URBAN DATA INTEGRATED MANAGEMENT AND SCENARIO DEVELOPMENT IN THE CONTEXT OF ACHIEVING SDG INDICATORS

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Abstract: *Urban planning has encountered numerous challenges due to the rapid growth of the cities in order to provide for suitable living circumstances, including satisfying the need for basic services, affordable housing for all residents, transportation and employment, and to fulfil the main Sustainable Development Goals (SDGs). The urban development must be guided by national and local authorities in order to maximize opportunities, requiring a harmonic coordination between policies and investments. The concept of Digital Twin has many opportunities to expand in the future, since it is constantly evolving, developing new features to provide the data required to optimize products and processes in a safe environment and decreasing the risks and costs of introducing new procedures. ArcGIS Urban is designed to improve urban planning and decision making and offers users the option of viewing multiple potential development perspectives and subjecting them to public review to ensure that the benefits of the community restrictions outweigh the costs.*

Keywords: *urban planning; GIS; geospatial data; Digital Twin; ArcGIS Urban; SDG*

1. Introduction

Recently, the use of Digital Twins in spatial planning has increased, as they are designed to support workflows and help evidence-based decision-making. The traditional analogue data is reorganized on digital platforms, currently used in several fields such as urban planning, construction, automotive industry, health services, power generation equipment and manufacturing. Digital Twin can be used for physical objects (e.g.: buildings, wind turbines) or for the entire city. Cities like Ottawa, New York and Maracaibo have a Digital Twin.

ArcGIS Urban enables all parties to work together to design, assess and analyse possible scenarios within cities, targeting both the public and private sectors. The ESRI solution is meant for all users, regardless of role or location. It provides the tools and information needed for planning, decision making, effective communication and collaboration and problem solving. By using ArcGIS Urban, planners can create multiple scenarios within the same plan, make comparisons between the existing and the proposed scenarios and evaluate the impact on the area regarding the relationship between the city and its inhabitants as well as the impact on the environment.

ArcGIS Urban is successfully used in Seattle, Honolulu, Arlington, Uppsala, San Francisco and Boston. The main problem these cities are facing is population growth. ArcGIS Urban is used to identify potential areas for development and those with issues, while focusing on finding solutions for a suitable and sustainable development of the city. Thus, planners can propose zoning changes to meet specific needs. Zoning is a key component in establishing an integrated urban development and requires ongoing studies in order to understand its results "on site". Through zoning, issues such as urban congestion, pollution, and ensuring appropriate living circumstances could be solved.

The case study presents two possible scenarios for the site between Buzești Boulevard, Polizu Street and Calea Griviței and the impact it could have on the area. I have chosen this location since it's in the heart of Bucharest and has a lot of potential for urban growth.

2. The State of the Art – Digital Twin and ArcGIS Urban planning

David Gelernter highlighted the idea of Digital Twin technology, published in his book “Mirror Worlds”, in 1991. The one who first applied this concept was Michael Grieves in 2002 and was publicly presented at a Society of Manufacturing Engineers conference, in Michigan. The "Digital Twin" term was introduced in 2010 by John Vickers from NASA [1]. In order to research, simulate and train crews for space missions, NASA replicated spacecrafts, beginning with the 1960s, thus being the pioneers of Digital Twin technology. Since Digital Twin is still a developing concept, there is no consensus on its definition. Its initial formulation by NASA mentioned the existence of three dimensions: physical, virtual and connection. The connection part is the one that exchanges information between the physical and the virtual space [2].

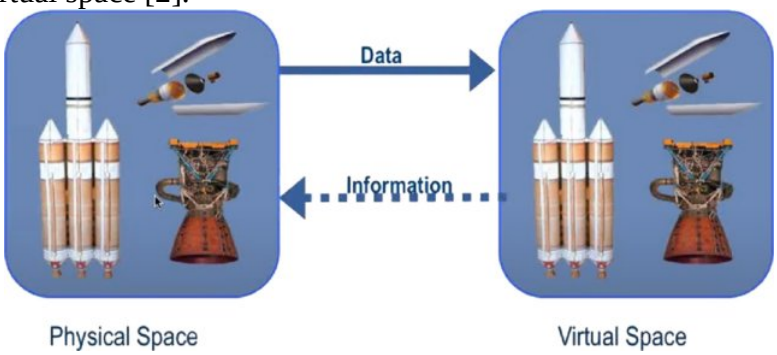

Figure 1 - The three dimensions of the Digital Twin [1]

Digital Twin is a virtual representation of the real world that accurately mirrors a physical object, creating copies of natural and built environments, which may include duplicates of the structure, functionality and behaviour of its real counterpart. Data collection and integration is improved, allowing real-time visualization and offering the possibility to make advanced analysis predictions, while enabling information and collaboration between interested parties [3]. A Digital Twin can be constantly updated, in real time, with data collected from different devices, such as sensors. This could anticipate possible failures and can influence decision-making to improve future solutions. For example, sensors of a wind turbine provide data about its performance, energy production, temperature and weather conditions. The collected data is applied to the digital copy. This connection between the real and digital worlds is the software's asset.

The difference between a Digital Twin and another model made with a 3D software is the virtual environment created and the real time data integration. A 3D application represents a simulation that studies a certain process, while a Digital Twin has the ability to develop

several simulations, analysing different perspectives. Currently, the Digital Twin is used in several fields, including manufacturing, power generation, automotive, health services and urban planning. Digital Twin is used in healthcare for personalized healthcare or strategic planning. Personalized healthcare consists in performing simulations to identify the best treatment for patients. Strategic planning implies the creation of a Digital Twin of the hospital that includes medical processes and operational strategies in order to optimize them [4].

Using Esri's GIS Enterprise software, a Digital Twin is being built for the City of Ottawa, tracking the city's development, and creating solutions to support short and long-term planning. Data collection is done annually, creating a detailed 3D network of the city. Digital Twin was useful for the development of the new Zoning Plan, approved at the end of 2022 and valid for 30 years. The project is in the stage of integrating BIM and IoT workflows to obtain an image as realistic as possible. Ottawa needs to build new housing and improve urban infrastructure. Density is the key element in achieving this goals. Analysing the data, planners identified the areas where zoning has to be changed [5].

Utility networks can benefit from the usage of Digital Twin to increase sustainability, cut costs and boost efficiency. In California, utility networks are accessible online. This helps both engineers and field workers to identify network issues and their impact on the system and customers during water outage occurrences [6]. Using AI, engineers can do assessments and forecast pipeline faults, establishing the priority of the necessary repairs.

Figure 2 – Digital Twin – Water Network [6]

Another example is New York - Vision Zero. This Dashboard offers traffic data information provided by IoT sources and sensors, such as pedestrian traffic tracking and smart cameras. Authorities can monitor traffic collisions in real time and make predictive analysis to improve pedestrian safety [7].

The Digital Twin of the city Maracaibo was created by Esri Venezuela and Zulia University [7]. The project used ArcGIS Urban and related solutions like CityEngine and includes a wide range of indicators and variables, such as zoning, urban regulations, property information and energy consumption. Digital Twin can create a location-based broad perspective, assessing the impact of different scenarios. Easy access to data enables faster decision-making, while interaction and collaboration between departments is encouraged.

In Arlington, Texas, ArcGIS Urban was used to asses the existing zoning and to predict the residential areas where there would be an increased demand in the future. The case study indicates that using ArcGIS Urban, planners could have answers to questions such as: "Depending on the estimated population growth, can the city of Arlington meet the housing

demand with the existing zoning?", "To what extent can the current zoning meet the population's housing demand?", “What would need to be changed to meet housing demand?”, “What measure could change the outcome?” [8].

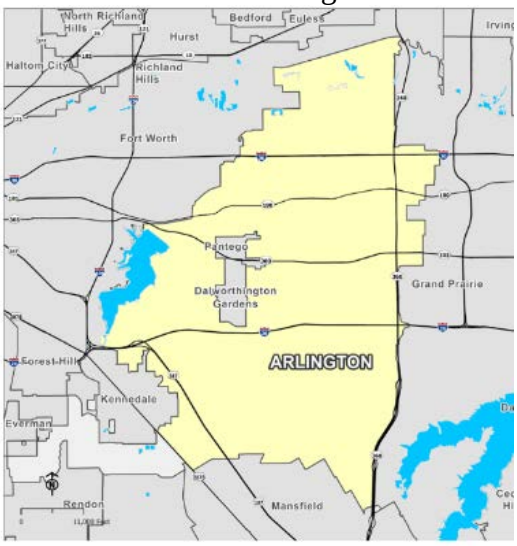

Figure 3 - Arlington city limits [8]

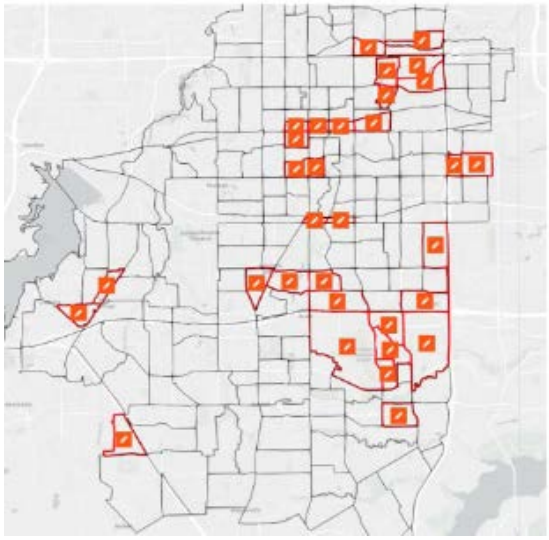

Figure 4 - Areas with future housing shortages [8]

ArcGIS Urban has been successfully used to assess zoning changes in Honolulu and Seattle. In Seattle the “boom” of IT companies resulted in the fastest population growth form last decade in USA. Consequently, the city must absorb 60 new residents daily [9]. The new jobs created present challenges for planners in maintaining affordable housing. The authorities implemented a new building permit system and used ArcGIS Urban software for 3D rendering of the city and zoning requirements.

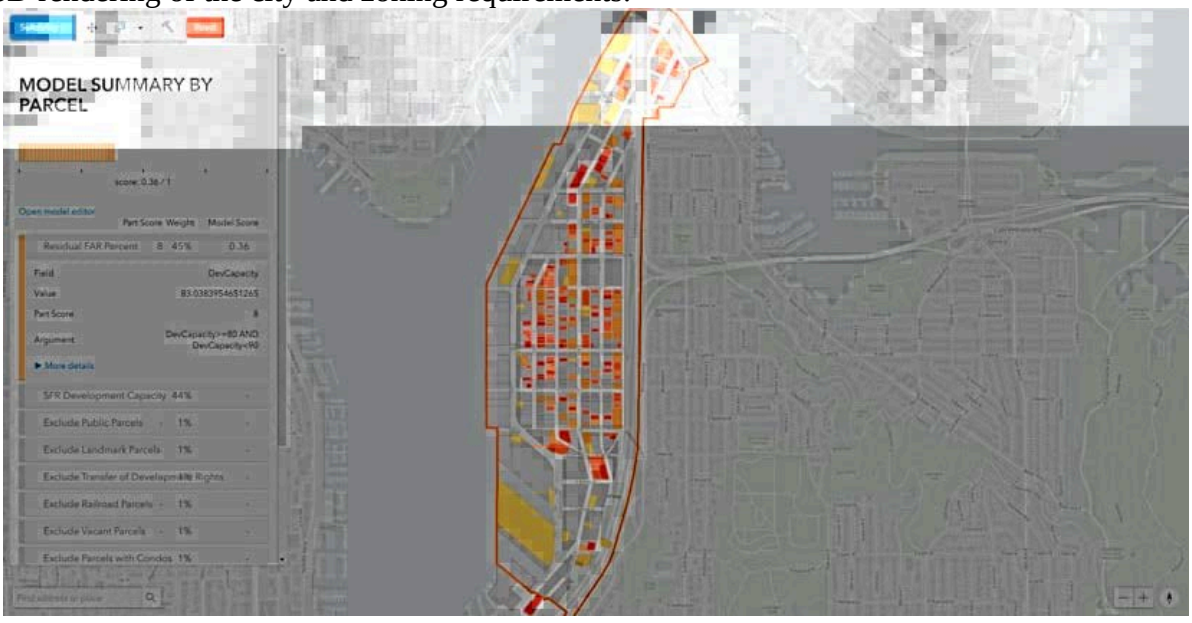

Figure 5 - Eastlake neighborhood zoning in ArcGIS Urban [9]

The city of Honolulu faces the problem of finding the balance between accommodating the masses of tourists and the need for affordable housing for its residents, both accommodated in a limited space. By integrating their building permit systems into the ArcGIS Urban platform, planners concluded that a very small percentage of buildings had a large economic impact on the community. In fact, 7% of building permits contributed to over

40% of the total constructions completed in 2018 [10]. Using ArcGIS Urban, the interested parties could monitor the impact of the zoning changes, identify the problems and find solutions.

In Europe, ArcGIS Urban is being used for planning a new neighbourhood in Uppsala, Sweden [11]. Planners have created the 3D model of the city and included the zoning plan, in order to have a better perspective on the city and how to integrate the new neighbourhood. Thus, the new neighbourhood will be built on forest land currently owned by the city and is required to adopt a sustainable urban development without reducing the biodiversity. Green corridors will be created, integrating the existing trees on the site, and the buildings have been designed so that large groups of trees are included in their inner courtyards.

3. Spatial Planning in ArcGIS Urban

ArcGIS Urban is an ESRI 3D solution designed to improve urban planning and decision making [12]. ArcGIS Urban is part of the Esri Geospatial Cloud and consists of three components: an Urban Overview web application for the public, an Urban Planning web application for the professionals and CityEngine for desktop workstations. Urban Overview allows users to visualize projects within a city, encouraging public transparency and the involvement of the community. CityEngine is a part of ArcGIS Urban that enables advanced workflows which include detailed modelling, such as street furniture or building facades.

Planning in ArcGIS Urban is done with the help of three key elements: plans, projects and indicators. There are two types of plans: zoning and land use plans. Using “Plans” is recommended for large-scale and long-term developments, while “Project” planning can be used for short-term plot-level planning processes. Projects can be classified according to the stage they are in: proposed, approved, under construction and executed [13].

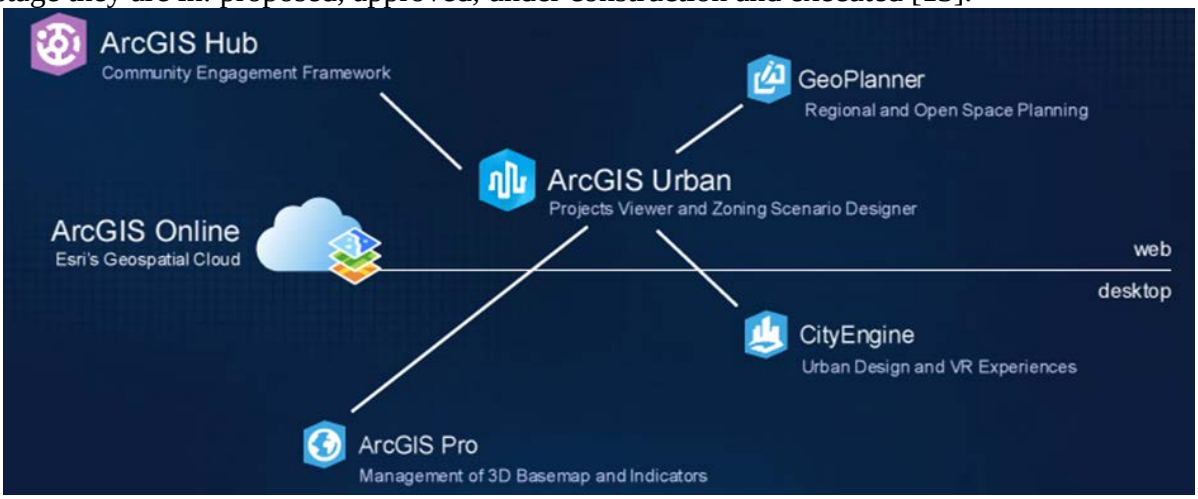

Figure 6 - ArcGIS Urban and the correlation with other ESRI solutions [13]

ArcGIS Urban allows planners the create "what if" scenarios, so they could consider various hypotheses with clearly defined development policies in order to issue predictions about the new jobs created, population growth, density, CO_2 emissions, consumption of energy and water etc. The development of several alternative scenarios in the same plan allows the comparison between the existing situation and the proposed scenarios, evaluating the influences on the area considering the relationship between the built space within a city and its inhabitants, as well as the impact on the environment.

Zoning can be done by entering the following parameters: maximum height, maximum number of floors, FAR, coverage, land use categories and building types. Proper

zoning can solve problems related to overcrowding, pollution, ensuring adequate living conditions, thus preventing chaotic development within the cities. Zoning has a significant role in achieving an integrated urban development and must be subjected to continuous evaluations in order to understand its "on site" results.

ArcGIS Urban offers the possibility to set up buildings with various functions as well as the creation of new types of buildings with mixed use such as a three-story underground parking, while the ground floor can have public functions (retail, restaurants, cafes, exhibitions) and on the upper floors there could be private functions (living, offices). The "envelope" of the building can be displayed, according to the urban planning indications introduced. If the proposed building doesn’t comply with these requirements, the program issues a warning for that breach.

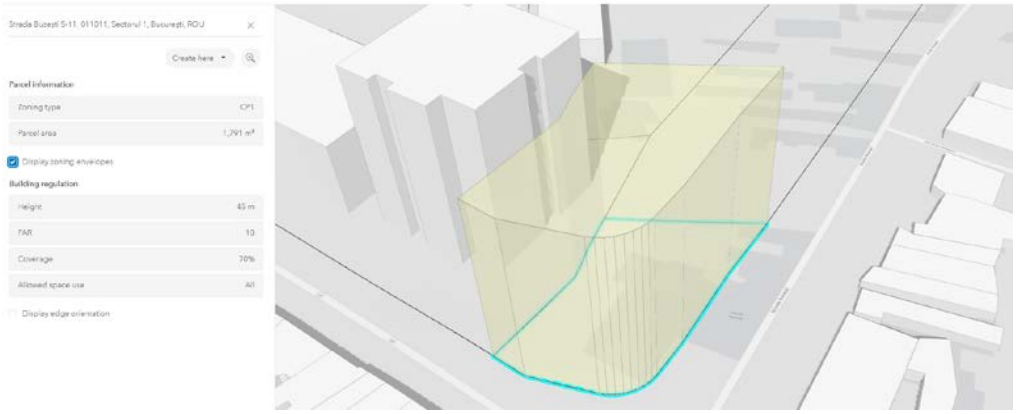

Figure 7 - Building "envelope" [14]

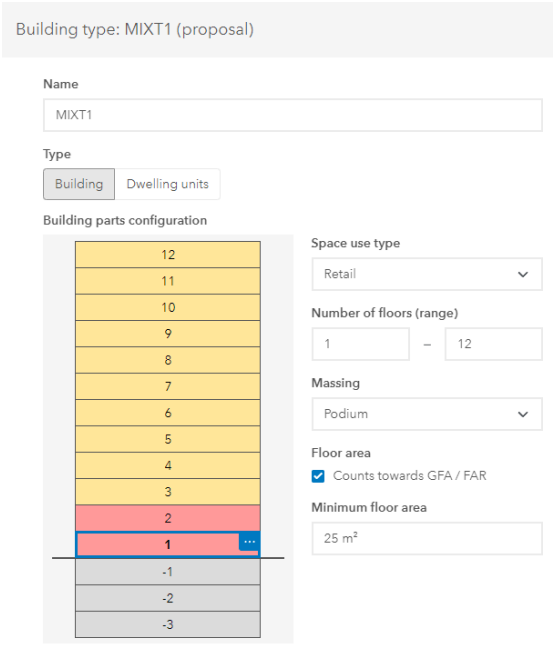

Figure 8 - Creating a new mixt use building [14]

From the Analysis menu the user can create profiles of the landscape as well as of the newly created scene. The "line of sight" command provides the option to pick the observation point, the targeted objectives and then to check viewpoints from a certain location. With ArcGIS Urban, planners can make analysis regarding daylight and shadow casting, by setting the desired date and time.

Figure 9 – Profile [14]

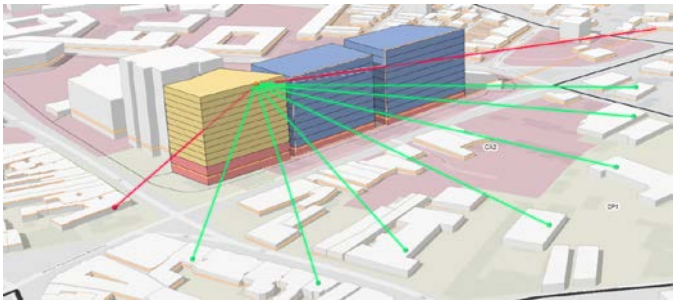

Figure 10 - Line of sight [14]

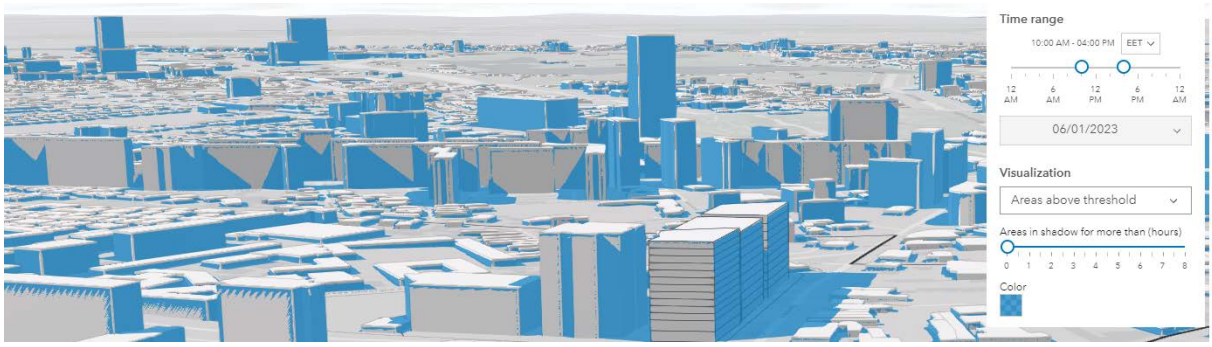

Figure 11 - Shadow forecasting [14]

4. Sustainable Development Goals as objectives in the urban planning approach

Due to the migration from rural to urban settlements, the accelerated expansion of cities has led to a boom in mega-cities. According to the United Nations (UN), 68% of the world population is projected to live in urban areas by 2050 [15]. Therefore, new policies need to be adopted in order to obtain sustainable cities.

The new 2030 Agenda adopted by UN describes 17 Sustainable Development Goals (SDG) with 169 associated targets. Making cities and human settlements inclusive, safe, resilient and sustainable is the 11th Goal and it has 10 targets. Sustainable development is unobtainable unless the management of urban spaces is rethought. Sustainable cities imply accessible public transport, affordable and safe housing, access to green public spaces, career and business opportunities, resource efficiency, equal opportunities for all inhabitants and access to basic services. There needs to be a special attention paid to those in vulnerable situations [16].

Figure 12 - SDG Goal 3, 9, 13 [17]

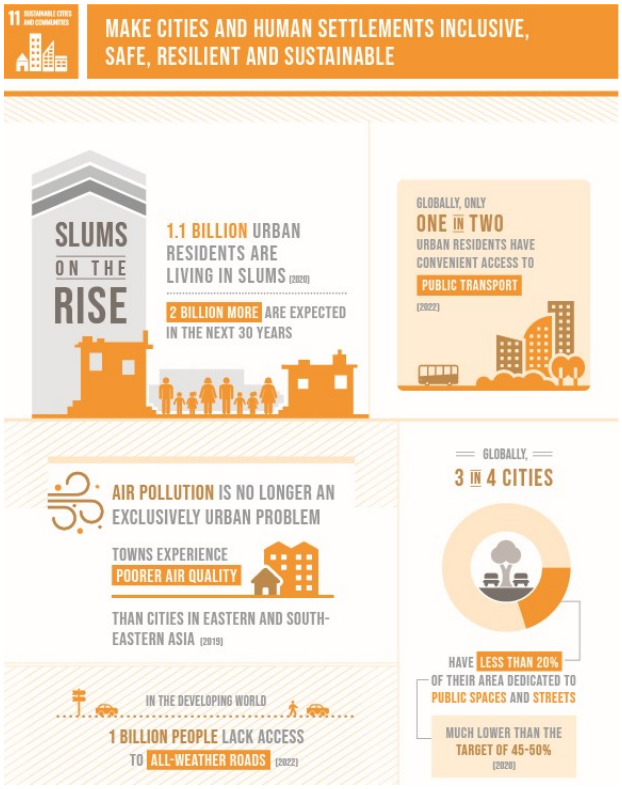

Figure 13 - SDG, Goal 11 [17]

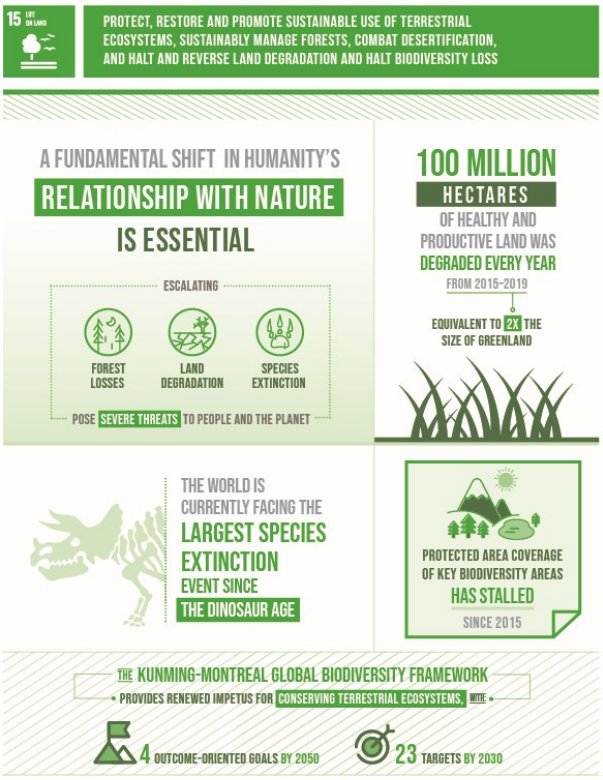

Figure 14 - SDG, Goal 15 [17]

In order to obtain a productive city the varied needs of urban residents need to be met. Access to free healthcare, public spaces and sustainable urban mobility plans would enhance inclusion and social cohesion. A transformative action is essential, with coordinated and collaborative policies in the pursuit of a sustainable and climate-resilient development [17].

With ArcGIS Urban planners can analyse the air quality considering the CO_2 emissions and the waste management. The zoning and urban indicators are included, improving the planning process by gathering data from different sources. The proposed projects are public, allowing citizens to engage, thus obtaining an inclusive urban planning.

5. Case study

The proposed study area is located in Sector 1, Bucharest, containing the parcels bordered by Polizu Street, Buzești Boulevard and Calea Griviței. Most buildings in the area were built in the second half of the 19th century and the first half of the 20th century. The area was massively transformed when the Northern Railway Station was built. The studied area is heterogeneous, with diverse urban functions and buildings from different historical periods and styles. The construction of the North Station delimits the two types of evolution of the area, a "natural" evolution followed by a modern one [18]. Buzești Boulevard was widened based on the Zoning Plan (PUZ), which led to numerous demolitions, including historical monuments such as Cinema Marna. This resulted in divergent opinions among architects and urban planners as well as residents, thus the area needs to be revived.

Because an intervention in this area requires a long-term approach, a “Plan” was created, suitable for large-scale and long-term urban developments. With the Plan boundary defined, ArcGIS Urban displays the zoning and parcels published in ArcGIS Online.

Figure 15 - Creating a Plan [14]

Figure 16 - Zoning according to General Urbanistic Plan [14]

There were elaborated two scenarios for the study area. The first scenario aims to comply with the current regulations. On Buzești Boulevard two buildings are proposed. The one located at the intersection between Buzești Boulevard and Calea Griviței is a residential building and the second one is an office building. Both have public ground floors intended for commerce and underground parking. The buildings have the same height regime (14 floors), the maximum allowed in the area according to the local regulations. The reason for this proposal is that the office buildings already existing on the site, Mark Tower and One Victoriei Center, flanking the front on Buzești Boulevard, both have 14 floors.

Scenario 1 proposes a building on Calea Griviței (4 floors) with the ground floor intended for commerce, and the upper floors for exhibition spaces. Two buildings are proposed on the front of Polizu Street, the one near Polizu Maternity Hospital being an office building whose ground floor is a medical center. The second proposed building is a hotel. The buildings on Polizu street keep the street alignment of the buildings on the neighbouring plots. The layout of the proposed buildings aims to create a public space in the center of the plot. A mixed landscaped area with green spaces, which can host cultural events, exhibitions, fairs and screenings, designed to shelter the inhabitants from the city's noise. The planning aims to

encourage pedestrian traffic. The buildings use, the height regime, the alignment, the coverage and FAR, comply with the regulations of the zones CA2 and CP1.

CP1 is a central sub-area that has to maintain the traditional urban fabric included in the protected area. The existing buildings have a low height regime, with 2-4 floors. The local urban planning regulation admits functional conversions compatible with the character of the area and the protection status of the buildings. CA2 is also a central sub-area with complex functions, with buildings of medium and high height and with accents over 45 meters. Functions of general interest specific to business centres are admitted: office buildings, banks, libraries, media centres, hotels, shopping centres, etc.

Figure 17 - Scenario 1 [14]

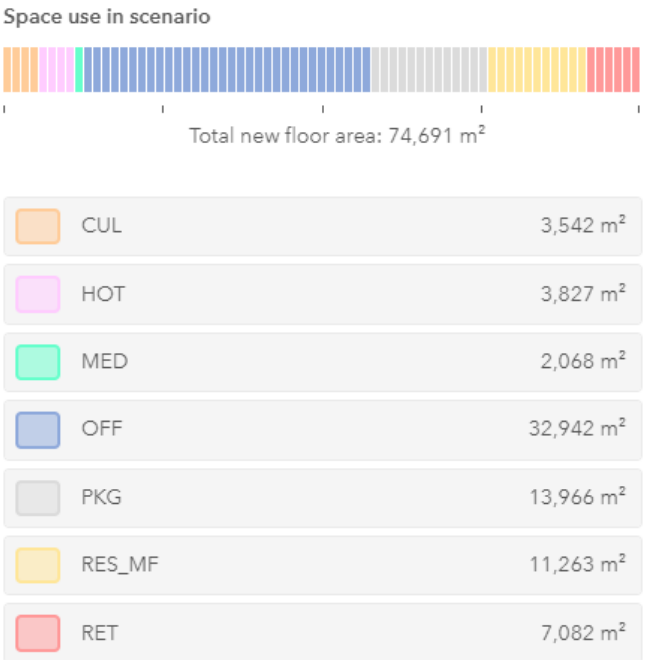

Figure 18 - Space use in Scenario 1 [14]

The Dashboard shows the number of housing units and residents the proposed building could accommodate, the number of jobs created, how many parking spaces it would have, the amount of CO2 emitted, the energy and water consumed, etc. Thus, the Dashboard shows the users an overview of the scenario and its impact on the area.

The second scenario connects the plots on Buzești Boulevard, proposing three office buildings with 4 floors, with public ground floor. The buildings on the Polizu Street and Calea Griviței are intended for leisure activities: a cultural center, libraries, cinemas, exhibition spaces, commercial spaces, restaurants, bars and cafes.

ArcGIS Urban offers the user the possibility to change the urban indicators (Parcel override). In this case, the plot located at the intersection of Buzești Boulevard and Calea Griviței is part of the CP1 zone and the indicators were changed in order to have the same urban planning indicators as the neighbouring plot that is part of zone CA2.

Figure 19 – Changing indicators [14]

Figure 20 – Merged plots [14]

In this scenario, the height on Buzești Boulevard was reduced, in order not to deepen the rift created by the doubling of the boulevard that divided the area. The new height regime proposed is 4 floors, with the ground floor intended for commercial spaces and the first floor for offices.

The proposed buildings on Polizu Street and Calea Griviței are intended for both residents and tourists. A center for cultural and educational activities is proposed on Calea Griviței, with exhibition and workshops spaces, a theatre or a cinema. The buildings on Polizu street have a different use, the first being a shopping center and the second a medical center with a laboratory on the ground floor, and the 2 upper floors can belong to an educational unit such as the "Carol Davila" University of Medicine and Pharmacy in Bucharest, thanks to the vicinity of the Polizu Maternity Hospital. The second scenario follows the same approach as in Scenario 1 in terms of the alignment of the proposed buildings, keeping the street alignment on all sides of the block.

Figure 21 - Scenario 2 [14]

We have the possibility to save several viewports, thus being able to compare the proposals of the two scenarios. Three viewports were created for this project, forming perspectives for each street that delimits the area. The planner can select from the Daylight menu the time and date, important data for architects to be considered while designing.

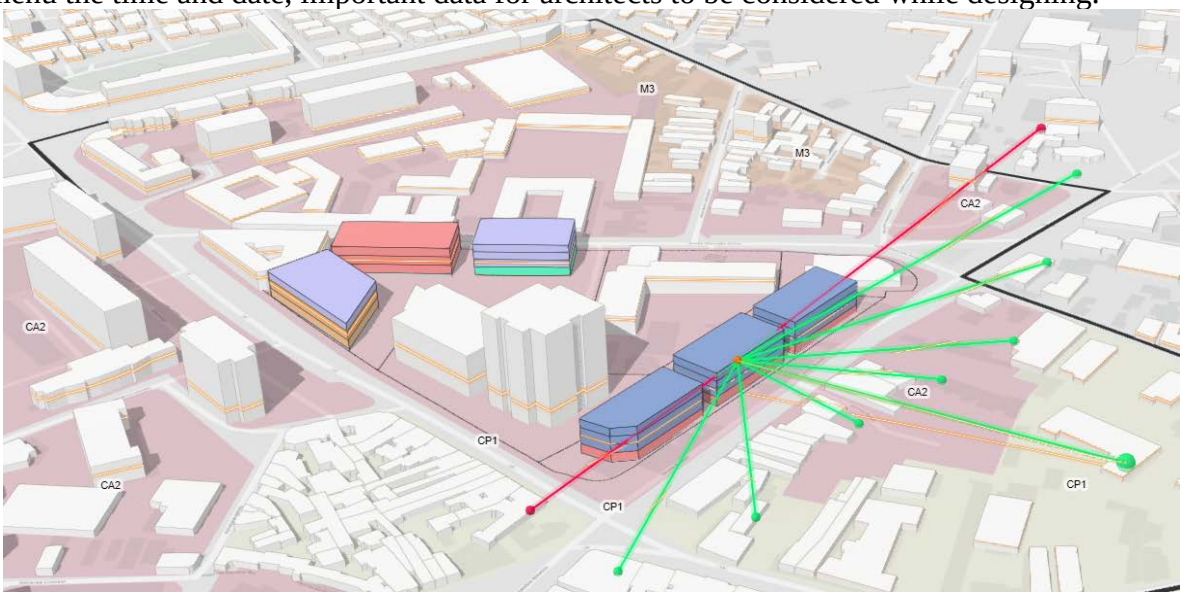

Figure 22 - Line of sight - Scenario 2

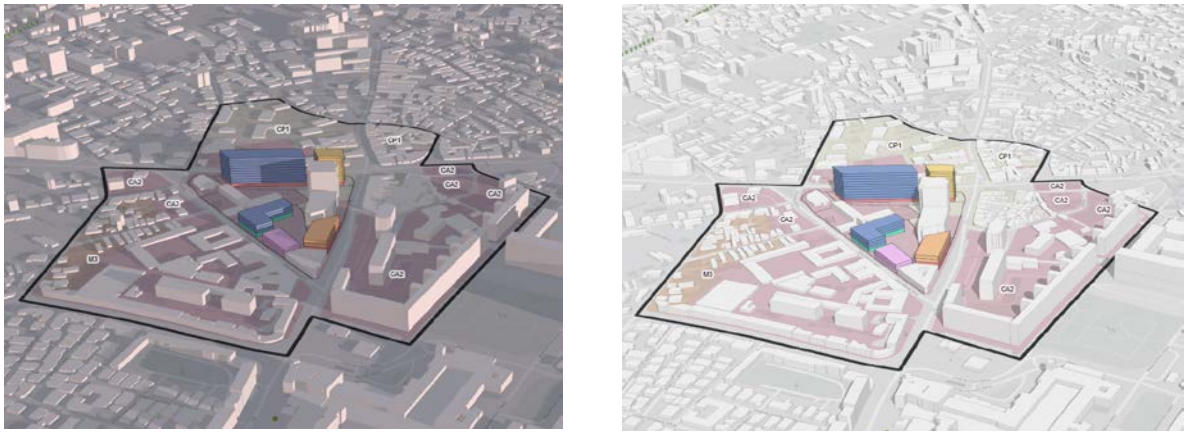

Figure 23 - Daylight study – December and June 16:00

6. Conclusions

Based on the developed case study we have demonstrated the usefulness of using state-of-the-art software solutions for detailed urban analysis. Thus, it is possible to estimate the impact a project could have within a city in terms of addressing deficits and the appropriate management of the area's potential. The communication can be improved internally, between authorities and planners, as well as externally with the public, that can send feedback for the proposed projects.

The technical barriers, that often stand in the way of using geospatial data and could influence proposals and decisions, especially in contexts where decisions need to be made quickly, can be overcome. Decision-making transparency and the active involvement of citizens, together with the urban planning elements made available by ArcGIS Urban software, can be key tools in the workflow of developing cities.

Another major advantage is the contribution such an approach can make to achieving the SDGs mentioned. An interactive and interdisciplinary way of working is needed, with the possibility to manage geospatial data in a focused way, depending on the objective.

Any municipality can strive to modernise the way it works and the transparency of the decisions it makes that impact on urban planning and community life in an area. We believe that such an initiative is not only likely, but also desirable to be implemented by local public authorities, with GIS being an important basis for development and planning.

Such an objective can be achieved only through collaboration between specialists from different fields of activity, by raising awareness of the importance of each specialist input with an impact on geospatial development.

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