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IMPLEMENTATION OF INDUSTRY 4.0 TECHNOLOGIES FOR BUILDING SMART CITIES: GLOBAL EXPERIENCE

The current situation of the development of society with a simultaneous increase in the burden on the environment requires a change in the concept of socio-economic development. This change has led to a transition from the so-called "brown/grey economy", with its high carbon emissions, significant waste, and high consumption of natural resources, to a "green/circular economy", which is low-carbon and resource-efficient. The rapid development of ICT and the continuation of this development through cloud computing, the (industrial) Internet of things, and e.g. artificial intelligence within Industry 4.0 also contribute to the broad implementation of the principles of the green economy in all areas of public life. The Digital Economy and Society Index (DESI) allows us to evaluate the digital development of EU countries [1]. The leaders in this indicator are the Scandinavian countries and the Netherlands. The constituent elements of the DESI index are human capital, connectivity, integration of digital technology, and digital public services. The International Telecommunication Union provides the following definition: "A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve the quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects" [2]. Experts define a smart city as an urban environment that uses technology to increase the benefits and reduce the disadvantages of urbanization for residents.

An analysis of world experience shows the significant promise of introducing smart strategies in the development of modern, more sustainable cities. The leaders in the Smart City Index are Singapore, Zurich, Oslo, Taipei, and Lausanne [3]. Barcelona was one of the first cities in the EU to develop and implement a smart strategy in 2014, and has made significant progress in modernizing urban infrastructure. Barcelona has repeatedly been named one of the smartest cities in the world. In particular, the city infrastructure has been changed through loE (Internet of Everything) and loT (Internet of Things) sensors to monitor and control traffic, to monitor noise, air quality and pollution etc. The Barcelona strategy covered three key areas: 1) international positioning; 2) international cooperation; 3) "smart" local programs. The city uses loT. One use-case for loT-sensors includes electronic scales integrated into the garbage bins with the transfer of data on the weight of the garbage loaded to them to the "cloud" storage in order to notify the service company when the containers need to be collected [4]. Vienna also has one of the most detailed strategies with short and long-term goals (until 2030 and 2050 respectively). The main goal of the Vienna Strategy is to achieve a high level of quality of life, combined with the conservation of resources (through innovation) by 2050. London has introduced smart solutions aimed at protecting business infrastructure from cyber-attacks. The FinTech industry and the education sector are developed, where the necessary skills are provided using the free online training platform - Digital Business Academy. The Digital Health.London program has also been implemented in the field of healthcare, smart heating networks, electricity, waste management and water supply.

Stockholm, according to its own strategy, aims to become climate and financially sustainable, environmentally smart, and cohesive. A special place in the Strategy is occupied by digital inclusion (Stockholm Digital Care), digitalization of the educational process (creation of online educational platforms), "smart" environmental solutions (installation of solar-powered BigBelly garbage cans that automatically pack garbage and signal fullness), smart - lighting, etc. Stockholm is also a member of the EU's GrowSmarter project, bringing together cities to develop and disseminate smart city solutions in the energy, infrastructure, and transport sectors.

Norway has a strong innovation culture, highly tech-savvy citizens, and a public sector that uses strict procurement requirements to promote new thinking and sustainable development. In August 2019, a "Roadmap for Smart and Sustainable Cities and Communities in Norway" was adopted. Since the buildings and construction industry accounts for approximately 40% of the national energy consumption, and significant use of electrical power for heating in the long winter months - smart heat-pumps, solar-power, and loT-based technology significantly improve energy efficiency in buildings. Norway is a leader in advocating

the use of "open data", and joint public-private ventures to advance reusable data-sharing tools and processes in order to manage traffic, facilitate the work of entrepreneurs, and contribute to the development of smart solutions for smart cities in general [6]. Norwegian public and private actors are actively involved in joint projects to develop smart city models. In particular, +CityxChange (Positive City ExChange) is a smart city project that has been granted funding from the European Union's Horizon 2020 research and innovation program in the call for 'Smart cities and communities.' The Norwegian University of Science and Technology (NTNU) is the host and leads the +CityxChange consortium together with the Lighthouse Cities Trondheim Kommune and Limerick City and County Council [7]. The project is based on the following ideas: Prototyping the Future through Integrated Planning and Design; Enabling the Future through Creation of a Common Energy Market; and Accelerating the Future through CommunityxChange with all stakeholders of the city. And of course, people are the key to Smart Sustainable Cities.

As for Ukraine, here, of course, the pioneer and leader in this direction is the capital of the state - Kyiv. In recent years, the authorities of other Ukrainian cities have been showing an increased interest in smart infrastructure development projects, implementing digital technologies and increasing the level of "intellectualization" of urban infrastructure. In particular, facial recognition technology and other IT technologies are widely used. Thanks to this, it is possible to make contactless payments in retail chains, as well as for travel in public transport. A "smart" lighting system is used that reacts to traffic, and thanks to it, information about the state of the environment (temperature, air quality, noise level, etc.) is accumulated. Almost all cities have smart meters for water and gas consumption, and the use of "smart" garbage containers that signal their fullness is becoming more and more relevant. Smart projects are architected and built by teams of specialists in Kharkiv, Lviv, Dnipro, Vinnytsia, Poltava, Drohobych, Kyiv, Mukachevo, and other cities. Among the main areas and directions of digital transformation in cities are e-democracy and city management, education, medicine, ecology, urban mobility, and public safety [4]. Kyiv(Ukraine) is ranked as the 82nd out of 118 countries, up 4 positions compared to 2020. Unfortunately, due to the war, many Ukrainian cities have been partially destroyed to date, and several cities have been completely destroyed. We believe that the development of urban renewal projects should be carried out on the basis of a green economy using Industry 4.0 technologies- and look to the inclusive Society 5.0 strategy in Japan for inspiration [8]. The implementation of the EU experience in the transition to an urban green economy will contribute to the post-war reconstruction of Ukrainian cities, in particular, based on the Smart-City concept.

In this context, it is important to exchange international experience, participate in joint developments, and train students considering the experience of advanced countries in this area. Since 2018, a project of collaboration between the Norwegian University of Science and Technology (NTNU) and the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (KPI) aimed at improving higher education in the field of Industry 4.0 through the exchange of knowledge and experience [9]. We argue that the presence of smart digital infrastructure is a prerequisite for the existence of Smart-City, as it ensures the collection and processing of large amounts of data to create an efficient and sustainable environment. This system combines two key technical components: 1) sensors and storage devices that transmit information in real-time and 2) powerful, smart information and computing system that is architected to fit the dynamic requirements. The combination of various sources of obtaining, at first glance, disparate "big" data, makes it possible to form a real idea of social problems: ensuring sustainability, population mobility, maintaining health and preventing diseases, life safety, etc. The ability to receive data from a wide range of sensors in public places, in transport systems, and in energy networks may provide a real-time understanding of the scale of transport and energy flows, the level of pollution, and human behaviour. Thus, the main characteristic of smart infrastructure is the interconnectedness and generation of data that can be rationally used to improve the effectiveness of decision-making and implementation.

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