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RESEARCH ARTICLE

THE ROLE OF DIGITAL TECHNOLOGIES IN THE DEVELOPMENT OF SUSTAINABLE ARCHITECTURE IN KAZAKHSTAN

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Abstract. *In today's world, digital technologies play a crucial role in the development of architecture, particularly in the context of striving for sustainability, which has led to the study of this concept within Kazakhstan. The region stands at the crossroads of tradition and innovation, where the state is advancing the integration of digital innovations into architectural design while preserving its rich cultural heritage. This study examines how digital technologies can contribute to the creation of sustainable and functional architecture in Kazakhstan, highlighting the benefits of artificial intelligence, Building Information Modeling (BIM), 3D printing, as well as virtual and augmented reality. The application of these technologies enables more precise planning and implementation of architectural projects, taking into account the natural and climatic conditions, socio-economic requirements, and cultural-historical context of the region. Special attention is given to analyzing the resource potential of different regions in Kazakhstan, allowing for the optimal use of local resources and the integration of architectural structures into the existing landscape while maintaining their uniqueness and identity. Thus, digital technologies open new opportunities for creating sustainable and efficient architectural solutions that meet modern requirements for comfort and safety while promoting environmental conservation. The study emphasizes the importance of integrating new technologies with cultural and historical aspects to ensure the harmonious development of architecture in Kazakhstan. In conclusion, the authors highlight how digital technologies enhance the quality of architectural projects and contribute significantly to the development of sustainable architecture, advancing the concept of green building that blends innovation with tradition. This approach provides a foundation for the further development of architecture in Kazakhstan aimed at achieving high standards of sustainability and quality of life.*

Keywords: *digital technologies, sustainable architecture, development of Kazakhstan, green technologies, energy efficiency.*

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ҒЫЛЫМИ МАҚАЛА

ҚАЗАҚСТАННЫҢ ТҰРАҚТЫ СӘУЛЕТІН ДАМЫТУДАҒЫ ЦИФРЛЫҚ ТЕХНОЛОГИЯЛАРДЫҢ РӨЛІ

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Аңдатпа. *Қазіргі әлемде цифрлық технологиялар сәулет өнерін дамытуда, әсіресе орнықты дамуға ұмтылу контексінде шешуші рөл атқарады, бұл Қазақстан шеңберінде осы тұжырымдаманы зерделеуге себеп болды. Дәстүр мен жаңашылдықтың қиылысында орналасқан аймақ, мұнда мемлекет өзінің бай мәдени мұрасын сақтай отырып, тек қана емес, сәулеттік дизайнға цифрлық инновацияларды енгізу жолында. Бұл зерттеу жасанды интеллект, ғимараттарды ақпараттық модельдеу (BIM), 3D-басып шығару, сондай-ақ виртуалды және толықтырылған шындықтың артықшылықтарына баса назар аудара отырып, цифрлық технологиялардың Қазақстанның экологиялық және функционалдық сәулеті шеңберінде құруға қалай ықпал ететінін қарастырады. Бұл технологияларды қолдану аймақтың табиғи-климаттық жағдайларын, әлеуметтік-экономикалық талаптарын және мәдени-тарихи контекстін ескере отырып, сәулет жобаларын дәлірек жоспарлауға және іске асыруға мүмкіндік береді. Қазақстанның әртүрлі өңірлерінің ресурстық әлеуетін талдауға ерекше назар аударылады, бұл жергілікті ресурстарды оңтайлы пайдалануға және сәулет объектілерін олардың бірегейлігі мен бірегейлігін сақтай отырып, қолданыстағы ландшафтқа біріктіруге мүмкіндік береді. Осылайша, цифрлық технологиялар жайлылық пен қауіпсіздіктің заманауи талаптарына жауап беріп қана қоймай, қоршаған ортаны сақтауға ықпал ететін тұрақты және тиімді сәулеттік шешімдерді құрудың жаңа мүмкіндіктерін ашады. Зерттеуде мәдени және тарихи аспектілерді ескере отырып, жаңа технологияларды интеграциялаудың маңыздылығы атап өтіледі, бұл Қазақстанда сәулет өнерінің үйлесімді дамуын қамтамасыз етуге мүмкіндік береді. Қорытындылай келе, авторлар цифрлық технологиялар сәулеттік жобалардың сапасын қандай жолмен жақсартатынына назар аударады және тұрақты сәулеттің дамуына айтарлықтай үлес қосады.инновациялар мен дәстүрлерді жан-жақты біріктіретін жасыл құрылыс тұжырымдамасы. Тұжырымдаманың мұндай тәсілі тұрақтылық пен өмір сапасының жоғары стандарттарына қол жеткізуге бағытталған Қазақстандағы сәулет өнерін одан әрі дамыту үшін негіз береді.*

Түйін сөздер: *цифрлық технологиялар, тұрақты сәулет, Қазақстанның дамуы, жасыл технологиялар, энергия тиімділігі.*

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НАУЧНАЯ СТАТЬЯ

РОЛЬ ЦИФРОВЫХ ТЕХНОЛОГИЙ В РАЗВИТИИ УСТОЙЧИВОЙ АРХИТЕКТУРЫ КАЗАХСТАНА

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Аннотация. *В современном мире цифровые технологии играют ключевую роль в развитии архитектуры, особенно в контексте стремления к устойчивому развитию, в этом стало причиной изучения данной концепции в рамках Казахстана. Регион, находящаяся на перекрестке традиций и новаторства, где государство на пути внедрения цифровых инновации в архитектурное проектирование и не только, сохраняя при этом свое богатое культурное наследие. Это исследование рассматривает, как цифровые технологии могут способствовать созданию в рамках экологичной и функциональной архитектуры Казахстана, делая акцент на преимуществах искусственного интеллекта, информационного моделирования зданий (BIM), 3D-печати, а также виртуальной и дополненной реальности. Применение данных технологий позволяет более точно планировать и реализовывать архитектурные проекты, учитывая природно-климатические условия, социально-экономические требования и культурно-исторический контекст региона. Особое внимание уделяется анализу ресурсного потенциала различных регионов Казахстана, что позволяет оптимально использовать местные ресурсы и интегрировать архитектурные объекты в существующий ландшафт, сохраняя при этом их уникальность и идентичность. Таким образом цифровые технологии открывают новые возможности для создания устойчивых и эффективных архитектурных решений, которые не только отвечают современным требованиям комфорта и безопасности, но и способствуют сохранению окружающей среды. В исследовании подчеркивается важность интеграции новых технологий с учетом культурных и исторических аспектов, что позволяет обеспечить гармоничное развитие архитектуры в Казахстане. В заключении авторы делают акцент на том, что каким путем цифровые технологии улучшают качество архитектурных проектов, и вносят значительный вклад в развитие устойчивой архитектуры, развивая концепция зеленого строительства, которые разносторонне сочетают в себе инновации и традиции. Такой подход концепции предоставляет основу для дальнейшего развития архитектуры в Казахстане, направленного на достижение высоких стандартов устойчивости и качества жизни.*

Ключевые слова:. *цифровые технологии, устойчивая архитектура, развитие Казахстана, зеленые технологии, энергоэффективность.*

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

АЛҒЫС / ҚАРЖЫЛАНДЫРУ КӨЗІ

Зерттеу жеке қаржыландыру көздерін пайдалана отырып жүргізілді.

МҮДДЕЛЕР ҚАҚТЫҒЫСЫ

Авторлар мүдделер қақтығысы жоқ деп мәлімдейді.

БЛАГОДАРНОСТИ/ИСТОЧНИК ФИНАНСИРОВАНИЯ

Исследование проводилось с использованием частных источников финансирования.

КОНФЛИКТ ИНТЕРЕСОВ

Авторы заявляют, что конфликта интересов нет.

1 INTRODUCTION

In Kazakhstan, as in the rest of the world, solutions are needed to address environmental issues and achieve sustainable development. To meet the challenge of sustainability in architecture, the market is increasingly utilizing cutting-edge technologies - ranging from 3D modeling and Building Information Modeling (BIM) to artificial intelligence (AI). These tools help ensure that homes and buildings are not only visually appealing and comfortable but also resource-efficient, conserving energy, water, and other essential resources.

The response to these challenges has been the active integration of digital technologies into architectural practice, representing a modern approach to design and construction. This approach encompasses a broad range of innovative technologies, including AI, BIM, 3D modeling and printing, as well as the use of virtual and augmented reality (VR/AR), aimed at enhancing sustainability and efficiency in architecture. Naturally, transitioning to new technologies is not without challenges. Investments in new equipment, training of specialists, and legislative changes are necessary to ensure these advancements are implemented effectively. However, through these efforts, the construction industry in Kazakhstan is becoming more modern and innovative. Globally, there are numerous examples of successful applications of digital technologies in construction, and Kazakhstan aims to align with these trends.

This study focuses on analyzing the impact of digital technologies on shaping sustainable architecture in Kazakhstan. The “Future Architecture of Kazakhstan” model places significant emphasis on “green” technologies, such as water-saving methods, the use of renewable energy sources, and strategies for improving the energy efficiency of buildings. This underscores the aim to synthesize technological innovation with ecological approaches - a critical pursuit for a country striving to create an environmentally friendly and sustainable architectural environment while preserving its cultural and historical heritage. The study explores the potential of BIM and 3D printing to enhance the accuracy of design solutions and optimize the use of materials and resources. It also evaluates the role of AI in addressing routine tasks and examines the use of VR/AR in the design process and stakeholder interactions. A key part of the analysis is assessing how these technologies contribute to the environmental sustainability of buildings and urban structures, as well as investigating ways to integrate them into architectural planning processes that take into account Kazakhstan’s unique regional conditions.

2 LITERATURE REVIEW

The literature review highlights the contributions of research on digital technologies in the context of cultural-historical and sustainable architecture, as well as their impact on the development of construction in Kazakhstan.

Energy efficiency, as a crucial aspect of sustainable architecture, is discussed in Amory Lovins’ (**Amory, 2011**) work Reinventing Fire: Bold Business Solutions for the New Energy Era, which proposes a comprehensive approach to transitioning to renewable energy sources and implementing energy-efficient technologies across various industries, including architecture.

Research by Issabayev G.A. (**Issabayev, 2020**) introduces the concept of a digital agro-polis for the sustainable development of rural settlements. Hardin and McCool’s (**Hardin & McCool, 2015**) studies emphasize the enhancement of project planning and management through the use of BIM. The application of BIM for the restoration of Notre-Dame de Paris and the preservation of its historical value through the use of traditional materials is illustrated by Guselnikov V.S. and Krupennikov I. (**Guselnikov V. S. & Krupennikov I.).**

Additive technologies, particularly 3D printing in construction, show potential for sustainable development by minimizing waste and utilizing eco-friendly materials, as noted by Kornweitz (**Kornweitz, 2021**). VR and AR technologies, described by Milgram, Takemura, Utsumi, and Kishino (**Milgram, Takemura, Utsumi, Kishino, 2005**), improve design processes and stakeholder

engagement, making project visualization more intuitive. Chaillou (**Chaillou, 2020**) and Abacioglu (**Abacioglu, 2020**) explore the application of AI, highlighting new methods of interaction between humans and technology to accelerate the self-organization of the design process.

The importance of preserving cultural heritage is emphasized in the works of Abdrassilova G.S. and Danibekova E.T. (**Abdrassilova & Danibekova, 2021**), as well as Glaudinova M., Galimzhanova A., and Glaudinov B. (**Glaudinova, Galimzhanova A, Glaudinov B. 2021**), and Baitenov E. (**Baitenov, 2023**), who investigate the balance between historical identity and modernity in architecture.

3 MATERIALS AND METHODS

This study employs a combination of interdisciplinary approaches. An analysis of global and local examples of the use of digital technologies, such as BIM, AI, 3D printing, and VR/AR, has been conducted to identify best practices that can be adapted and applied for the development of sustainable architecture in Kazakhstan. The methodology incorporates knowledge from various fields, including digital culture and cultural-historical heritage, which has helped in identifying and structuring key aspects of the content.

4 RESULTS AND DISCUSSION

This section presents the findings of the research dedicated to the role of digital technologies in advancing sustainable architecture in Kazakhstan, focusing on their potential and practical application.

4.1 APPLICATION OF BIM AND 3D TECHNOLOGY

The study revealed that Building Information Modeling (BIM) and 3D modeling technologies play a critical role in architecture and construction in Kazakhstan. These technologies enhance project planning and facilitate better construction management, from the design phase to the building's operational use. They contribute to making buildings more energy-efficient and help reduce waste (**Yitmen, 2021**). However, as with any emerging field, there are challenges. For instance, BIM implementation can be costly, especially for smaller projects that may not justify the investment, potentially increasing overall project expenses (**Hardin & McCool, 2015**).

A prominent example from global practice is the restoration of Notre-Dame de Paris after the fire. Restorers used BIM modeling and advanced technologies to expedite the restoration process while preserving the historical value by employing traditional materials. The use of Autodesk Revit for creating a detailed model of the cathedral **Figure 1**, AutoCAD for drawings, Recap for processing laser scanning data, BIM 360 for collaborative project work, laser 3D scanners, drones, and other associated technologies enabled precise planning and documentation of the work. The project also employed digital twins and IoT to enhance the cathedral's management, which aids in preventing future catastrophes, showcasing a blend of heritage conservation and innovation (**Guselnikov, 2022; Krupennikov, 2023**).

Drawing lessons from these examples, several key approaches can be identified for preserving historically significant structures in regions spanning from the ancient settlement of Otrar and Sygnak to the majestic mausoleums of Aisha-Bibi, Babaji Khatun, and Khoja Ahmed Yasawi. The application of laser scanning and photogrammetry technologies allows for the creation of precise 3D models of these sites. This facilitates the assessment of their condition and aids in planning restoration efforts while considering the architectural and historical specificities.

Virtual modeling using software such as Revit and related programs opens up new opportunities for detailed visual analysis and optimization of the restoration process, ensuring the authenticity and uniqueness of each site. An important aspect is the integration of traditional restoration methods with

modern technologies, contributing to the durability and sustainability of structures (**Nabiev et al., 2019**).

The installation of monitoring systems with sensors, including seismometers and thermo-anemometers, to track changes in the condition of structures in real-time allows for the timely detection and prevention of potential damage, which is critical for traditional materials and historically valuable sites.

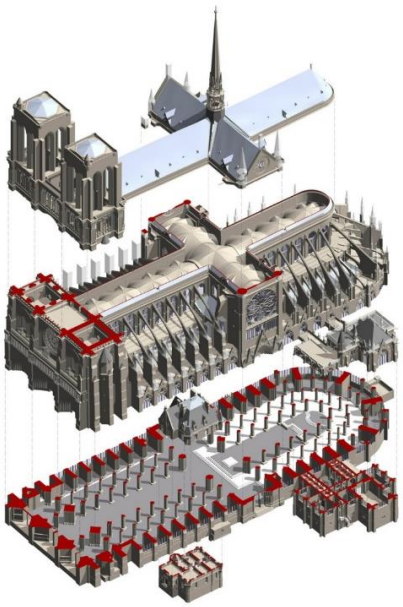

Figure 1 – BIM model of Notre-Dame developed by EPA and Autodesk.
(Retrieved from: URL: http://surl.li/rdsjen)

3D printing offers new methods for using eco-friendly materials, enabling the construction of energy-efficient buildings with unique forms, making construction more accessible, eco-friendly, and economical. However, the adoption of these technologies in Kazakhstan faces challenges such as the high cost of software and equipment, as well as the need for specialist training. Despite this, the prospects for using digital technologies in Kazakhstan's construction industry appear promising due to decreasing technology costs, government support, and increasing awareness of their benefits. One of the first 3D-printed houses was built in Moscow's region by the startup Apis Cor in 2015.

From 2020 to 2022, 3D printing demonstrated its effectiveness and began to spread in construction, attracting significant investments. By 2023, over 1,000 buildings had been 3D printed, and the technology started being used for building settlements, with a regulatory framework developing to support it **Figure 2**, (**Kornweitz, 2022**).

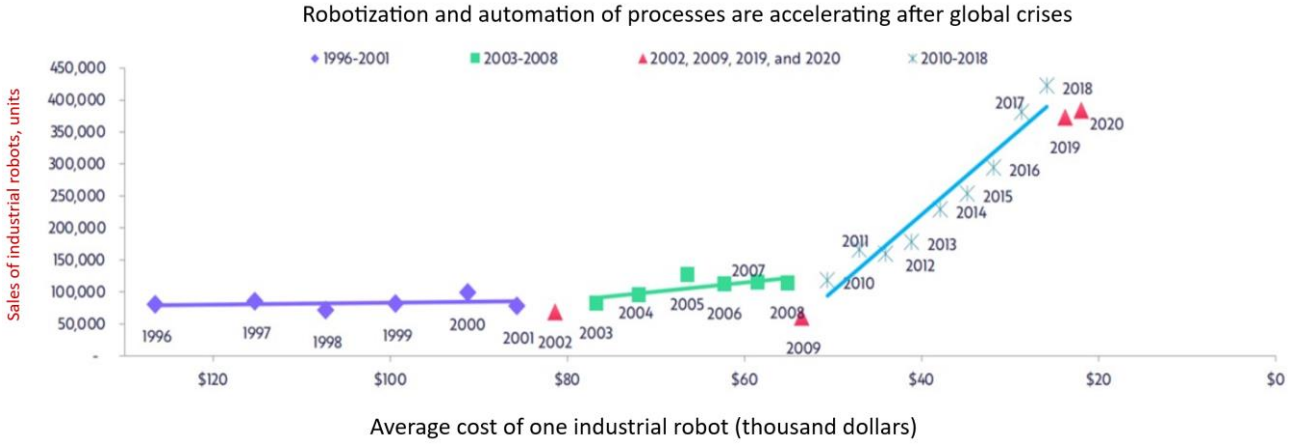

Figure 2 – Statistics on the use of 3D printing. (Retrieved from: URL: http://surl.li/fccgxo)

An example is a two-story house in Germany built using 3D printing. The walls of the house were constructed layer by layer, with a production rate of five minutes per square meter of wall **Figure 3**, (**Kornweitz, 2022**).

Figure 3 – The first residential house created with 3D printing in Germany, 2020. URL: https://habrastorage.org/getpro/habr/upload_files/412/d91/493/412d91493671aaebd2e8feb6079713ab.jpg

3D printing offers new methods for using eco-friendly materials, enabling the construction of energy-efficient buildings with unique forms, making construction more accessible, eco-friendly, and economical. However, 3D printing in construction has its drawbacks, including high costs and technological complexities. It is not always more cost-effective than traditional methods due to the expense of equipment and materials. Challenges include wall quality issues and the need for temperature control during printing. Despite these limitations, the technology has found applications in various areas, including the construction of wind turbine supports. The implementation of 3D printing is slowed by the need for standardization and certification of new materials and methods. Developing these standards takes time, and specialists face the task of adapting the technology and overcoming various barriers.

4.2 INTEGRATION OF VR/AR, ARTIFICIAL INTELLIGENCE, AND INDUSTRY 4.0 PRINCIPLES

Virtual tours of buildings, cities, or historical sites have become popular as a means of engagement and education. Augmented Reality (AR) enables the visualization of future structures within real-world environments, enhancing the understanding of architectural designs. For instance, new VR technologies, such as Apple Vision Pro, offer novel opportunities for studying and preserving cultural heritage. These technologies simplify the creation and interaction with virtual models of archaeological findings, reducing the risk of damage (**Milgram et al., 2005**). Developers employ various tools to create educational materials that promote cultural heritage.

Artificial intelligence (AI) is transforming the field of architecture by automating design processes. AI assists architects in analyzing large datasets to develop innovative projects, enhancing all stages of design and introducing new construction methods and materials (**Chaillou, 2022; pro-tim.ru, 2023**).

In Kazakhstan, archaeological research supported by the “Cultural Heritage” program utilizes modern technologies to study historical sites. Preservation projects for ancient settlements and mausoleums leverage laser scanning and 3D modeling to facilitate documentation and digital restoration. Virtual reconstructions allow for detailed studies of architectural monuments, producing highly accurate digital replicas.

These methods have proven valuable in the restoration of cultural and historical sites in Kazakhstan and in archaeological research, as demonstrated by the example of the Sygnak settlement Figure 4. Partial approaches to the study and restoration of Sygnak have provided insights and sparked interest in the history and culture of the region (Nabiev et al., 2019).

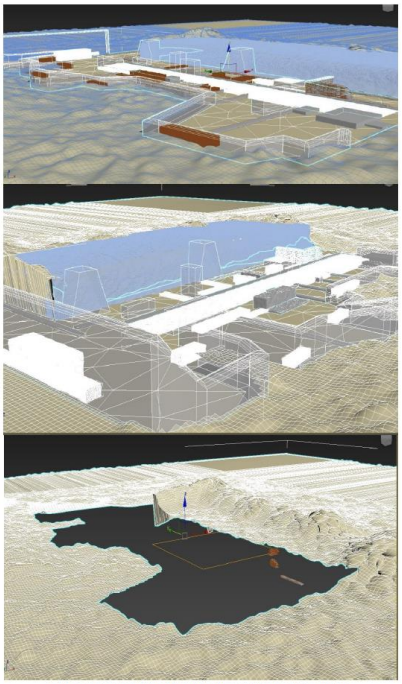

Figure 4 – Models of the virtual reconstruction of the Sygnak settlement (Nabiev et al., 2019).

At the symposium on sustainable construction, Abacioglu T. discussed how Industry 4.0 contributes to building a future where construction is environmentally friendly, economically feasible, and socially responsible. Sustainable development here is viewed as a means to meet current needs without compromising future generations. This involves reducing waste and increasing recycling through new technologies such as 3D printing.

The concept of Industry 4.0 brings innovations to construction through automation and intelligent technologies, making processes more efficient and less harmful to the environment. Abacioglu emphasized the importance of balancing environmental, economic, and social goals and highlighted the need to maintain the human element within technological progress to ensure that construction is not only smart but also sustainable (Abacioglu, 2020).

4.3 SUSTAINABILITY AND CULTURAL HERITAGE: THE «FUTURE ARCHITECTURE OF KAZAKHSTAN» MODEL

The Bronze Age and antiquity left a significant imprint, while the Middle Ages contributed castles and mausoleums that reflect the spirit of their time. Modern ethnographic approaches emphasize the importance of preserving traditional methods and materials while adapting them to contemporary needs. The use of traditional ornaments helps maintain national identity, while modern architecture merges innovation with respect for cultural heritage. The regional characteristics and rich history of Kazakhstan inspire the creation of architecture that embodies the unique nature of the locality.

Natural, climatic, socio-economic, and cultural-historical factors play a key role in shaping architecture. Economic prosperity and social requirements determine building types and materials, while cultural traditions and historical heritage are expressed through styles and designs. The regional characteristics of Kazakhstan, including the unique artistic imagery of each area, give architecture

not only functionality but also cultural significance. The southern region, as a center of economic and cultural development since the Middle Ages, maintains its uniqueness in architectural solutions.

The new architecture of Turkestan draws inspiration from historical buildings, such as the mausoleum of Khoja Ahmed Yasawi, creating a unique cityscape that blends tradition and modernity. This approach allows Turkestan to preserve its identity in an increasingly globalized world, offering a fresh perspective on traditional Eastern architecture and highlighting its role as a spiritual center (**Abdrassilova & Danibekova, 2021**).

In Astana, the transformation of the city's architectural landscape combines tradition with modern architectural trends. The concept of "chance" in architecture characterizes the current state of architecture in Kazakhstan, reflecting the process of adapting to change, exploring new forms and styles, and striving to create a new national identity (**Glaudinova et al., 2022**).

Green Technologies. Architecture plays a crucial role in the development of sustainable technologies, such as wind turbines, water conservation, and energy efficiency. Wind energy reduces electricity consumption and enhances the sustainability of buildings. Water conservation has become essential with the introduction of new regulations, such as those in Kazakhstan starting in 2024. In the UAE, "steam fountains" are used to humidify and cool the air to combat heat. Desalination and the use of low-carbon materials make buildings more eco-friendly and resilient.

Sustainable architectural and agricultural projects, both within and beyond Kazakhstan, are being developed based on ecological principles and the latest technologies. Research focuses on methods such as drainage systems and passive heating, which protect buildings from extreme weather conditions and increase energy efficiency. The use of local materials and innovative solutions improves livestock conditions on farms and enhances agricultural sustainability. These examples demonstrate the potential for developing previously unsuitable land for agriculture, maintaining the natural balance, and improving life in small settlements (**Iskhodzhanova & Salimbekova, 2022**).

Within the framework of a sustainable system, the concept of a digital agro-polis aims to create sustainable rural eco-settlements in Eurasia for the cultivation of organic products using modern technologies while minimizing environmental impact. This includes the use of IT systems for resource management, drones for crop monitoring, blockchain technologies for product quality assurance, big data analysis for optimal crop planning, educational programs for local residents, and the use of renewable energy sources, contributing to the economic well-being of rural areas (**Issabayev & Issabayeva, 2020**).

Use of Traditional Building Materials. Kazakhstan produces a wide variety of building materials, including cement, asbestos products, concrete structures, ceramic materials, plastics, roofing materials, facade cladding, and more, including glass and stone products. The architecture of Kazakhstan shows respect for traditional building materials, which reflect the historical and cultural heritage of the country's various regions. These materials not only embody local traditions but are also adapted to climatic conditions, offering natural solutions for ensuring sustainability and comfort **(forbes.kz, 2023**).

Many "green" materials may not meet environmental standards, a practice known as "greenwashing," making it important to verify their compliance with eco-certifications and standards (**Spiegel & Meadows, 2011**). Combining new concrete production technologies with traditional materials enables the construction of more sustainable and energy-efficient buildings. The use of local resources in new concrete formulations reduces environmental impact and preserves ties to tradition. The introduction of non-heated, self-compacting concrete in the production of precast reinforced concrete has reduced electricity consumption from 146 kWh to 125/48 kWh (**Kolesnikova & Alguzhina, 2021**).

In Western Kazakhstan, the use of stone, shell rock, limestone, and clay in construction reflects the region's rich history of creating necropolises, mosques, settlements, and homes capable of withstanding strong winds and sandstorms. These materials provide coolness during hot summer months and retain heat during cold winters.

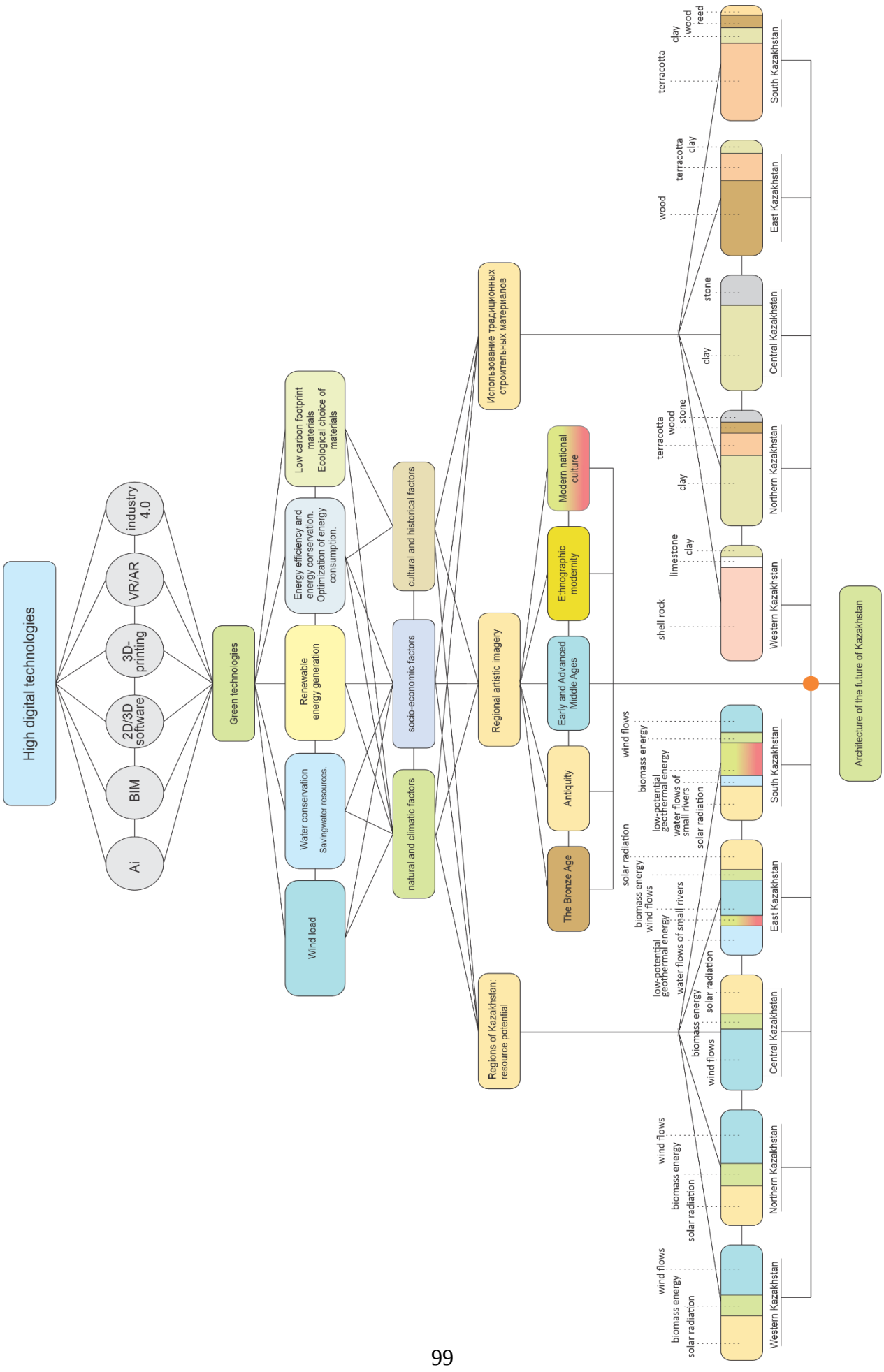

Figure 5 – «Future Architecture of Kazakhstan» Model (Nabiyev, 2024).

Northern Kazakhstan, with its harsh winters, has long utilized traditional building materials such as clay, terracotta, wood, and stone to create warm homes capable of withstanding low temperatures.

Central Kazakhstan traditionally uses wood, clay, and stone, reflecting the availability of resources for building warm homes in a continental climate. These materials integrate harmoniously into the region's landscape.

In Eastern Kazakhstan, where the climate is wetter and colder, wood and stone are preferred for providing reliable protection from wind and precipitation, as well as for retaining indoor warmth.

Southern Kazakhstan predominantly uses terracotta, light-colored clay and stone, wood, and reeds, which effectively absorb sunlight and prevent overheating of buildings during summer. These materials are also highly durable, maintaining their aesthetic qualities for centuries.

The use of traditional building materials in Kazakhstan reflects the centuries-old history and culture of the regions and provides practical solutions for creating comfortable and sustainable housing in diverse climatic conditions.

In the future architecture of Kazakhstan, as shown in **Figure 5**, it is crucial to consider cultural heritage and resilience to change. We must adapt traditions to new technologies so that buildings can withstand climatic and social challenges while preserving the uniqueness of architecture. Innovations must be used wisely so that small changes in design or materials can significantly enhance building sustainability. It is equally important to maintain cultural values, integrating modern and traditional elements into a harmonious whole. Our goal is to create spaces that serve current needs without forgetting the past and future (**Baitenov, 2023**).

5 CONCLUSIONS

The study on digital technologies in architecture demonstrates that the use of BIM and 3D printing enhances project efficiency, reduces waste, and optimizes resource utilization. The application of AI, VR/AR, and Industry 4.0 principles improves design processes and reduces errors, contributing to the overall efficiency of construction. Further implementation and adaptation of these technologies to local conditions and needs will advance the construction industry and improve the quality of the urban environment. Digitalization also plays a crucial role in preserving cultural and historical heritage, allowing for precise documentation and recreation of structures while adapting traditional materials to modern sustainability requirements.

The study recommends the development of educational programs, digital technology standards in architecture, and platforms for experience exchange. It is advised to explore the economic efficiency, social and cultural impacts of these technologies, and the integration of renewable energy sources to achieve sustainability and energy efficiency. The adoption of digital technologies, such as BIM, 3D printing, VR, and AR, has the potential to transform construction, making it more efficient and eco-friendly, while ensuring the preservation of Kazakhstan's cultural traditions.

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