Implementation of GIS-based Smart Community Information System and concepts of Digital Twin in the field of urban planning in Uzbekistan

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Abstract. This article describes initiatives implemented in Uzbekistan to create a GIS-based Smart Community Information System (SCIS) and concepts of Digital Twin in the field of urban planning. The goal of the project is to create a GIS-based SCIS by introducing the concept of a Digital Twin to provide 3D maps, and plans, collect data necessary for spatial analysis and planning of territories, maintain and provide city master plans and district master plans, territorial zoning, land use and development rules, building codes and regulations, control over the process of construction, operation, repairs, and renovation. Based on the Esri product solutions, such as ArcGIS City Engine, ArcGIS Pro, Image Analyst, 3D Analyst, and ArcGIS Enterprise \ AGOL were created the initial version of the Digital Twin of the city of Tashkent. Also used CAD files, data from OSM, Airbus (DEM 24m), and SketchUp to work with detailed models and other data from different sources. The platform with advanced artificial intelligence and machine learning will provide reality capture, GIS and BIM integration, and real-time Internet of Things (IoT) support, allowing clients and organizations to collect, model, visualize, analyze and predict information on infrastructures and processes.

1 Introduction

The world is undergoing the largest wave of urban growth in history. More than half of the world's population now lives in towns and cities, and by 2030 this number will swell to about 5 billion. Much of this urbanization will unfold in Africa and Asia, bringing huge social, economic, and environmental transformations. Urbanization has the potential to usher in a new era of well-being, resource efficiency, and economic growth[1]. Already, some of the world's megacities are overpopulated. Municipalities do not always cope with garbage collection, the supply of communal resources and electricity from district to district is not uniform, etc. In order to provide the population with high-quality urban services, administrations are increasingly introducing various information systems.

According to Boris Glazkov, Director of the Center for Strategic Innovations of Rostelecom, on average, Smart Cities save up to 30% of electricity, 15% of water, and 20% of

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the time spent by drivers and passengers in traffic congestion, said in November 2016 at the Internet of Things in Smart City forum[2].

1.1 International experience - Analysis of the best world practices and standards

According to the he IMD-SUTD Smart City Index Report 2021[3] we can define that in the first place was Singapore of the city amongst the 118 cities. The Ratings for each city were calculated from the city's performance relative to the other cities within the group. The IMD-SUTD Smart City Index (SCI) assesses the perceptions of residents on issues related to structures and technology applications available to them in their city. The list of the Top-10 highest-ranked cities is demonstrated in Table 1.

Table 1. Top-10 highest-ranked cities according to The IMD World Competitiveness Center`s Smart City Index 2021[3].

Smart City Rank 2021	City	Smart City Rating 2021	Structure 2021	Technology 2021	Smart City Rank 2020	Change
1	Singapore	AAA	AAA	AAA	1	—
2	Zurich	AA	AAA	A	3	▲ +1
3	Oslo	AA	AAA	A	5	▲ +2
4	Taipei City	A	A	A	8	▲ +4
5	Lausanne	A	AAA	A	NEW	—
6	Helsinki	A	AA	A	2	▼ -4
7	Copenhagen	A	AA	A	6	▼ -1
8	Geneva	A	AA	A	7	▼ -1
9	Auckland	A	A	A	4	▼ -5
10	Bilbao	BBB	A	BBB	24	▲ +14

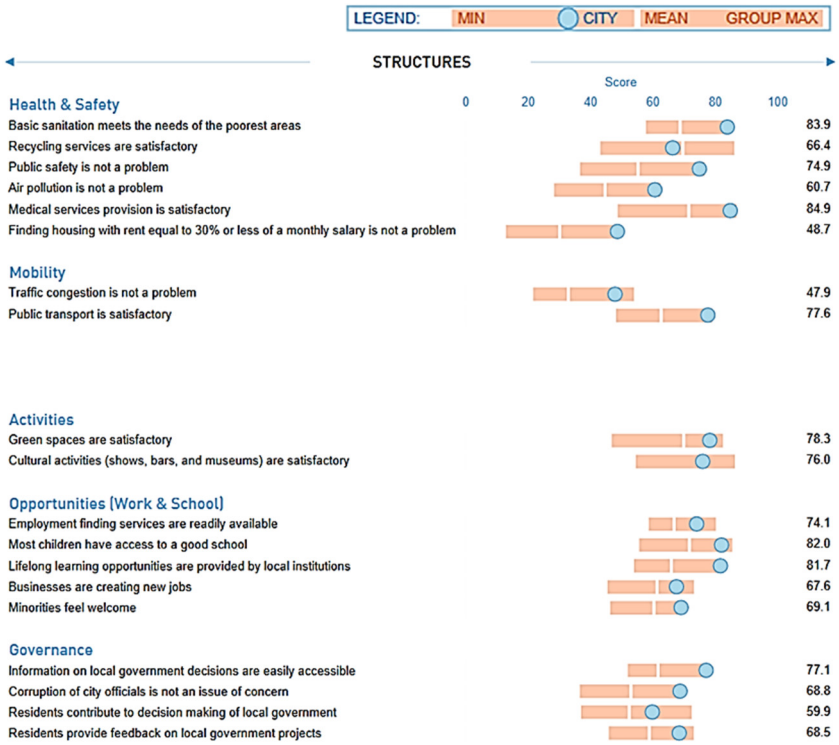

Fig. 1. The Structures pillar referring to the existing infrastructure of the Singapore city. Each pillar is evaluated over five key areas: health and safety, mobility, activities, opportunities, and governance.[3].

There are two pillars for which perceptions from residents are solicited: The Structures pillar referring to the existing infrastructure of the cities (Figure 1), and the Technology pillar describing the technological provisions and services available to the inhabitant (Figure 2).

No wonder Singapore is in the first place in the Smart City ranking, many modern technologies have been introduced and integrated in the city. Singapore is expected to build a future eco-city called Tengax. Spanning five districts (plantation, garden, park, "brick" district and forest hill), the eco-city Tengaks with 42,000 houses will be the 24th settlement built by the government of Singapore after World War II. However, according to the project's website, it will be the first "smart" eco-city in the country (Figure 3).

According to the authors of the project, roads and railways will be built underground, as well as additional pedestrian zones will be created, which will allow the government of Singapore to reduce carbon dioxide emissions by 2030 and halve by 2050.

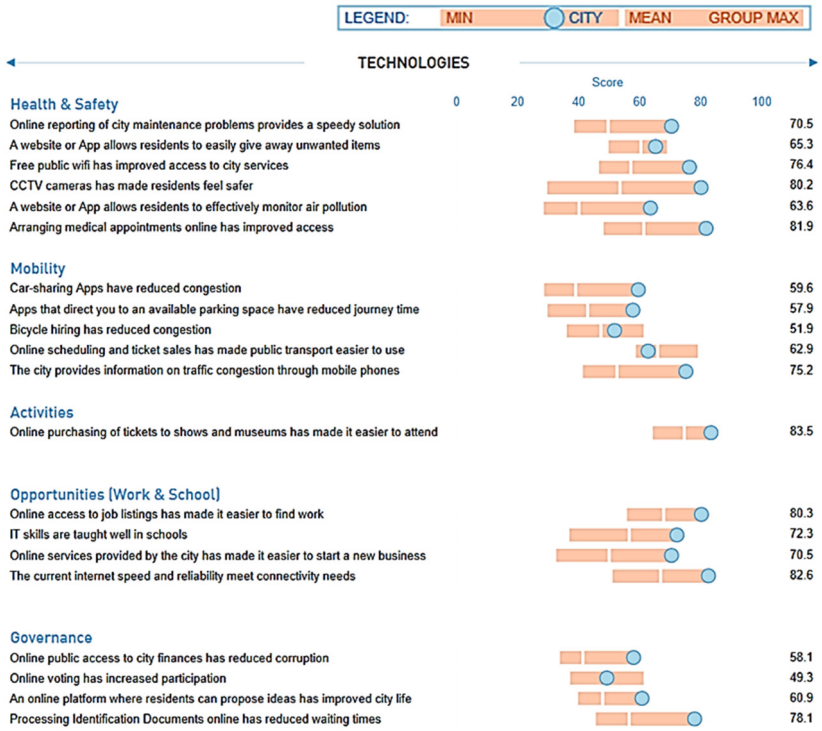

Fig. 2. Technology pillar describing the technological provisions and services available to the inhabitants in Singapore city.

Fig. 3. Design of the new future eco-city called Tengax, Singapore.

1.2 Initiatives implemented in Uzbekistan.

Despite the fact that the cities of Uzbekistan are not included in the list of Smart Cities 2021, many projects in this direction are being implemented in our country. For example, in July 2017, President of Uzbekistan Shavkat Mirziyoyev made a proposal to turn the country's capital into a "Safe City". One of the “Safe City” projects is already operating in the city of Tashkent: “smart” video surveillance cameras are operating at 120 intersections, fixing violations. The first stage of the project will be implemented in 2017-2019. During this time, it is planned to create video analytics systems, install video surveillance and automate the receipt of reports about incidents in Tashkent. In 2019–2021, the Safe City will be implemented in all regional centers, and in 2021–2023 it will cover the entire country[4].

In the spring of 2020, the President of the Republic of Uzbekistan set the task of digitalizing the urban space of the capital and creating a more comfortable and safer environment for residents, entrepreneurs and tourists. For this task, the Department of Digital Development of Tashkent was established. And on February 1, 2022, the Center for Spatial Research and Visiology announced the launch of the GRAFIT integrated geoanalytical platform, which aggregates information from more than 60 departments, integrates city services and provides everything necessary to solve three main tasks: operational management, strategic planning and making investment decisions[5].

In 2022, under the leadership of the Ministry of Construction of the Republic of Uzbekistan, the implementation of the project Creation of GIS-based Smart Public Information System (SCIS) and the concept of a Digital Twin in the field of urban planning began. The responsible organization for the creation of GIS-based SCIS is "Toshkentboshplan LITI" State Unitary Enterprise. At the time of publication of the article, with cooperation of Esri State and Local Government team the initial version of the Digital Twin of the city of Tashkent was created. This article informs about this GIS-based SCIS and initial version of the Digital Twin of the city of Tashkent.

2 Materials and methods

City Information Modeling (CIM) applications are dependent on the rapid technological development and local training, the limitations relate to the capacity of the public power to enable the application, incorporation, and implementation of practical solutions. Implementing 3D models of cities in urban management and planning can benefit local governments and serve as reinforcement in proportion as it overcomes preexisting practices that hinder innovation diffusion processes [4].

It is known that a real smart city uses a 3D digital base map, which provides real-time information within the boundaries of a certain area, block and building. These maps - also known as "Digital Twins" (DT) - include buildings, infrastructure, vegetation, transportation, and so on down to the level of individual floors and rooms. They are the basis for a real Smart City. And the technology of Geographic Information Systems (GIS) is the basic basis of any complex DT. DT can digitize the physical world, providing various data for the whole process[6].

A major problem in digitizing planning and design practices is the misfit with current software. Urban designers need to deliver engaging illustrations of future cities, master plans or design guidelines. Facing a choice between GIS, Computer Aided Design (CAD), Building Information Modelling (BIM) or 3D modelling software, urban designers often sketch and draw over printed two-dimensional cadastral maps that derive from GIS[7]. For example [7] to address the lack of appropriate software for planners and urban designers, were developed their own new City Information Modelling (CIM) software which were integrate GIS data that

stores cadastral maps and creates a digital drawing board for urban designers and other actors in the urban planning and development processes.

As technology advances, there is an increasing need to create 3D city models for a variety of applications such as 3D cadastre, geodesign, urban planning, facility management, modeling and analysis[8]. And on the other hand, many GIS platforms have come online in recent years such as ArcGIS Online, Google Maps Engine, GeoCommons, MapBox, OpenStreetMap, WorldMap, etc. These kind of platforms have made creating, interpreting, and mapping locational data easier and more intuitive, enabling people from all walks of life to create their own datasets and maps online[9]. In order to design the online 3D terrain visualization overlaid with satellite image data by using GIS software, there are some considerations that we need to be aware about that the quality of the visualization depends on the GIS software used[10, 11].

Smart cities and smart communities are those that make the lives of their citizens better. Esri is the leader in spatial thinking and pioneers the technology that helps governments of all sizes build smart communities. Esri's smart community information system (SCIS) establishes four technology tenets governments need to deliver smart communities and smart cities[12]:

1. Planning and Engineering. Today, planning and engineering disciplines must balance the needs of people, infrastructure, and the environment. Esri's GIS-based SCIS allows governments to model the impacts of proposed development, adjust to shifting demographics and lifestyles, and account for changes in climate change and economic shifts.

2. Operational Efficiency. Esri's SCIS collects information in real time and feeds it back into performance dashboards for real impact. More efficient workflows come from collecting information at the source, dispatching staff to where they are most needed, and maximizing materials and resources to improve response times while reducing costs.

3. Data-Driven Performance. Increasingly, smart devices, the Internet of Things (IoT), and cloud computing are feeding data on the locations of people, nature, vehicles, and infrastructure. When governments geo-enable data and enterprise systems, they can bring about business intelligence, establish more efficient workflows, improve communication, and tackle an issue in its entirety as opposed to its individual parts. Esri's GIS-based SCIS helps communities drive down costs, reduce time to action, and support decision-making and policy decisions that improve the overall quality of life, neighborhood by neighborhood.

4. Civic Inclusion. Esri's GIS-based SCIS provides an opportunity to evolve how governments think about civic inclusion. Mapping and spatial analytics help governments better understand their community makeup and help citizens understand what happens and why, in a context of where they live.

These four tenets are interdependent and made up of complimentary networks of data, solutions, implementations, training, and partners. Founded in location, fueled by data, and designed to improve decision-making, this system works to improve the world we live in. Esri recognizes that with the right people, processes, and technology, any community can become smarter[12].

Having studied the world experience and development of GIS technologies, as well as the number of qualified specialists in the field of land management and urban cadaster in Uzbekistan, we decided to use Esri ArcGIS software and develop GIS-based SCIS of Tashkent. The advantage of Esri's products is that they allow organizations to see the Digital Twin (DT) in the context of other information models, such as electrical and plumbing networks, urban spaces, or the environment.

3 Results and discussion

This project started on March 1, 2022 and the goal of the project is to create a GIS-based SCIS by introducing the concept of a Digital Twin to provide 3D maps, plans and collect data

necessary for spatial analysis and planning of territories, maintaining and providing city master plans and district master plans, territorial zoning, land use and development rules, building codes and regulations, control over the process of construction, operation, repairs and renovation.

To create the initial version of the Digital Twin of the city of Tashkent, the project used data from OSM, Airbus (DEM 24m), images from AGOL, SketchUp to work with detailed models (Figure 4).

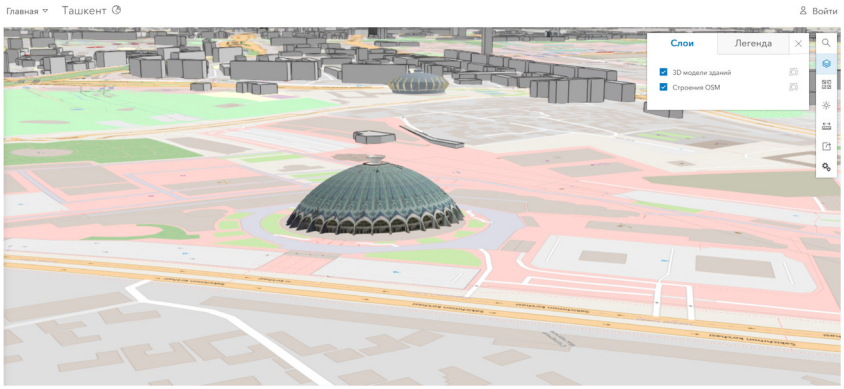

Fig. 4. Example of detailed building created SketchUp and OSM data (buildings) added to the scene as 3D blocks.

ArcGIS City Engine for generating buildings with "standard" facades, building a roadbed (Figure 4). ArcGIS Pro + Image Analyst – were used to tree recognition using machine learning for vegetation classification (Figure 5).

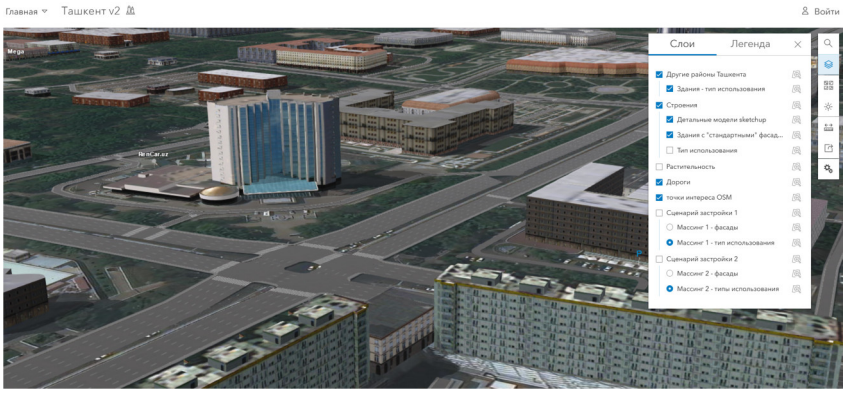

Fig. 5. Buildings with “standard” facades and roadbeds generated with ArcGIS City Engine and added to the 3D scene.

ArcGIS Pro + 3D Analyst were used for data preparation, project design, and publication on the Portal (Figure 6).

Fig. 6. All trees and vegetation were recognized and classified using machine learning.

Fig. 7. User interface of the initial version of the CIM.

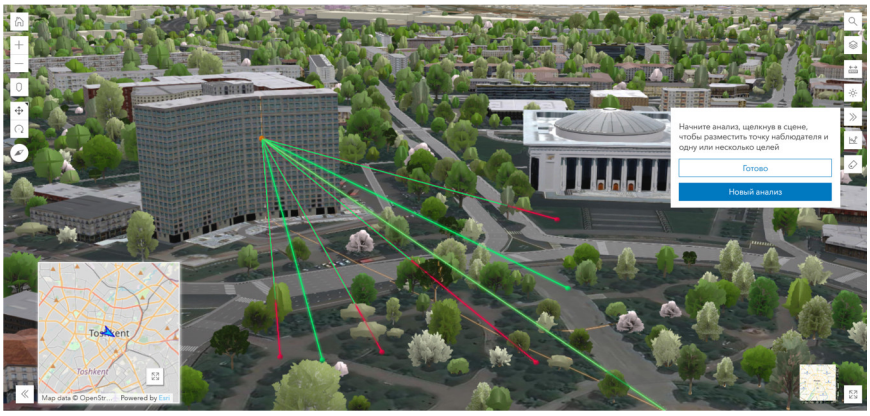

Fig. 8. Analyses with Adding an observer point tool, where the user, by clicking on the scene, can place an observer point and one or more targets.

With ArcGIS Enterprise \ AGOL were provided access to a 3D scene via the web. Some spatial analysis tools such as Adding an observer point (Figure 8), tool for creating a Relief profile (Figure 9) and The Daylight tool (Figure 10) allows users to change the sunlight and shadow settings in your scene for different times of the day and year.

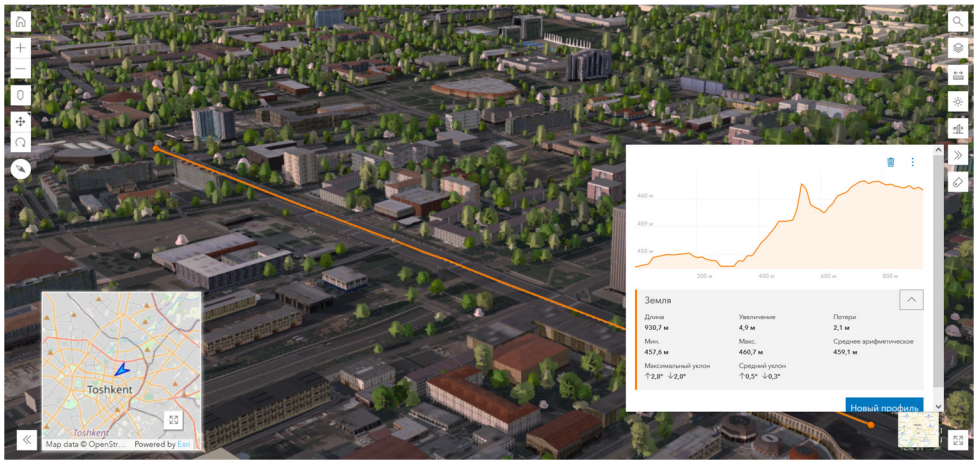

Fig. 9. Tool for creating a relief profile, where it is quite simple for the user to draw a line to obtain information about the relief profile of the selected direction.

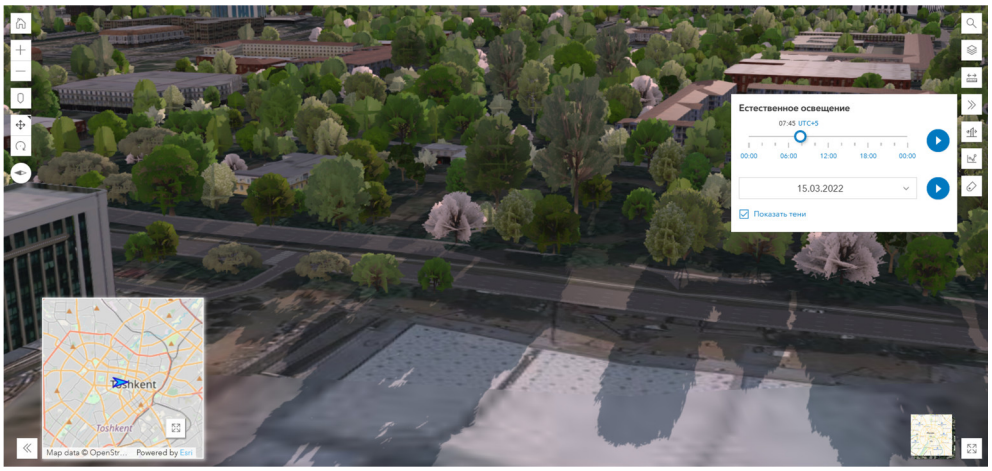

Fig. 10. With the Daylight Tool, the user will be able to adjust the effect of sunlight and shadows, including time, date, animation methods, and shadow display.

4 Conclusions

GIS-based SCIS and the Digital Twin of the city of Tashkent that we are creating will allow clients and organizations to collect, model, visualize, analyze and predict information on infrastructures and processes, combining the capabilities of many other information systems for more accurate understanding and support for making effective decisions.

GIS-based SCIS will provide reality capture, GIS and BIM integration, real-time Internet of Things (IoT) support, advanced artificial intelligence and machine learning. The data will be integrated into a centralized data warehouse and/or using open standards, the platform will have a variety of end user interfaces for data production, analysis and reporting, as well as city design and management. Engineers and urban planners can view web-based, shareable 3D models to determine the number of housing units that might be created under the proposed regulation change. These efforts are part of a larger push to support healthy community development and address housing affordability issues using data. More efficient workflows come from being able to collect information at the source, dispatching staff to where they are

most needed. By geo-enabling data and enterprise systems, governments can enhance business intelligence, establish more efficient workflows, improve communication and tackle an issue in its entirety as opposed to its individual parts.

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