. In these theoretical foundations, the importance and position of new materials in promoting construction, protecting cultural heritage, reducing energy consumption, and the country's industrial development were emphasized. New technologies bring different opportunities and challenges for Iranian architecture

**Table 2:** Technological criteria in Iranian architecture with the approach of using new materials

Criteria	Explanations	Related Examples / Items	Advantages / Significance	Challenges / Limitations
Compatibility with Iranian Climate and Culture	Materials must be aligned with various climates and Iranian cultural identity	Indigenous materials, mud brick, fired brick, natural plaster	Enhancing architectural identity, energy savings	Lack of suitable technology and technical knowledge
Resistance to Earthquakes and Specific Climates	Materials should withstand earthquakes and environmental changes	Green materials, resistant materials against humidity and cold	Ensuring occupant safety, reducing financial and human losses	High costs, limited standards
Efficiency and Long-term Durability	Materials must have a long service life and require minimal maintenance	Green concretes, composite materials, nanotechnology	Reducing maintenance costs, increasing structural lifespan	Lack of comprehensive and widespread technologies domestically
Environmental and Green Features	Materials should be eco-friendly, energy-efficient, and recyclable	Indigenous materials, zero-energy buildings, smart materials	Reducing pollution, conserving natural resources	High initial costs, public awareness deficits
Economic Feasibility and Localization Capability	Materials should be locally produced using internal resources and technology	Indigenous materials, domestic manufacturing technologies	Cost reduction, development of domestic industry and employment	Lack of indigenous technologies, limited investment
Flexibility in Design and Construction	Materials should be adaptable for diverse and innovative designs	Polymer-based, new composites, smart materials	Creating diverse buildings, meeting various needs	Lack of standard and scientific technologies
Development of Technology and Innovation in the Material Industry	Technologies should be modern, up-to-date, and developable domestically	Nanotechnology, 3D printing of materials, smart technologies	Competitiveness in global markets, reducing dependence on foreign technologies	Lack of investment, weaknesses in research infrastructure

and construction. By formulating appropriate policies, standardizing and localizing materials, scientific and technological cooperation, and government support, these technologies can be used in the path of sustainable development and Iranian architectural culture. In the future, paying attention to green materials and smart technologies, developing domestic and foreign markets, and integrating new technologies into large projects will pave the way for the country to achieve its development goals, and Iran can be recognized as one of the pioneers in the region and the world in this field. (Tab. 2) (Fig. 1 to 4)

*Challenges and limitations of technology development in sustainable architecture in Iran*

The development of new technologies in the field of architecture in Iran faces several challenges that must be considered in the process of their development and consolidation. One of the main problems is the lack of research

and development infrastructure. Iran is still in the development stage in the field of new technologies, especially nanotechnology and digital manufacturing technology, and requires large investments, promotion of a culture of innovation, and development of research centers. Cultural and educational limitations, especially the lack of awareness and professional training in the field of new technologies, are other problems. Many architects and builders are still not familiar with new technologies or consider them to be underused, which causes a slowdown in the implementation of technology-based projects. The development of the education system in the field of architecture and technology requires reforming education methods and promoting a culture of innovation. In addition, economic limitations, especially the high cost of new technology and materials, are another issue that limits the efficiency and widespread use of

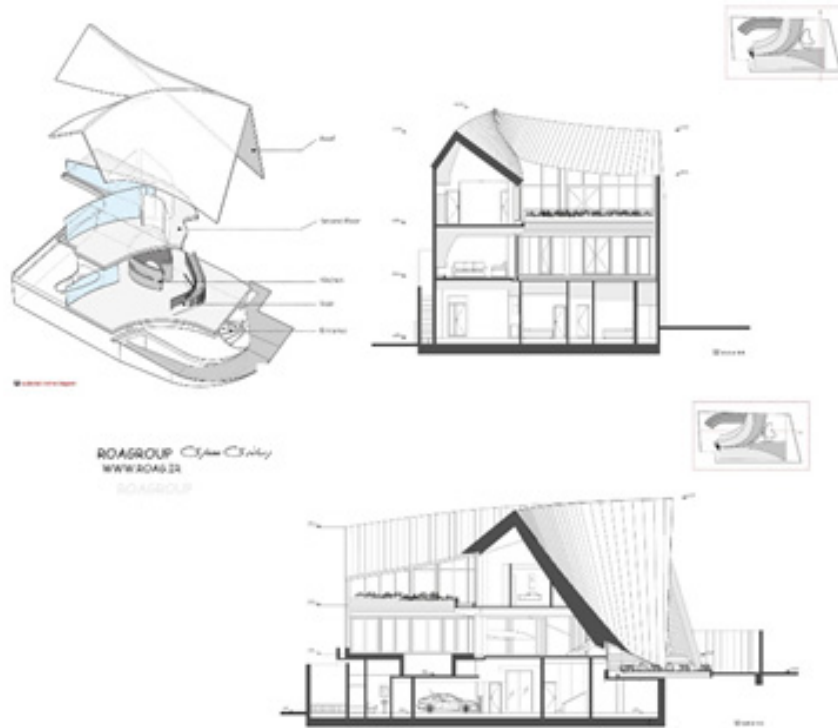


Figure 1 to 4: Figure 1, right: Masha Villa, Damavand, Figure 2, middle: Kahrizak residential building, Figure 3 and 4, left and bottom: Younger Brother's Villa, Lavasan, Tehran

new technologies in many projects in Iran. The lack of strong government support policies in the technology sector has an impact on the lack of development of these technologies. Another problem is the lack of national and international standards related to new materials and technologies, which has led to uncertainty about their conclusions and effectiveness. This issue poses a problem in the process of accepting and trusting new technologies in the construction industry. Therefore, the development of reliable and comprehensive standards is essential. In the face of challenges, there are many opportunities for de-

veloping technology and designing sustainable buildings in Iran. One of the most important of these opportunities is the cultural richness and traditional architecture of Iran, which shows that the intelligent use of local materials and technology can lead to sustainable architecture based on the Iranian lifestyle (Gorji Mahlabani, 2015). This approach is known as an example of technology localization and sustainable development. Also, government and private sector investments in green and new technologies can play an important role in developing and accelerating the process of adapting to climate

change and reducing the negative effects of traditional construction. Successful domestic and foreign examples in this field can pave the way for new policies and projects (Afshari Basir et al., 2011). The use of new technologies is also a great opportunity to improve efficiency and reduce resource consumption in existing buildings. Renovation of historical and traditional buildings with new technologies, in line with preserving cultural values, can help develop environmentally friendly architecture. In this process, smart software and new materials play a key role (Balikhani, 2010). In this regard, the development of supportive and incentive policies, along with education and promotion of technology, can help institutionalize new technologies in the country's construction industry. Holding specialized exhibitions, establishing technology and laboratory centers, and international cooperation in the field of technology are operational examples of these opportunities (Fruton, 2011).

*The role of policymaking and education in the sustainable development of Iranian architecture*

The macro-policies of the government and relevant institutions play a decisive role in facilitating and promoting new technologies and the development of sustainable architecture. Developing national and international standards for the acceptance, validation, and accreditation of green and new technologies in the construction industry is one of the most important tasks of policymakers. In Iran, the lack of these standards is one of the main obstacles that delays the process of adopting new technologies. Incentive policies, such as tax reductions, subsidies, and low-interest loan facilities, can also create the necessary motivation for architects, contractors, and material manufacturers to move towards green and environmentally friendly technologies. These policies should be designed in a way that, while preserving the country's economic interests, is in line with environmental goals. Education and promotion of a technology-oriented culture at the level of universities, specialized centers, and the general community are other

vital elements in sustainable development. Educational programs should be based on new technologies, green architecture principles, and the recovery of traditional Iranian architectural values. These trainings, while improving the level of technical knowledge, can change the attitude and behavior of residents and builders towards sustainable development. On the other hand, the use of new technologies in education, such as digital simulation, augmented reality, and virtual reality, can make the process of teaching issues related to sustainable architecture more attractive and effective. The use of these technologies, especially in universities and higher education centers, plays an important role in cultivating future generations of architects and craftsmen who are familiar with and engaged with technology and sustainability.

*Culture-building and socialization in the process of sustainable development of Iranian architecture*

Creating a culture and providing accurate information about sustainability concepts and new technologies plays a fundamental role in changing society's attitude towards environmental protection and the importance of green architecture. In Iran, due to its deep cultural roots and long-term knowledge of local architecture and materials, utilizing traditional knowledge and combining it with new technologies can play an effective role in the acceptance process (Farahani et al., 2018). In this regard, the media, virtual networks, and public educational programs play a fundamental role. Holding information campaigns, local workshops, and creating symbolic buildings can institutionalize the culture of using green technologies and sustainable architecture in society (Akbari and Mohseni, 2020). Forming professional associations and organizations, with a focus on sustainability concepts, and promoting them at the national level, can have more weight and credibility in the process of cultural reforms. The development of local and indigenous approaches, and the emphasis on cultural and traditional values, play an important role in the process of culture-building. Iranian architec-

ture, due to its styles and materials adapted to the climate, is a great tool for promoting sustainability concepts. In this regard, the coordination between traditional teachings and modern technology can be a suitable solution for social and cultural acceptance (Hosseini and Ebadi, 2017).

*Technological development in modern Iranian architecture and its role in sustainability*

In recent years, the growing trend of technological development in modern Iranian architecture has provided new opportunities for achieving sustainability goals. Integrating modern technologies with Iranian architecture not only improves the quality and efficiency of buildings, but also ensures the preservation of the country's cultural identity and historical heritage. Examples such as smart buildings, houses with indigenous materials, and modern technology are successful examples in this area that have been able to meet the needs of contemporary society while preserving traditional values (Hosseini and Ebadi, 2017). One of the most important benefits of using technology in Iranian architecture is the reduction of energy and natural resource consumption. Modern technologies in cooling and heating systems, solar energy utilization, and energy-saving materials directly contribute to reducing environmental impacts. In addition, virtual technologies such as 3D design, functional modeling, and virtual reality have made it possible to design, evaluate, and modify projects at an early stage, which reduces waste and costs. Within the country, companies and design centers should increase trust in new technologies through specialized training, branding, and proving the effectiveness of technology in exemplary projects. Investing in green and smart technologies demonstrates a commitment to sustainable development and foresight. Policies should also be developed and implemented to support technology-based projects in the form of financial facilities and incentives (Akbari and Mohseni, 2020). In summary, technology, as a driving force in the evolution of modern Iranian architecture, is not only a solution to environ-

mental problems but also a factor in preserving cultural identity and economic development. This requires cooperation between industry, academia, and the government to achieve a sustainable, cultural, and technological architecture. The development of new technologies has positive effects on environmental aspects. Improving energy efficiency, using environmentally friendly materials, and utilizing renewable technologies, in line with sustainability goals, can ensure a significant reduction in the negative impacts of construction on the environment (Kamali and Mousavi, 2019). In the economic sphere, new technologies are associated with high investment costs in the short term, but in the long term, reducing energy consumption and maintenance creates significant savings. It seems that the use of local materials and new technologies, in addition to reducing costs, creates opportunities for economic development and job creation in the country's construction industry (Akbari and Mohseni, 2020). Also, technology exchange with other countries, based on scientific and commercial interactions, can help transfer more advanced technologies and, as a result, improve the level of the country's construction industry. The country, given its cultural and climatic capacities, can become a successful example in the region in the development of environmentally friendly technologies (Hosseini). The development and adoption of new technologies in architecture have important effects on the cultural and social structures of society. New technologies not only facilitate technical and design activities, but can also change attitudes, values, and social behaviors. Changes in consumption patterns, environmental awareness, and public education can significantly move the culture of life and behaviors of society towards sustainable concepts (Akbari and Mohseni, 2020). In Iran, paying attention to cultural heritage and traditional values alongside new technologies is of great importance. The penetration of digital technologies and new tools makes it possible for the Iranian architectural heritage to

be restored, reconstructed, and promoted in a new way, which will preserve cultural identity (Maleki et al., 2019). Given the changes in lifestyle, the demand for buildings with modern and technological designs is an opportunity for cultural awareness. Technology-based projects, by utilizing traditional elements and local materials, can lead to the formation of a rich and balanced cultural identity (Hosseini and Ebadi, 2017). Also, new technologies, in the role of virtual education, cultural and media programs, can raise public awareness about the concept of sustainable construction. Finally, social changes towards environmental values and active participation in development processes require smart cultural policies that can strengthen the acceptance of technology and sustainable development in society (Namati et al., 2021). This approach has a direct impact on the success of development programs and sustainable architecture. (Tab. 3)

**METHODOLOGY**

The type of research is analytical and applied in purpose, and there is a developmental approach in the context of examining concepts. The method of collecting information is library and documents that are used from sources such as books, articles, and internet resources. In this research, qualitative writing has been used to study and analyze in depth the theoretical foundations, experiences, and views of specialists, architects, and experts in the field of architecture and technology in Iran. The main purpose of choosing a qualitative method is to understand meaningfully, explain concepts, and discover hidden relationships in the field of development and technological transformation in Iranian architecture. To collect the required data, semi-structured interviews, study of related documents and documentation, and focus groups will be used. In the following, by examining concepts, content analysis, and using inductive reasoning, the main results of the research can be stated.

**Table 3:** Opportunities and solutions in Iranian architecture with the approach of using new technologies

Key Solution	Significant Role in Development	Barriers and Challenges	Opportunities and Strategies
Preserving Cultural Identity, Addressing Environmental and Economic Challenges	Promoting the school of Iranian architecture that is resilient and environmentally friendly	Lack of standards and sufficient awareness	Education, policymaking, indigenous technologies
Indigenous Materials, Green Technologies, Climate-Based Design	Improving energy efficiency, reducing construction and maintenance costs	Limitations of modern technologies, lack of technical knowledge	Continuous training, international collaborations, technology transfer
Equipment shortages, Lack of awareness, Economic and standardization limitations	Need to change perceptions, increase public sensitivity, revise government policies	Resistance to adopting new technologies, cultural resistance	Goal-oriented policies, cultural and educational campaigns
Cultural Heritage, Domestic and Foreign Investment, Modern Technologies	Developing sustainable construction industry, employment creation, attracting investments	Lack of national coordination, absence of an industry and technology-focused culture	Creating research and development centers, financial support, online training
Developing national standards, incentive policies, continuous education	Increasing technical capacity, facilitating technology transfer, enhancing skills	Lack of clear policies and implementation, weak educational programs	National programs, community participation, providing financial facilities
Media, Cultural Programs, Community Participation, Promoting Indigenous Values	Changing perceptions, increasing awareness and public participation	Cultural resistance, low media activity	Cultural campaigns, public education, local participation
Smart Building, Digital Design, Innovative Materials, Cultural Heritage Preservation	Improving construction quality, reducing resource consumption, preserving cultural heritage	High initial costs, shortage of specialized workforce	Technology adoption, specialized training, expanding the market for new technologies

## **DISCUSSION AND FINDINGS**

### *Main challenges in following new technologies and sustainable development in Iranian architecture*

In the analysis of data collected from the interviewees, several challenges were identified in achieving sustainable architecture and utilizing new technologies. Many participants pointed out the instability and lack of technical infrastructure and technology-based equipment in architectural projects. They believed that in many cases, new technologies are very expensive and unavailable, or there are no suitable alternative technologies within the country, therefore, implementing projects based on green and new technologies has become a serious challenge. On the other hand, inadequate training and inexperience of human resources were cited as another important obstacle. Many architects and project managers believed that training related to new technologies in the country's educational system is not sufficiently developed and after graduation, most people are not properly familiar with current technologies. This issue causes projects to often face a lack of technology and technical knowledge and fail to establish real sustainability in projects. In addition, economic constraints and lack of financial resources were the most important challenges mentioned. Many technological activities required special long-term investments that could not be provided in the current economic conditions of the country. Government policies were also declared incomplete and inadequate in many cases, failing to provide the necessary support to encourage the use of green and modern technologies. Problems related to existing regulations and standards were also important obstacles. Researchers stated that the lack of comprehensive and up-to-date standards has complicated and time-consuming the process of designing and implementing new projects. The lack of compliance of current programs with international standards has made the process of technological development in Iran slow and flawed. In addition to these issues, cultural resis-

tance and traditional attitudes in many regions of the country have prevented the acceptance of new technologies. Architects and architectural activists stated that some members of society consider the change in traditional approaches to be accompanied by concerns about preserving cultural identity, and this factor has caused a decrease in interest in using new technologies. Overall, economic, educational, standardization, and cultural challenges were identified as the most important obstacles to the development of sustainable technology and architecture. These obstacles require multifaceted solutions, along with coherent policies and long-term planning.

### *Opportunities and facilitating factors in following technology and sustainable development*

In contrast, interviewees expressed a positive attitude and potential opportunities for developing sustainable architecture and utilizing new technologies. One of the most important opportunities is Iran's rich cultural heritage and diverse climate and natural environment, which can be the basis for innovative and environmentally friendly designs. Many believe that utilizing indigenous materials and local technologies not only reduces costs but also strengthens cultural identity. Also, government investments and support programs in the form of financial facilities, low-interest loans, and incentive schemes were mentioned as important factors in encouraging companies and architects to move toward green technologies. A group of interviewees emphasized that by reforming policies, the necessary operational and financial incentives for implementing technological projects can be easily provided. Architects emphasized that holding workshops and specialized courses related to new technologies can significantly improve the level of technical skills, which is the basis for the invincibility of sustainable projects. In addition, the advancement of digital technologies such as parametric design, building information modeling (BIM), and smart structures has provided unique opportunities for the development of modern architecture in Iran. Many believe that

these technologies enable creative designs with minimal errors, save time and money, and improve biological structures. Also, international cooperation and knowledge exchange with advanced countries and institutions play an important role in transferring technology and global standards to the country. Participation in conferences, cooperation agreements, and joint projects improves the level of technology and knowledge of the professional community, and this trend was presented as a unique opportunity to accelerate the process of sustainable development. Overall, the exploitation of cultural heritage, policy support, continuing education, new technologies, and regional and global cooperation are important opportunities to overcome obstacles and realize the development of sustainable architecture in Iran.

*Strategic and policy proposals to promote technological development in Iranian architecture*

Based on data analysis, the most important solution proposed to facilitate the development of sustainable architecture is to develop a comprehensive and coherent program at the national level. This program should include the development of national and international standards, financial and incentive policies, and strategies for training and human resource development. Interviewees emphasized the creation of independent and active institutions in the field of research and development of technology in architecture, which should continuously evaluate and localize new technologies. Supporting research and development centers and encouraging innovation play a key role in improving the level of technology and reducing dependence on foreign technologies. In addition, it is necessary for the government and the private sector to work together to establish an active system to promote green technologies and teach practical implementation steps for structured and long-term projects. Creating financial, supervisory, and support policies can facilitate technological and sustainable projects and strengthen the incentive to invest in these areas. Another sug-

gestion is to develop specialized training and workshop centers, hold ongoing workshops, and promote a culture of innovation in the field of architecture and technology. On the other hand, advertising and public awareness play an important role in changing the attitude of society and decision-making institutions and should be placed alongside practical solutions. Finally, the formation of regional and international cooperation networks, and the creation of a competitive and motivating atmosphere in the construction industry, can help build a culture, transfer technology, and improve the level of sustainable projects in Iran. These policies and actions pave the way for a major transformation in the field of Iranian architecture and realize the vision of sustainable development in the near future.

#### **CONCLUSION AND RESULTS**

It can be concluded that economic and financial barriers are the biggest challenge in the path of adopting new technologies, as most technological projects require long-term investments and sustainable financial support, which are currently limited in the country. The lack of technical infrastructure and modern equipment, along with high costs and insufficient equipment in the country, causes projects based on green and new technologies to face many difficulties and, in practice, makes it more difficult to benefit from new technologies. In addition to economic issues, the lack of specialized human resources and adequate training in the field of new technologies is another important obstacle. The country's higher and technical education system has not yet been able to provide the necessary level of skills and technical knowledge to meet the needs of modern technology, which negatively affects the quality and efficiency of architectural projects and prevents the full development of new technologies. In addition to these challenges, standardization problems and the lack of coherent and coordinated policies at the national level slow down and limit the process of technological development in Iran. The lack of international standards and

non-compliance with global criteria make the process of designing and implementing new projects more complex and time-consuming, and thus, technological opportunities in this area remain limited. Despite these obstacles, a great opportunity lies in Iran's extensive cultural heritage and climatic diversity, which can be a source of inspiration for environmentally friendly designs and strengthening cultural identity. The use of indigenous materials and local technologies reduces costs and at the same time strengthens the cultural and identity of projects. On the other hand, advances in digital technologies such as BIM and parametric design have provided a unique opportunity for creating creative and efficient architecture; technologies that simultaneously save time and money and enable innovative designs. In conclusion, international cooperation, knowledge and technology transfer, and supportive policies are the main keys to overcoming obstacles and ensuring sustainable development in Iranian architecture. Continuous education, information exchange, and benefiting from global experiences can help eradicate technical and cultural obstacles, and as a result, strengthen domestic capabilities and improve sustainable architecture indicators. Therefore, the secret to success in this path is a smart combination of traditional resources and new technologies, along with long-term policies and regional and global cooperation. Overall, the analysis of the challenges and opportunities facing the development of technology in Iranian architecture shows that there are major obstacles in the economic, educational, standardization, and cultural fields that slow down the development of new technologies in construction.

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**HOW TO CITE THIS ARTICLE**

Ghiassinejad, A. (2025). The evolution of Iranian architectural technology with regard to modern technology in the use of building materials. (e727484). *International Journal of Urban Management and Energy Sustainability*, (), e727484

DOI: [10.22034/ijumes.2025.2066593.1318](https://doi.org/10.22034/ijumes.2025.2066593.1318)

