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RESEARCH ARTICLE

CREATING SAFE URBAN ENVIRONMENTS THROUGH THREE-DIMENSIONAL DIGITAL MODELS OF CITIES: INSIGHTS FROM KAZAKHSTAN

Z.Z.Tolegen[1], Y.G. Popov[2], G.S. Mugzhanova[2], A.A. Kostcova[2], O.P. Eismont[3] *

[1]International Educational Corporation, 050043, Almaty, Kazakhstan
[2] Kokshetau University named after Abay Myrzakhmetov, 020000, Kokshetau, Kazakhstan
[3] GKKP Construction and Technology College, 020000, Kokshetau, Kazakhstan

Abstract. *Global urbanization and urban population growth emphasize the need for a safe and comfortable urban environment, especially in large cities such as Almaty in Kazakhstan. The fusion of historical architectural ensemble with new development, along with compositional aspects of urban aesthetics, raises urban development issues. Thus, the street-road network and communications vary in the degree of wear and tear and load, which requires logistical support from road and utility services and energy supervision. In addition, the threat of earthquakes and other disasters requires effective evacuation strategies. This article presents the effectiveness of a digital 3D city model as an innovative solution for improving urban safety. The methodology uses the concepts of "protective space", "eye on the street" and "city for people" to establish safety criteria. At the same time, given the relevance, special attention is paid to seismic safety. Using information and communication technologies, this model forms and then continuously updates the basic principles of urban development. Using comparative analysis, photography and morphological mapping, she explores architectural and urban planning strategies for safe spaces at different scales, from individual buildings to neighborhoods. The proposed smart digital model aims to improve urban safety by helping to identify and address safety issues. This approach expands the scope of urban planning methods, stimulates interdisciplinary research to improve the quality of life in cities and contributes to the development of the smart city initiative in Kazakhstan.*

Keywords: *urbanization, safe environment, 3D model, smart city, seismic safety*

***Corresponding author**
Olga Eismont, e-mail: violvi_85@mail.ru

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ҒЫЛЫМИ МАҚАЛА

3D ЦИФРЛЫҚ ҚАЛА МҮЛГІЛЕРІН ПАЙДАЛАНҒАН ҚАУІПСІЗ ҚАЛА ОРТАСЫН ҚҰРУ: ҚАЗАҚСТАНДЫҚ ЗЕРТТЕУ

Ж.Ж. Төлеген[1], Ю.Г. Попов[2], Г.С. Мугжанова[2], А.А. Косцова[2], О.П. Эйсмонт[3,*]

[1]Халықаралық білім беру корпорациясы, Алматы, 050028, Қазақстан
[2]Абай Мырзахметов атындағы Көкшетау университетінің, Көкшетау, 020000, Қазақстан
[3]МККҚ Құрылыс-технологиялық колледжі, Көкшетау, 020000, Қазақстан

Аңдатпа. *Жаһандық урбанизация және қала халқының өсуі, әсіресе Қазақстанның Алматы сияқты ірі қалаларында қауіпсіз және жайлы қалалық ортаның қажеттілігін көрсетеді. Тарихи сәулет ансамблінің жаңа дамумен үйлесуі, қала эстетикасының композициялық аспектілерімен қатар, қала құрылысы мәселелерін көтереді. Осылайша, көше-жол желісі мен коммуникациялары тозу және жүктеме дәрежесінде әр түрлі болады, бұл жол және коммуналдық қызметтерден материалдық-техникалық қамтамасыз етуді және энергетикалық қадағалауды қажет етеді. Сонымен қатар, жер сілкінісі мен басқа да апаттар қаупі эвакуацияның тиімді стратегияларын қажет етеді. Бұл мақалада қала қауіпсіздігін арттырудың инновациялық шешімі ретінде цифрлық 3d қала моделінің тиімділігі ұсынылған. Әдістемеде қауіпсіздік критерийлерін белгілеу үшін "қорғаныс кеңістігі", "көшедегі көз" және "адамдарға арналған қала" ұғымдары қолданылады. Бұл ретте өзектілігін ескере отырып, сейсмикалық қауіпсіздікке ерекше назар аударылады. Ақпараттық-коммуникациялық технологияларды қолдана отырып, бұл модель қала құрылысының негізгі принциптерін қалыптастырады, содан кейін үнемі жаңартып отырады. Салыстырмалы талдауды, фотографияны және морфологиялық картаны қолдана отырып, ол жеке ғимараттардан бастап аудандарға дейінгі әртүрлі масштабтағы қауіпсіз кеңістіктерге арналған сәулет және қала құрылысы стратегияларын зерттейді. Ұсынылған ақылды цифрлық модель қауіпсіздік мәселелерін анықтауға және шешуге көмектесу арқылы қалалық қауіпсіздікті жақсартуға бағытталған. Бұл тәсіл қала құрылысы әдістерінің аясын кеңейтеді, қалалардағы өмір сүру сапасын жақсарту бойынша пәнаралық зерттеулерді ынталандырады және Қазақстандағы "ақылды қала" бастамасының дамуына ықпал етеді.*

Түйін сөздер: *урбанизация, қауіпсіз орта, 3D моделі, ақылды қала, сейсмикалық қауіпсіздік*

***Автор-корреспондент**
Ольга Эйсмонт, e-mail: violvi_85@mail.ru

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НАУЧНАЯ СТАТЬЯ

СОЗДАНИЕ БЕЗОПАСНОЙ ГОРОДСКОЙ СРЕДЫ С ПОМОЩЬЮ ТРЕХМЕРНЫХ ЦИФРОВЫХ МОДЕЛЕЙ ГОРОДОВ: ИССЛЕДОВАНИЯ ИЗ КАЗАХСТАНА

Ж.Ж. Төлеген [1], Ю.Г. Попов [2], Г.С. Мугжанова [2], А.А. Косцова [2], О.П.Эйсмонт[3]*

[1] Международная образовательная корпорация, Алматы, 050028, Казахстан
[2] Кокшетауский университет имени Абая Мырзахметова, Кокшетау, 020000, Казахстан
[3] ГККП Строительно-технологический колледж, Кокшетау, 020000, Казахстан

Аннотация. *Глобальная урбанизация и рост городского населения подчеркивают необходимость создания безопасной и комфортной городской среды, особенно в крупных городах, таких как Алматы в Казахстане. Слияние исторического архитектурного ансамбля с новой застройкой, наряду с композиционными аспектами городской эстетики, поднимает вопросы городского развития. Таким образом, улично-дорожная сеть и коммуникации различаются по степени износа и нагрузки, что требует материально-технической поддержки со стороны дорожных и коммунальных служб, а также энергетического надзора. Кроме того, угроза землетрясений и других стихийных бедствий требует эффективных стратегий эвакуации. В этой статье представлена эффективность цифровой 3D-модели города как инновационного решения для повышения безопасности в городах. В методологии используются концепции "защитного пространства", "глаз с улицы" и "город для людей" для определения критериев безопасности. При этом, учитывая актуальность, особое внимание уделяется сейсмической безопасности. Используя информационно-коммуникационные технологии, эта модель формирует, а затем постоянно обновляет основные принципы городского развития. Используя сравнительный анализ, фотографии и морфологическое картографирование, она исследует архитектурные и градостроительные стратегии создания безопасных пространств в разных масштабах, от отдельных зданий до микрорайонов. Предлагаемая интеллектуальная цифровая модель направлена на повышение безопасности в городах, помогая выявлять и решать проблемы безопасности. Этот подход расширяет сферу применения методов городского планирования, стимулирует междисциплинарные исследования для улучшения качества жизни в городах и способствует развитию инициативы "Умный город" в Казахстане.*

Ключевые слова: *урбанизация, безопасная среда, 3D-модель, умный город, сейсмическая безопасность*

***Автор-корреспондент**
Ольга Эйсмонт, e-mail: violvi_85@mail.ru

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CONFLICT OF INTEREST

The authors state that there is 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

Architectural and urban planning principles are key to a safe urban environment **(Tolegen, Pomorov, & Issabayev, 2023)**. Today, the transformation and reconstruction of the modern city environment are becoming relevant, taking into account the latest modern technologies and social requirements, with the observance of users' interests at a level that is not as quantitative as qualitative **(Ying, Oosterom, & Fan, 2023, Konbr, & Mamdouh, 2022)**. Almaty is the largest city of Kazakhstan. All major financial and cultural objects are concentrated here, and the beautiful mountain scenery attracts not only residents of Kazakhstan but also tourists **(Tolegen, Imanbayeva, Trofimov, Popov, & Amandykova, 2022)**. The number of citizens especially increases during the school season, in the city, concentrated many higher and secondary educational institutions. These aspects make Almaty a center of attraction for construction companies that deploy active residential and public building construction **(Tolegen, Konbr, Karzhaubayeva, Sadvokasova, Nauryzbayeva, & Amandykova, 2023, Tolegen, Moldabekov, Kosheno, & Mugzhanova, 2018)**. Block or point construction introduces new objects into the existing context, often violating the principles of "neighbourhood".

For example, violation of access control, complete shading of neighboring buildings and violation of insolation requirements, conditional nature of landscaping. The city's most important problem is that Almaty is in the zone of the 9-point earthquake. Therefore, earthquake resistance is one of the main issues in creating a safe urban environment **(Zhaina, Kaltay, Mukhtarova, Beibit, & Amandykova, 2022)**. In addition to the threat of destruction and collision of buildings, there is a problem of a lack of information and orientation for evacuation of people, designated open areas, and temporary facilities that could be installed to serve the population **(Tolegen, Issabayev, Yussupova, Murzalina, & Amandykova, 2022)**. Problems are associated with the infrastructure of residential areas of the post-Soviet period, which still occupy a significant part of the urban area. The unfavorable factors include the presence in the volumetric and spatial solution of residential buildings of blind unviewable ends, poor natural lighting in entrances, lack of comfortable public spaces, etc. Most of these residential properties are rented out and subject to frequent changes of tenants, which increases the problems of lack of social control and creates discomfort for residents and pedestrians. Another important factor in justifying the relevance of this topic is the need for cities in Kazakhstan to comply with international safety indices **(Iskhojanova, Zayats, & Sarttarova, 2022)**.

It should be noted that active construction not only increases the density of the urban environment but also significantly expands the territory of the entire city of Almaty. For example, in the early 2000s, the city's boundaries included eight districts. Nowadays, the territory of Almaty consists of 11 districts. Expanding the urban area leads to the extension of the main street network and the emergence of new ones. The street network is organized according to the historically established Almaty scheme - the road and sidewalk principle. According to this approach, transport is given 2-4 road lanes, and the size of sidewalks is 1 meter. This leads to non-compliance of pedestrian streets to safety requirements, creating comfortable conditions for people and forming visual and aesthetic properties.

Considering all the aspects described above, creating a safe urban environment is the most important issue for the City Hall and among architects, urban planners, urbanists, designers, etc. The creation of a safe urban environment is the most important issue for City Hall. Specialists often organize seminars, competitions, and conferences, where the main task is to search for new ideas and proposals for solving the problems of urban environment safety **(Gholipour, Mahdinejad, Saleh & Sedghpour, 2021)**.

Specialists of seismology, builders, and architects are currently working on the passportization of buildings for seismic resistance. The passportization covered 10,525 objects built before 2001, including residential buildings, social facilities - schools, kindergartens, polyclinics, hospitals, and administrative buildings. It was carried out to examine buildings for earthquake resistance to identify defects and deterioration of structures **(Abdirayim, 2023)**. A third of the 10,525 objects in the city

surveyed as part of the passportization do not meet the norms of seismic resistance, and a thousand houses were recognized as dilapidated by experts and recommended to be demolished.

Based on the results of the passportization, electronic passports were created with the surveyed 10,525 objects linked to the electronic map 2 GIS. For each object on the map, there is a photo and information about whether the building is earthquake-resistant or not, what will happen to the building in case of an earthquake in Almaty, and whether there is a place to gather. Old buildings that have been remodeled pose a particular threat.

This trend became widespread in the early 2000s when the first floors of panel houses were reconstructed as stores and pharmacies with separate entrances. To introduce the concept of "city for people" in Almaty, the famous Danish architect and urban design consultant and author of the concept of "city for people", Jan Gale, was invited to Kazakhstan in 2014-2016. The architect gave six lectures in Almaty to representatives of the city authorities, city planning council, architecture students, and builders.

The expert noted that Almaty has huge spaces, large neighborhoods, and sparse development. This creates some discomfort. Many underground and elevated crosswalks do not allow people to use the space of streets to cross without steps on zebra. Catastrophic lack of comfortable space for pedestrians on the streets of the city. Almaty has a unique natural potential - the city is close to nature and has numerous green spaces. Despite these advantages, the main problem of the city is air pollution. The idea of a "city for people" has been partially realized in Almaty. Bicycle lanes and stations for bicycles and scooters have appeared.

Part of the city streets were reconstructed with safety islands. It should also be noted that the city of Almaty currently has a digital three-dimensional model, but its main purpose is economic. Providing general information and the structure of the urban environment to attract investors for the construction of new facilities. Therefore, this study aims to validate the need to create a unified platform that can assess the safety of the urban environment and present possible options for architectural and urban planning solutions.

Based on the studied sources raising the issues of developing a model for organizing the construction of an urban environment, the main security risks should be identified: criminal, infrastructural, environmental and seismic.

The relevance of the study lies in the development of a system of general security and improving the quality of life in the cities of Kazakhstan.

Thus, the purpose of this study is to justify the need to create a single platform that could assess the safety of the urban environment and present possible options for architectural and urban planning solutions. This study is aimed at developing the concept of a digital three-dimensional model of the city as an architectural and urban planning method for creating a safe urban environment.

2 LITERATURE REVIEW

Theoretical aspects of organizing urban environment safety are reflected to a certain extent in scientific works of foreign and domestic scientists. Depending on the stages of urbanization, various theories of architectural urban planning were put forward and tested, types of ensuring safety and organizing life in cities were considered.

In her book, "The Death and Life of Great American Cities", Jane Jacobs **(Jacobs, 1961)** emphasized the importance of "eyes on the street" in keeping urban areas safe. Her theories emphasize the importance of active streets and mixed-use buildings to keep people in constant presence, which helps reduce crime.

Oscar Newman's **(Newman, 1972)**: "defensible space theory, proposed in 1972, asserts that certain architectural and planning decisions can increase safety by strengthening territorial control and creating clear boundaries between public and private spaces".

CPTED (Crime Prevention Through Environmental Design), a concept developed in the 1970s, is based on the idea that architecture, physical planning, and environmental design can influence human behavior and reduce the likelihood of crime. The principles of CPTED include improving

visibility and lighting, maintaining order and cleanliness, restricting access, and fostering a sense of community **(Jeffery, 1971, Elsayed, 2024)**.

Kevin Lynch **(Lynch, 1960)**, in his book "The Image of the City", published in 1960, explores how people perceive and orient themselves in urban spaces. The book's main idea is that successful urban design must consider the ease of orientation and understanding of the urban environment by its residents and visitors. Lynch argues that five basic elements are necessary to create an "image of the city" in people's minds: paths (roads, trails), boundaries (delineators of spaces), neighborhoods (distinguishable sections of the city), nodes (focal points such as squares and intersections), and landmarks (notable objects). These elements help people form a stable mental image of the city, making navigating and perceiving the urban environment easier.

Le Corbusier **(Corbusier, 1987)** in his works, including the book " The City of To-morrow and its planning", put forward the ideas of separating urban functions, creating wide avenues and large green spaces, and applying strict geometry in the layout. These ideas aimed to solve the problems of congestion and disorganization in traditional cities, which is relevant to safety issues. Le Corbusier advocated the creation of different levels for pedestrians and vehicular traffic, which was intended to reduce traffic accidents and improve pedestrian safety and comfort.

Many studies developed an integrated approach to planning the urban environment, considering social, economic, and aesthetic aspects of life. He substantiated the need to create multifunctional urban areas that balance residential areas, public spaces, and recreational areas. Recent trends in planning contributed significantly to developing concepts for creating safe and human-centered urban spaces. His approach to urban design centers around improving citizens' quality of life by making urban spaces safer, more comfortable, and more accessible to all categories of people **(Krebs, Mayr, Rezwan, Höftberger, König, Salas, Jong, & Cani, 2023)**.

The book Architectural Design of Earthquake Resistant Buildings by Christopher Arnold and Robert Reitherman emphasizes the importance of integrating architectural and engineering approaches to create safe and aesthetically pleasing buildings. Arnold and Reitherman emphasize a multidisciplinary approach to design, emphasizing the importance of collaboration between architects, civil engineers, and structural engineers **(Arnold, & Reitherman, 1989)**.

Research in the field of urban development shows that at the present stage, focusing on the international level, for Kazakhstan it is relevant to unite individual intellectual cases based on a single platform of a digital three-dimensional model of urban development, using architectural and urban planning principles for solving criminal, environmental, infrastructural and seismic safety.

3 MATERIALS AND METHODS

In the course of the research, collection and study of domestic and foreign experience in architectural urban planning were conducted. Groups of urban environment safety risks were identified and systematized, the basic principles of "protected space" were defined, including in seismic areas. Such forms of design as morphological mapping, three-dimensional modeling, creation of digital twins were proposed. Through the research, certain conclusions were made on the relevance of the transition to an integrated approach to the formation of the "smart city" model.

It is known that recent scientific and technological advances have changed the boundaries of knowledge. They will generate the next wave of breakthrough technologies that significantly impact urban society **(Anselmo, Ferrara, Corgnati, & Boccardo, 2023, Doshibekova, Jurinskaya, Tashpulatov, Zhilisbayeva, Sarttarova, Akbarov, & Kalmakhanova, 2023)**. The development of digital twin technologies has significantly influenced the use of virtual cities and mobility in smart cities. Digital twins provide a platform for developing and testing various systems, algorithms, and mobility policies, which may be employed in creating new safe cities **(Bayer, & Pruckner, 2023)**.

A control system using a digital twin for emergency pedestrian evacuation can improve the overall evacuation efficiency **(Han, Zhao, & Li, 2020)**. Digital twins can make cities more efficient, smarter, sustainable, safer, and inclusive **(Konbr, & Abdelaal, 2022)**. To date, various options for digital twins of cities have been developed. For example, city digital twin systems have already been

developed, such as urban transport, disaster management, citizen participation **(Dembski, Wössner, Letzgus, Ruddat, & Yamu, 2020)**, infrastructure management **(Pedersen, Borup, Brink-Kjær, Christiansen, & Mikkelsen, 2021)** or urban planning **(Schrotter, & Hürzeler, 2020)**.

In particular, this is a current problem of digital twins in physical urban infrastructure because they model a wide number of systems that need to be integrated into one tool. City digital twins can drive the development of smart city concept and urban models to a new level. Taking advantage of data collected in smart cities and automatically introducing them into a model of the city and its system, an accurate digital replica is supported that can autonomously interact with the city. Digital twins of cities can not only model, reflect, and interact with the city physical aspect of the city but can also focus on the social and economic aspects.

4 RESULTS AND DISCUSSION

Architectural and urban planning principles of formation are the most important aspects of organizing safe urban environments. For example, since the COVID-19 outbreak, there has been a renewed focus on the links between cities, urban planning, and the pandemic, which has led urban planners and policymakers to question the future of the urban built environment **(Mouratidis, & Yiannakou, 2022)**. Proper planning of projects in the urban environment is how cities enhance outdoor living conditions and urban and public health **(Buffoli, Mangili, Capolongo, & Brambilla, 2022)**. The urban environment influences the lives of urban dwellers in terms of both health and the behaviors they may exhibit, encouraging or discouraging activity and the adoption of good lifestyles **(Faedda, Plaisant, Talu, & Tola, 2022)**. The built environment and mobility system significantly impact people's mobility behavior and activity patterns and, in turn, affect the entire population's health and quality of life **(Giles-Corti, Vernez-Moudon, Reis, Turrell, Dannenberg, Badland, Foster, Lowe, Sallis, & Stevenson, 2016)**. Outdoor spaces allow urban children to engage in physical activities, foster social interactions, and facilitate relaxation **(Reimers, & Knapp, 2017, Hoseeini, Salehinia, Shafaei, & Sedghpour, 2021)**. This significance becomes particularly important in high-density urban environments where the availability of open spaces is often constrained. The efficient design of outdoor open spaces allows the creation of functional and enjoyable recreational areas within the confines of the available space **(Hoseeini, Salehinia, Shafaei, & Sedghpour, 2021, Konbr, Elsayed, & Elboshy, 2023, Tang, & Woolley, 2023)**.

The theoretical concept of the three-dimensional digital model is based on the idea of understanding the city and urban life as a living organism using various self-regulation mechanisms. According to the proposed idea, the digital three-dimensional model integrates indicators that ensure a safe environment in the city of Almaty. The research methodology is based on identifying concepts that use architectural-urban planning methods to create a safe urban environment. These concepts are: "protecting space", "eyes on the street", and "city for people".

Based on the study of research material, the basic principles and systematized criteria for creating a safe urban environment at the level of "building", "yard", "street" and "district" are defined in **Table 1**.

Under the proposed concept, a digital three-dimensional model can identify architectural and urban planning inconsistencies with the above recommendations.

Table 1

Systematization of the safe environment at the levels: building, yard, street, and district based on the principles of "protecting space", "eyes on the street", and "city for people" (authors' materials).

Territoriality	**BUILDING**	**YARD**	**STREET**	**DISTRICT**
	Buildings of various ages	The distinction between private and public space	High pedestrian trafficking	High building density
Natural observation	Orientation of windows in kitchens and	The only direct path to the building entrance	Avoiding barriers and visibility of entrances	Straight street configuration

	common rooms exits to the courtyard			
Mixed land use	Organization of public spaces for common use	Functional zoning and subject organization of the yard for all groups of people	24-hour street maintenance	Variety of housing types
Broken windows theory	Aesthetically attractive, durable materials	Use of equipment made from quality materials	Organization of streets as equipped public spaces for meetings and communication	Lack of large unused spaces, maintaining order
Access control	Variation in the degree of openness at the boundaries of public spaces	Access control	Real symbolic barriers	Small neighborhoods

As noted above, the territory of Almaty is the most earthquake-prone zone in Kazakhstan. One of the important aspects of seismic safety is the presence of urban open spaces in the urban environment near the residential area. According to this concept, a digital three-dimensional model allows the identification of the required areas of open spaces in each residential area and limits the construction of new facilities in case of violation of the permissible norm.

This digital three-dimensional model reflects the seismic characteristics of each architectural feature. The digital three-dimensional model's programmed program will reflect the seismic deterioration of buildings, emergency buildings, etc **(Table 2)**.

Table 2
Requirements for organizing a safe environment in seismic areas: building, yard, street, district (authors' materials).

Building	**Configuration of vertical building ledges**	**Configuration of incoming corners**	**Possibility of collision with neighboring buildings**	**Building configurations**	**Potential weaknesses in construction**	**Building response to ground movement**
Yard	Communication systems, such as loudspeakers or information boards, can help organize and carry out evacuations and provide vital information during and after an earthquake.	Designation of safety zones in courtyard spaces	Lighting systems are functional in case of power failures, and the presence of information signs indicates the direction to safety zones and evacuation exits.	All landscaping elements must be securely fastened, including trees, benches, playgrounds, and art objects.	Assess the probability of damage or collapse of buildings during a real earthquake.	Paths and exits from courtyard spaces must be clear of obstacles to ensure unhindered evacuation of people. Regular inspection and maintenance of these paths are essential.
Street	Resistance to seismic influences. Quality of materials and technologies used	Streets must be equipped with an effective drainage system to prevent flooding after earthquakes	Separation of traffic and people in case of evacuation	Transformation into evacuation routes.	Lighting systems and safety signs that can operate even during a power outage.	Evacuation zones are designated accessible to all residents in the event of seismic activity.
District	Designating open, safe spaces for people to gather during an earthquake	Designation of open spaces for the placement of temporary objects	Optimization of the location of infrastructure facilities and development areas	Develop risk-decreasing strategies	Areas of the region most vulnerable to earthquakes	Information about soil types

Based on the compiled criteria, **(Table 1, Table 2**

Table) on the example of one district of the city, a comparative analysis of compliance with the principles of "protecting space", "eyes on the street", and "city for people" was carried out.

In the 2010 s, the smart city concept (i.e., a city where the administration and citizens cooperate with new technologies to make the city more efficient, intelligent, sustainable, safer, inclusive, and democratic) was popularized, and cities were sensorized **(Ferré-Bigorra, Casals, & Gangolells, 2022)**. Nevertheless, current approaches cannot usually directly interact with the city urban digital twins, which can potentially change this and drive the smart city concept and urban models to the next level. By taking advantage of the data that are gathered in smart cities and automatically introducing them into the city model and its systems, an accurate digital replica capable of autonomously interacting with the city is maintained.

This study draws attention to consider architectural and urban planning methods as key factors in organizing a safe urban environment in a smart city system. At the present stage, the concept of "smart city" has become widespread as a new dimension of the use of digital technologies to create a comfortable infrastructure and improve the quality of life of people in cities by creating safe urban environments **(Tolegen, Moldabekov, Kosheno, & Mugzhanova, 2018)**.

The main protective means are electronic or mechanical video surveillance systems, access control, strengthening of building structures, etc. Sometimes, they replace compliance with the requirements of the spatial planning characteristics of buildings and architectural and urban planning principles of forming a safe urban environment, which fade into the background.

The emphasis on the maximum use of information technology tools to ensure security in the urban environment, without paying due attention to architectural and urban planning techniques, leads to high financial costs when used.

According to the proposed concept, a digital three-dimensional model can identify architectural and urban planning inconsistencies with the above recommendations. Social dwellings and houses of cheap market segments have a particularly low security potential. However, expensive commercial complexes often do not use elementary spatial planning solutions to increase security, relying on security guards and surveillance cameras.

Modern residential areas are often built on point or block principles and are divided into "economy", "comfort", "business," and "elite" class residential complexes. Residential complexes, "economy", and "comfort" practically repeat the model of neighborhoods built in the post-Soviet period. Therefore, such problems as the presence of blind ends of buildings. There are no distinctions by zone and degrees of privacy; the public space begins right outside the apartment's threshold.

As noted above, the territory of Almaty is the most earthquake-prone zone in Kazakhstan, where construction of more than 9 floors was not allowed. Currently, the city has a huge number of buildings with more than 16 floors. Seismology specialists, builders, and architects are currently working on the certification of buildings for seismic resistance.

"There are technologies to test houses for seismic resistance. After the frame is built, a special simulator is put on the roof of the building, which rocks the building. However, the machine rocks the building from above, while the earthquake happens from below, so testing is incorrect. In reality, the shocks come from below; the foundations are at the bottom, not at the top" **(Oliynyk, Amandykova, Konbr, Eldardiry, Iskhojanova, & Zhaina, 2023)**. It is necessary to apply new technologies in construction and legislate it. A seismic isolator is a "pad" between the foundation and the columns. It does not allow seismic loads to be transferred from the foundation to the frame of the building," believes a representative of the Union of Builders of Kazakhstan.

Today, Building Information Modeling also plays an important role in the seismic design process. BIM modeling allows the creation of a digital model of a building, including its structure, materials, and systems, which helps visualize and analyze the earthquake behavior of the building. In addition, various scenarios, including seismic events, can be previewed using augmented reality elements to evaluate and predict their impact on the building. Additionally, this allows appropriate modifications and improvements at the design stage to ensure optimal seismic stability.

An important functional feature of the proposed numerical model is its ability to test the seismic

performance of buildings, demonstrate possible building collapse options, and calculate the hazardous area of collapse.

Even though the city is located in an earthquake-prone zone, the analysis shows that the architectural spaces under consideration do not meet the criteria for creating a safe urban environment **(Figure 1 – 8)**.

Figure 1 – Results compliance with the principles of "space protection, "eyes on the street": (a, b) Buildings of various ages; (c) Orientation of windows in kitchens and common rooms, exits to the courtyard (authors' materials).

Figure 2 – (a) Organization of public spaces for common use; (b) Aesthetically attractive durable materials; (c) Variation in the degree of openness at the boundaries of public spaces (authors' materials).

Figure 3 – Results of courtyard spaces correspondence with the principles of "space protection, "eyes on the street," and "city for people": (a) The distinction between private and public space; (b) The only direct path to the

building entrance; (c) Functional zoning and subject organization of the yard for all groups of people (authors' materials).

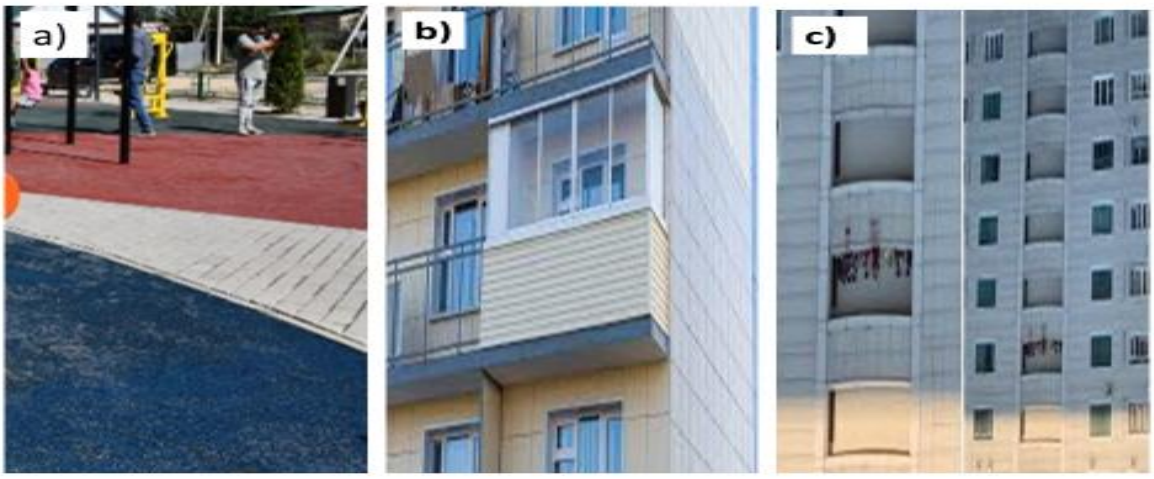

Figure 4 – (a) Use of equipment made from quality materials; (b, c) Access control (authors' materials).

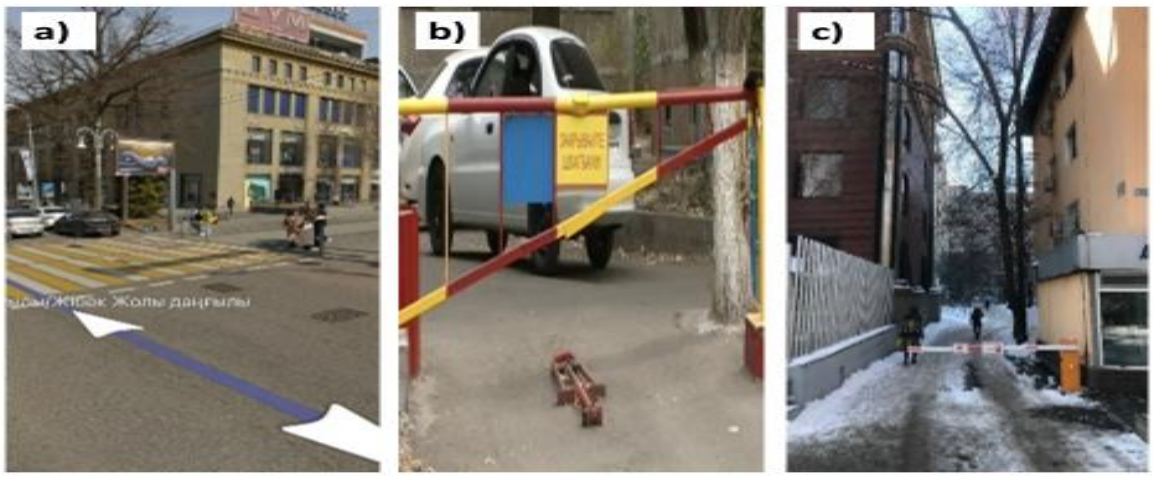

Figure 5 – Results of street compliance with the principles of "protection of space, "eyes on the street,"and "city for people": (a) High pedestrian trafficking; (b,c) Avoiding barriers and visibility of entrances (authors' materials

Figure 6 – (a) 24 hour street maintenance; (b) Organization of streets as equipped public spaces for meetings and communication; (c) Real symbolic barriers (authors' materials).

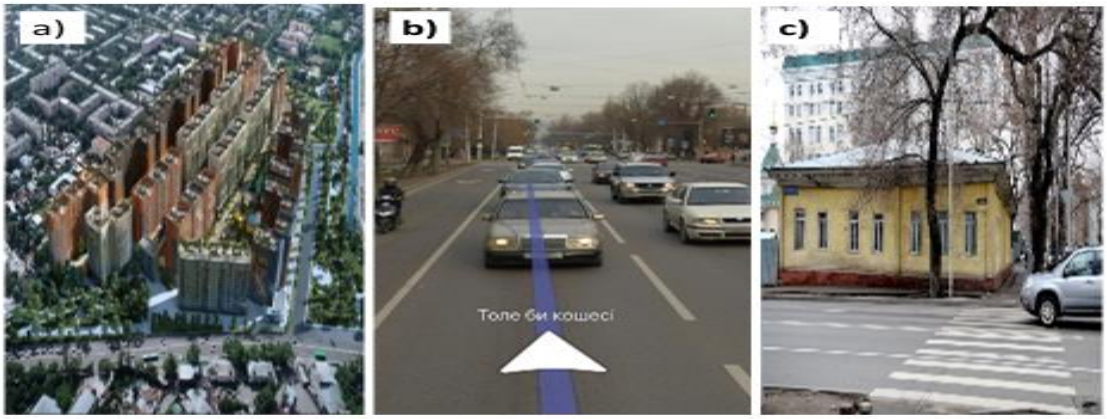

Figure 7 – District. Results of the neighborhood's compliance with the principles of "defensible space," "eyes on the street," and "city for people: (a) High building density; (b) Straight street configuration; (c) Variety of housing types (authors' materials).

Figure 8 – (a) Lack of large unused spaces, maintaining order; (b, c) Small neighborhoods (authors' materials).

The interdisciplinary features and functional capabilities that allow testing scientific developments and project proposals will make the digital three-dimensional model of the city the main guide in developing the "smart city" system in cities. Another important factor in substantiating the relevance of this topic is the need for cities to comply with international safety indices. The basis of the indices is the creation of maximum walking opportunities, reducing dependence on motor transport, and contributing to people's daily lives.

The UN has outlined the main urban planning directions in the real, sustainable urban development model. Also, this is the creation of environmentally friendly and affordable urban infrastructure. Therefore, promoting alternative architectural and urban planning visions and solutions for forming a safe urban environment is relevant for many countries. The concept of a digital three-dimensional model developed in this work using architectural and urban planning principles for solving criminal, environmental, infrastructural, and seismic safety will significantly contribute to creating comfortable conditions and improving the quality of life of people in cities.

5 CONCLUSIONS

This study analyzes existing architectural and technological models of urban development. The main security risks, such as criminal, infrastructural, environmental and seismic, are identified. Emphasizing the relevance of ensuring seismic safety, using the example of the city of Almaty, relevant recommendations are given. In order to comprehensively address the issues of managed urbanization in Kazakhstan, it is proposed to create a common neural platform in the form of a digital

three-dimensional model of a "smart" city, based on the architectural and urban planning principles of a safe environment, mobility and socialization of urban infrastructure.

The concept of a digital three-dimensional model of a city proposed in this study will effectively contribute to improving safety in the volumetric-spatial solution of interior spaces of buildings, improving comfortable conditions on pedestrian streets and landscaping open spaces of urban areas. High-quality results of transformations at the level of buildings, courtyards, streets and microdistricts will increase the safety of the entire urban area. The creation of a safe urban environment using a digital three-dimensional model is in tune with the rapid trend of the spread of information digital technologies and the inevitability of the dynamic development of smart city systems around the world. This trend poses new challenges for architects, urban planners, designers and builders and requires searching for new ideas in the issue of creating a safe environment. Further development of this research may be related to studying the integration of digital three-dimensional models with innovative discoveries in architectural and urban planning activities that contribute to the formation of a safe urban environment.

REFERENCES

1. **Tolegen, Z., Pomorov, S., & Issabayev, G.** (2023). The role of a three-dimensional digital model of a city in organizing a comfortable environment [Rol' trekhmernoy tsifrovoy modeli goroda v organizatsii komfortnoy sredy]. Bulletin of Kazakh Leading Academy of Architecture and Construction, 87(1), 121–128. https://doi.org/10.51488/1680-080x/2023.1-12 (In Russ.).
2. **Ying, S., Van Oosterom, P., & Fan, H.** (2023). New techniques and methods for modelling, visualization, and analysis of a 3D city. Journal of Geovisualization and Spatial Analysis, 7(2). https://doi.org/10.1007/s41651-023-00157-x
3. **Konbr, U., & Mamdouh, H.** (2022). A proposed strategy to evaluate nanomaterials in construction to boost sustainable architecture. Civil Engineering and Architecture, 10(7), 3206–3226. https://doi.org/10.13189/cea.2022.100732
4. **Tolegen, Z., Imanbayeva, Z., Trofimov, V., Popov, Y., & Amandykova, D.** (2022). On the Question of Humanization of Urban Spaces of Kazakhstan. Bulletin of Kazakh Leading Academy of Architecture and Construction, 84(2), 124–134. https://doi.org/10.51488/1680-080x/2022.2-14
5. **Tolegen, Z., Konbr, U., Karzhaubayeva, S., Sadvokasova, G., Nauryzbayeva, A., & Amandykova, D.** (2022). Assessment of safe access to pedestrian infrastructure facilities in the city of Almaty, Kazakhstan. Civil Engineering and Architecture, 11(1), 351–371. https://doi.org/10.13189/cea.2023.110128
6. **Tolegen, Z., Moldabekov, M., Kosheno, K., & Mugzhanova, G.** (2018). Roles of Public Ethnocultural Spaces in Kazakhstan. Astra Salvensis, 761-774. https://astrasalvensis.eu/blog/mdocs-posts/54-murataly-moldabekov-aida-d-tolegenova-kambarbek-koshenov-zhaina-tolegen-gulnar-mugzhanova-roles-of-public-ethnocultural-spaces-in-kazakhstan/
7. **Zhaina, T., Kaltay, N., Mukhtarova, A., Beibit, B., & Amandykova, D.** (2022). Review of studying methods for the problem of safety in the urban environment. Innovaciencia Facultad De Ciencias Exactas Físicas Y Naturales, 10(1), 1–7. https://doi.org/10.15649/2346075x.2958
8. **Tolegen, Z., Issabayev, G., Yussupova, A., Murzalina, G., & Amandykova, D.** (2022). Architectural and compositional concepts of environmentally safe urban arrangement. Civil Engineering and Architecture, 10(3), 1036–1046. https://doi.org/10.13189/cea.2022.100320
9. **Iskhojanova, G., Zayats, I., & Sarttarova, L.** (2022). Typological aspects of urban architecture design based on the principle of hybridity. Innovaciencia Facultad De Ciencias Exactas Físicas Y Naturales, 10(1), 1–8. https://doi.org/10.15649/2346075x.2976
10. **Gholipour, S., Mahdi Nejad, J., & Sedghpour, B.S.** (2021). Security and urban satisfaction: developing a model based on safe urban park design components extracted from users' preferences. Security Journal, 35(3), 863–892. https://doi.org/10.1057/s41284-021-00303-4

11. **Abdirayim, K.** (2023). If Tomorrow it «Shake»: Which Houses in Almaty are Safe During an Earthquake – Experts [Yesli zavtra "tryakhnet": kakiye doma v Almaty bezopasny pri zemletryaseniyakh - eksperty]. Satellite Kazakhstan. Accessed on 2/10. https://ru.sputnik.kz/20230412/esli-zavtra-tryakhnet-kakie-doma-v-almaty-bezopasny-pri-zemletryasenii---eksperty-33848484.html
12. **Jacobs, J.** (1961) The Death and Life of Great American Cities. New York: Random House. Invalid Record | Nielsen Library. (n.d.). Nielsen Library. https://adams.marmot.org/Record/.b11383811
13. **Newman, O.** (1972). Defensible Space - Crime Prevention Through Urban Design. Office of Justice Programs. (n.d.). https://www.ojp.gov/ncjrs/virtual-library/abstracts/defensible-space-crime-prevention-through-urban-design#0-0
14. **Jeffery, C.R.** (1971). Crime prevention through environmental design. American Behavioral Scientist, 14(4), 598. https://doi.org/10.1177/000276427101400409
15. **Elsayed, M.** (2024). Sustainable Campus: A Proposed General Framework for Transforming the Tanta University Campus into Sustainability. [PDF file] Wwweulc. https://www.academia.edu/110314408/Sustainable_Campus_A_Proposed_General_Framework_for_Transforming_the_Tanta_University_Campus_into_Sustainability
16. **Lynch, K.** (1960). The Image of the City. MIT Press. Massachusetts Institute of Technology Cambridge, Massachusetts and London. England, 202. https://faculty.ksu.edu.sa/sites/default/files/lynch_1960_the_image_of_the_city.pdf
17. **Corbusier, L.** (1987) The City of To-morrow and its planning (Dover Architecture): Le Corbusier, Frederick EtcHells, Frederick Etchells: 9780486253329: Amazon.com: Books. (n.d.). https://www.amazon.com/City-morrow-Planning-Dover-Architecture/dp/0486253325#detailBullets_feature_div
18. **Krebs, R., Mayr, S., Rezwan, S., Höftberger, K., König, T., Salas, V., Jong, S., & Cani, A.** (2023). Creating Resilient Public Spaces – a Global Perspective on the Conditions for Integrated Urban Development. REAL CORP: Ljubljana, Slovenia. Repository. https://repository.corp.at/996/
19. **Arnold, C., & Reitherman, R.** (1989). Architectural Design of Earthquake. New York. https://www.naturalhazards.govt.nz/assets/Publications-Resources/249-Architectural-Design-for-Earthquake-compressed.pdf
20. **Anselmo, S., Ferrara, M., Corgnati, S. P., & Boccardo, P.** (2023). Aerial urban observation to enhance energy assessment and planning towards climate-neutrality: A pilot application to the city of Turin. Sustainable Cities and Society, 99, 104938. https://doi.org/10.1016/j.scs.2023.104938
21. **Doshibekova, A., Jurinskaya, I., Tashpulatov, S., Zhilisbayeva, R., Sarttarova, L., Akbarov, R., & Kalmakhanova, M.** (2023). Effect of technological parameters on the process of copper deposition on chemically and chemical-galvanically nickel-plated fibers. Research Journal of Textile and Apparel. https://doi.org/10.1108/rjta-03-2023-0037
22. **Bayer, D., & Pruckner, M.** (2023). A digital twin of a local energy system based on real smart meter data. Energy Informatics, 6(1). https://doi.org/10.1186/s42162-023-00263-6
23. **Han, T., Zhao, J., & Li, W.** (2020). Smart-Guided Pedestrian Emergency Evacuation in Slender-Shape Infrastructure with Digital Twin Simulations. Sustainability, 12(22), 9701. https://doi.org/10.3390/su12229701
24. **Konbr, U., & Abdelaal, M.** (2022). Utilizing smart systems to enhance the sustainability of Egyptian administrative buildings. Civil Engineering and Architecture, 10(7), 2779–2808. https://doi.org/10.13189/cea.2022.100701
25. **Dembski, F., Wössner, U., Letzgus, M., Ruddat, M., & Yamu, C.** (2020). Urban Digital twins for smart cities and citizens: the case study of Herrenberg, Germany. Sustainability, 12(6), 2307. https://doi.org/10.3390/su12062307

26. **Pedersen, A. N., Borup, M., Brink-Kjær, A., Christiansen, L. E., & Mikkelsen, P. S.** (2021). Living and Prototyping Digital Twins for Urban Water systems: Towards Multi-Purpose Value Creation using models and Sensors. Water, 13(5), 592. https://doi.org/10.3390/w13050592
27. **Schrotter, G., & Hürzeler, C.** (2020). The digital twin of the City of Zurich for urban planning. PFG – Journal of Photogrammetry Remote Sensing and Geoinformation Science, 88(1), 99–112. https://doi.org/10.1007/s41064-020-00092-2
28. **Mouratidis, K., & Yiannakou, A.** (2021). COVID-19 and urban planning: Built environment, health, and well-being in Greek cities before and during the pandemic. Cities, 121, 103491. https://doi.org/10.1016/j.cities.2021.103491
29. **Buffoli, M., Mangili, S., Capolongo, S., Brambilla, A.** (2022). Explorative Study on Urban Public Space Renovation during COVID-19: Test of a Visual Web-Based Survey about the City of Saint German en Laye, France. Sustainability, 14(19), 12489. https://doi.org/10.3390/su141912489
30. **Faedda, S., Plaisant, A., Talu, V., & Tola, G.** (2022). The Role of urban environment design on Health During the COVID-19 Pandemic: A scoping review. Frontiers in Public Health, 10. https://doi.org/10.3389/fpubh.2022.791656
31. **Giles-Corti, B., Vernez-Moudon, A., Reis, R., Turrell, G., Dannenberg, A. L., Badland, H., Foster, S., Lowe, M., Sallis, J. F., Stevenson, M., Owen, N.** (2016). City planning and population health: a global challenge. The Lancet, 388(10062), 2912–2924. https://doi.org/10.1016/s0140-6736(16)30066-6
32. **Reimers, A. K., & Knapp, G.** (2017). Playground usage and physical activity levels of children based on playground spatial features. Journal of Public Health, 25(6), 661–669. https://doi.org/10.1007/s10389-017-0828-x
33. **Hoseeini, A., Salehinia, M., Shafaei, M., & Sedghpour, B. S.** (2021). Playful Environment: Literature Review on Environmental Affordances to Motivate Kids to Play (EAMKP). Iran University of Science & Technology, 31(3), 1–10. https://doi.org/10.22068/ijaup.31.3.516
34. **Konbr, U., Elsayed, M., & Elboshy, B.** (2023b). A framework for assessing the sustainability of Egyptian university campuses. Civil Engineering and Architecture, 11(4), 1909–1939. https://doi.org/10.13189/cea.2023.110419
35. **Tang, P., & Woolley, H.** (2023b). Optimizing urban children's outdoor play spaces: affordances, supervision, and design dynamics. Sustainability, 15(20), 14661. https://doi.org/10.3390/su152014661
36. **Ferré-Bigorra, J., Casals, M., & Gangolells, M.** (2022). The adoption of urban digital twins. Cities, 131, 103905. https://doi.org/10.1016/j.cities.2022.103905
37. **Oliynyk, O., Amandykova, D., Konbr, U., Eldardiry, D. H., Iskhojanova, G., & Zhaina, T.** (2023). Converging Directions of Organic Architecture and City Planning: A Theoretical Exploration. International Society for the Study of Vernacular Settlements, 10(8), 223–235. https://figshare.com/articles/journal_contribution/Converging_Directions_of_Organic_Architecture_and_City_Planning_A_Theoretical_Exploration/24265786