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LEVELS OF AI APPLICABLE IN SMART CITIES

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Purpose: A Smart City is the most essential ideology for city development. Technologies based on Artificial Intelligence are an indispensable part of this ideology. There is no smart city level in which its elements are not used. The article overviews the areas where cities have used technology based on Artificial Intelligence. The article aims to examine and present various applications of Artificial Intelligence in the context of smart cities. The article aims not only to identify and analyze the multiple levels at which AI can be used to improve the quality of life of residents and the efficiency of city services but also to draw attention to the challenges and potential implications related to the implementation of these technologies. Practical examples supported theoretical considerations.
Design/methodology/approach: The article uses a literature search. An in-depth analysis of the techniques used in Polish cities, not only those boasting the name of smart city, was carried out.
Findings: During research on the use of Artificial Intelligence in smart cities, several key areas were identified in which AI has a significant impact: traffic and transport management, energy management and sustainable development, public safety, waste, and natural resources management, services for residents and spatial planning and urban development. These results can serve as a basis for further research and development of AI implementation strategies in urban contexts.
Originality/value: The critical value of the article is its ability to identify and analyze both the opportunities and challenges associated with implementing AI in cities. The article contributes to a deeper understanding of smart cities' potential benefits and risks through a balanced approach considering technological, social, ethical, and environmental aspects.

Keywords: smart cities, Artificial Intelligence.

Category of the paper: Research paper.

1. Introduction

The recent population migration in Poland has resulted in the expansion of cities. Therefore, their development seems to be the natural order of things. This is all the more so because, as an artificial human creation, the city has a chance to develop new ideas, ventures, and innovative technologies (Sikora, 2013). In the digital transformation era, cities worldwide face the challenge of adapting to rapidly changing technologies and growing expectations of residents (Czupich, 2016; Papa, 2015). At the level of urban development, we talk about the concept of a Smart City, i.e., intelligent cities in which the life and development of people are better and more straightforward. Currently, smart city is used interchangeably with the names digital city and sustainable city, indicating the direction of transformation that cities are undergoing (Stawasz, 2016). The development of the smart city concept has been the story of the last dozen or so years. In 2015, views on smart cities introduced an approach based on the creative involvement of residents, i.e., the Smart City 3.0 model. According to the Smart City 3.0 model, cities must be open to the active attitude of residents in creating their development. The authorities' role is to create conditions to actively use the residents' creativity. This applies primarily to encouraging residents to use modern technologies and develop technological solutions. The Smart City concept is based on six pillars: smart economy, smart environment, smart people, smart governance, mobility, and quality of life (Allam, 2018).

Artificial Intelligence has become one of the key elements driving the development of the smart city concept. Thanks to its ability to analyze large data sets, learn from experience, and make decisions. Technologies based on artificial Intelligence can open the door to new possibilities in city management. They are starting from road traffic optimization to advanced public safety systems (Skalfist, 2020).

This article aims to explore the different levels at which AI is used in the context of smart cities, highlighting its potential benefits and challenges. As cities become increasingly computerized and connected, AI plays a crucial role in processing the vast amounts of data generated by city systems and residents, transforming them into useful information and intelligent solutions.

The article begins with a literature review on the role of AI in smart cities, then moves on to analyze specific applications of AI in various aspects of urban life, such as traffic management, public safety, resource management, public health, and interaction with residents. Then, the article focuses on specific areas in which the smart city concept is developed and examples of the use of artificial Intelligence in Polish cities.

2. Smart city ideology

There are many definitions of a smart city in the literature. They differ in the distribution of accents between the approach to technology, functionality of cities, and social issues. N. Komninos claims that a smart city is an area consisting of four main elements (Komninos, 2008): the population carrying out knowledge-based activities or a group of such activities; digital spaces of e-services and online tools for knowledge management, effectively operating institutions and procedures in the field of knowledge creation and the ability to be innovative and solve problems emerging for the first time. It is safest to provide a definition that covers all the ingredients mentioned. This is the definition presented by the Committee of Digital and Knowledge-based Cities in 2012: A smart city is "a city that uses information and communication technologies to increase the interactivity and efficiency of urban infrastructure and its components, as well as to raise the awareness of residents" (Trzesicki, 2020). It seems that the smart city concept is a natural consequence of the evolution of cities. This evolution took place starting from the city of knowledge, through the idea of a digital city, a smart city, to the vision of an ecological city, finally reaching the concept of a smart city (Łabędzki, 2022).

According to K. Łabędzki (Łabędzki, 2022), three generations of smart cities can be distinguished. The first generation concerns advanced technologies, and the solutions offered are unified and do not correspond to the individual characteristics of the city. When implementing cutting-edge technologies, the city authorities do not consult the city's residents on the need for their implementation. The second generation assumes that the city authorities are at the center of attention. The task of the city authorities is to look for solutions tailored to urban needs. The third generation of smart city ideology emphasizes the initiative of residents. In the third generation, residents express their opinions, needs, and expectations. Local government administration plays an advisory role here or supports the communication channel (Greser, 2022).

The problematic nature of the elements that make up every modern city makes it a complex socio-economic system. The development of this complex system depends mainly on the relationships between the components. Advanced information and communication technologies - ICT - are essential in the modern city. Using ICT technology results primarily in cost reduction (Skalfist, 2020).

3. The use of artificial Intelligence in smart cities

Artificial Intelligence (Różanowski, 2007) is an advanced field of computer science that focuses on creating and developing computer systems capable of performing tasks that traditionally require human Intelligence. These tasks include but are not limited to, pattern recognition, learning, reasoning, problem solving, perception, natural language processing, and decision making. Artificial Intelligence, in its basic form, is represented by algorithms that imitate the cognitive functions of the human mind, processing data and information from the environment, which allows machines to learn, adapt, and make autonomous decisions on their own (Kowalczewska, 2021).

Różanowski (Różanowski, 2007) distinguishes two approaches to the issues of artificial Intelligence: vital artificial Intelligence (strong AI) and the second approach - weak artificial Intelligence (weak AI). In the current reality, artificial Intelligence can be divided into three main categories, depending on the scope of its capabilities and advancement (Sądel, 2015):

1. Artificial Narrow Intelligence (ANI) - refers to AI systems that are designed and trained to perform a specific task. Such systems do not have general awareness or self-awareness but operate within a limited task scope. Examples include speech recognition programs, recommendation systems on streaming services, and chess algorithms,
2. artificial general Intelligence (AGI) - this is a hypothetical level of AI in which machines could demonstrate intellectual abilities comparable to humans, including the ability to learn, understand, adapt and apply knowledge to a wide range of tasks. AGI remains mainly in the sphere of theoretical research.
3. Artificial superintelligence (ASI) is a level of AI that would exceed human Intelligence in all aspects, from creativity and emotional abilities to social and technical skills. ASI is the subject of scientific and philosophical speculation, and its potential creation raises many ethical and safety-related debates.

Artificial Intelligence (AI) is increasingly crucial in city management, enriching and improving its functions. Thanks to advanced technology and learning algorithms, AI can analyze vast amounts of data, providing valuable information and forecasts that help make decisions to improve residents' lives. Artificial Intelligence can be used in many areas of city management.

Table 1.
Application areas of AI in Smart City

Area of application	**Characteristic**
Traffic and transport management	AI helps optimize urban traffic, manage public transport systems, and plan infrastructure. You can discuss how intelligent traffic light systems, camera data analysis, and traffic sensors contribute to smoother traffic and reduced traffic jams.
Energy management and sustainable development	AI can optimize energy consumption in public buildings, monitor and manage renewable energy systems, and predict energy demand. Such solutions include intelligent street lighting and energy management systems in buildings.

Cont. table 1.

Public safety and surveillance	AI is used to analyze images from city cameras to improve security, but this also raises privacy and ethical issues. Balancing security and privacy can be discussed.
Waste and natural resources management	Intelligent systems can help optimize waste collection, monitor air and water pollution levels, and manage natural resources.
Services for residents	AI can improve communication between residents and city authorities, e.g., through intelligent chatbots, problem-reporting systems, or personalized public services.
Spatial planning and urban development	Using AI to analyze large data sets can help in better spatial planning and urban development management, e.g., by analyzing demographic trends, resident behavior, or climate change.

Source: Own study.

3.1. Artificial Intelligence (AI) in traffic and transport management - Smart mobility

Traffic and transport management in the context of smart cities using artificial Intelligence (AI) is a dynamically developing field that opens new opportunities for more effective, safer, and more sustainable urban mobility management. AI plays a significant role in urban transport, starting with optimizing traffic lights. By analyzing data from cameras and traffic sensors in real-time, these systems can adapt traffic signals to current conditions, contributing to smoother traffic flow and reduced traffic jams.

Smart mobility is a system that provides mobility services tailored to users' preferences and corresponding to the city's sustainable development priorities through modern technologies (Aleta, 2017). The literature on the subject (Papa, 2015) shows two main approaches to smart mobility: technology-oriented and consumer-oriented strategies. The technology-oriented approach is based on applying information technology to transport infrastructure. According to this view, the development of intelligent mobility is possible thanks to the introduction of widespread digitization of means of transport. According to Grucza (Grucza, 2018), the "technocentric" orientation leads to dehumanization and loss of a sense of autonomy and thus wastes even the most innovative solutions. Therefore, implementing elements of smart mobility in cities requires cooperation with their inhabitants.

The aim of intelligent transport, apart from improving traffic and communication, is also to expand infrastructure using the latest ICT solutions, create intelligent mobility offers, use various digital solutions, such as smart parking, car-pooling, trip planning, car-sharing, bike-sharing, MaaS (Mobility-as-a-Service), ride-hailing or micro-mobility. It is also the development and implementation of solutions based on the technology of intelligent communication and data transmission systems (IST) or intelligent transport systems (ITS) (Zaheer et al., 2019).

The use of artificial Intelligence in the field of road traffic optimization is revolutionizing road traffic management. This makes significant improvements in flow, safety, and transport efficiency possible. This is due to the ability of artificial Intelligence to analyze vast amounts of data from cameras, sensors, GPS systems, and other sources in real-time. An additional advantage of Artificial Intelligence is the ability to predict the analyzed data. This enables the identification of traffic patterns, congestion, and road hazards. When road accidents occur, artificial Intelligence can react quickly, redirecting traffic and thus minimizing disruptions.

In Poland, the Intelligent Transport System (ITS) has been introduced in many cities. For ITS to function, it is necessary to equip roads with specific devices - measurement sensors, cameras, weather stations, variable message signs - along with supporting structures, build a communication network, provide software, and create facilities for people supervising the system's functioning. Such a system has been implemented in Chorzów. The role of ITS in Chorzów is to improve traffic in public and individual transport. It is an extensive system that supports several subsystems, particularly priorities for public transport vehicles and the linear traffic control and management subsystem. Drivers receive information about city traffic conditions, alternative roads, and available parking spaces. The system includes a visual monitoring system for intersections, including cameras for automatic license plate recognition. A similar system was created in Wrocław. The city of Gdańsk has used an intelligent transport system. TRISTAR monitors public transport routes and informs passengers about the departures of public transport vehicles. The ITS system in Bydgoszcz aims to shorten travel time by tram and motor vehicles. The Bydgoszcz ITS consists of subsystems, including traffic control with video monitoring, public transport management with dynamic stop information, parking information, and vehicle guidance to alternative routes.

Another area where traffic and transport management is being developed is using low-emission buses. In 2023, the city of Sosnowiec purchased 16 hybrid buses that offer great amenities for passengers - including USB chargers, Wi-Fi, monitoring of the passenger space and the surroundings at the front, rear, and right side of the bus, emission-free driving only on electric drive in designated zones in city centers, automatic system for detecting and extinguishing fire in the engine compartment and heating unit, air conditioning for the entire truck. Moreover, Sosnowiec is the first Polish city to introduce on-demand night public transport. The organizer of night bus transport is the city in cooperation with Blees. To use this form of returning home at night, you must use a particular application available on Google Play and the App Store. A passenger who wishes to travel will receive information about how long it will take for the bus to arrive at his stop. The bus will stop in the same places where tram stops are located on the street. In areas where the location of the tram stop makes it impossible for the bus to stop safely, there will be so-called virtual stops. The website www.sosnowiec.blees is available, which contains all applicable information, a map of stops, and instructions on how to use public transport.

Road safety is another area where artificial Intelligence is making a significant contribution. One of the most visible safety applications is traffic lights at pedestrian crossings. Traffic light systems dynamically adjust to the number of people waiting at crossings, crossing, and their speed. This is especially important for older people, children, and people with disabilities. For this reason, VALKKY systems implemented in many cities are critical, as they detect and signal pedestrians who want to cross the road. The first such system in Poland was used by the

city of Chorzów in 2012. Currently, such systems are used in many cities[1]. Similar solutions were utilized in Sosnowiec, where the sidewalks in the area were rebuilt, additional lighting was provided, and sensors were installed. In addition, automatic speed measurement devices were installed so that the driver and passers-by knew the speed at which the car was approaching. An innovation is the installation of the STOP PHONE system. Thanks to it, anyone with a special smartphone application will receive a warning when approaching a pedestrian crossing.

3.2. Application of Artificial Intelligence in energy management and sustainable development

Artificial Intelligence can have wide applications in environmental protection and is used to monitor, predict, and solve energy management and environmental protection problems. Smart grids use AI to optimize energy supply by predicting demand and adjusting production. This not only increases energy efficiency but also helps to reduce costs. Currently observed changes in the area of energy transmission and distribution are inextricably linked to the concept of intelligent energy networks, in which there is communication between all participants of the energy market, aimed at providing energy services while ensuring cost reduction and efficiency increase, as well as the integration of distributed energy sources. Smart networks are related to the development of new IT technologies, and the means to introduce the mentioned smart networks is to modernize existing networks and optimize all their elements. Optimizing energy transmission and distribution using artificial intelligence-based solutions requires much base data for analysis. Smart measurement systems are crucial for the functioning of smart energy grids and, therefore, for implementing solutions based on Artificial Intelligence.

New technologies and methods of energy storage enable intelligent integration with the power grid infrastructure and - which was an urgent goal - reduce the number of starts of fuel generators. Battery energy storage systems (BESS) provide extended operating time through intelligent management of connected loads. They can also be seamlessly integrated with alternative energy sources such as solar panels or fuel cells. This approach minimizes the use of generators and reduces their environmental impact. BESS installations will ultimately evolve to a model where users have their energy resources, providing them with the performance, reliability, and cost-effectiveness needed to support computing resources for Artificial Intelligence.

Energy-saving systems are An example of using Artificial Intelligence for environmental protection. Such a system was used in Lublin. It is an intelligent street lighting system. Lanterns reduce the light output when they do not detect movement and increase it when they see an approaching pedestrian, cyclist, or car. In Łódź, the portal rewitalizacja.uml.lodz.pl was created, which allows the inhabitants of Łódź to obtain comprehensive information on both the

[1] Based on: https://www.nist.gov.pl/rozwiazania-w-zakresie-smart-city-w-polsce

revitalization activities carried out in the city and the condition of the revitalization area. The portal is also a tool to support the monitoring processes of the Municipal Revitalization Program in terms of ongoing projects and changes in the socio-economic situation of the area. The portal also offers orthophoto maps, oblique photos, and 3D data on the city space. Through the portal, residents can also submit electronic applications for certificates confirming the location of real estate in the revitalization area. They will also find other information and news about activities in the area. In Ełk, sensors for measuring dust concentration were installed to monitor the city's air quality. The devices have the function of measuring air pollutants: suspended dust PM2.5 and PM10, ozone (O3), nitrogen dioxide (NO2), sulfur dioxide (SO2), benzene (C6H6), and carbon monoxide (CO). Two "EcoPolls" were also installed; they measure the concentration of air pollutants: PM1, PM2.5, PM10, and HCHO formaldehyde, as well as air temperature, pressure, and humidity. At the same time, they signal air quality using LED lighting according to the Polish Air Quality Index adopted by the Chief Inspectorate of Environmental Protection.

3.3. Artificial Intelligence in the field of public safety

Artificial intelligence systems are used in smart cities to monitor and ensure public safety. For example, video surveillance systems equipped with artificial Intelligence can identify suspicious behavior, detect incidents, and alert security services. Camera surveillance technology itself has been used for a long time, but combining it with artificial intelligence algorithms leads to new possibilities.

The scope of application of technology using artificial Intelligence in the everyday life of residents is most widely used, in a negative sense, in China. China actively uses technologies to track people's behavior. The analysis system creates reports about people who cross the street in the wrong place, who did not pay for a ticket, or about which part of the city riots began. The Chinese system provides penalties for people's inappropriate behavior. For example, a resident may be deprived of the right to start studies, the right to park his car, or the right to travel.

An example is the recognition and arrest of a criminal hiding in the crowd during a beer festival or being one of 60,000 guests at a concert in China. Due to their advantages, these systems are used in authoritarian and democratic countries. There are reports of their use in the United States, Germany, and Wales (Greser, 2022). It should be mentioned that technology based on artificial Intelligence is not limited to collecting facial images. It is also capable of managing other biometric data. These also include how you walk, the type of articulation, and the timbre of your voice. This also allows, for example, the identification of participants in telephone conversations in real-time. An ocean of emotional states is also possible. Such possibilities provide a wide range of side effects. They may be the basis for various discrimination - for example, people with a different skin color or gender.

In Poland, there are currently no systems in use that are being implemented to serve residents, making their everyday lives easier. An example is the city of Bydgoszcz, where the Dbamy o Bydgoszcz (DoB) application is available. The application is a tool thanks to which residents can report information about irregularities in the city and send suggestions regarding, among others, identifying architectural barriers for disabled people, illegal landfills, barriers to moving around the city on foot or by bike, improving the quality of life in the city. The implemented system comprises the website dobremy.bydgoszcz.pl and mobile applications. Thanks to DoB, city services can quickly and accurately take appropriate actions to solve the reported problem. Gołacz uses video monitoring, consisting of over 40 cameras throughout the city and the commune, operating 24 hours a day, seven days a week. This monitoring is being gradually expanded, and the appearance of cameras in public places that were not under its supervision has had a very positive impact on the residents' sense of security, reduced the number of crimes, and has often helped identify perpetrators of crimes, including those from outside the commune.

3.4. The Use of Artificial Intelligence in waste and natural resources management

Artificial Intelligence can have broad applications in waste and natural resource management and can be used to monitor, predict, and solve environmental problems.

AI can analyze waste generation data in different parts of the city, helping to optimize garbage collection routes and schedules. This can lead to reduced exhaust emissions from garbage vehicles and increased efficiency of the entire system. Advanced AI systems using image recognition can be used to automatically sort waste, which increases recycling efficiency and helps reduce waste going to landfills. AI can analyze water consumption patterns, predict demand, and identify leaks, allowing for more efficient water management and reduced waste.

The primary example of using artificial intelligence systems in environmental protection is AI solutions to monitor and improve Poland's natural environment constantly. They can analyze satellite data and process images, enabling monitoring of environmental changes, such as the development of city changes in water reservoirs or forest areas. Currently, there is an extensive ecological information system. They are included in various systems and databases, which are not necessarily interoperable but constitute a specific resource that artificial intelligence systems can use. There is a common concept of geoinformation to describe data presentation about objects in the surroundings, such as land development and utilities, using tools designed for this purpose. Sets of information about space can be divided into those whose creation is required by law and those created on their initiative by various institutions and individuals to achieve their goals. The potential possibilities of using geoinformation are determined by its subject scope, which is, by its very nature, very broad.

The city of Krakow prides itself on implementing intelligent solutions in urban space that directly improve the lives of residents. The concept of sustainable development and respect for the natural environment guides all activities. The latest investment of Krakowski Holding

Komunalny SA is the Thermal Waste Processing Plant. Currently, the Eco-combustion plant produces 65,000. MWH of electricity and 270 MWh of heat energy. Photovoltaic modules with a capacity of 60 kilowatts were installed on the roofs and facade of the Eco-incineration plant.

3.5. Services for Residents

A. Koriek and Joseph Stiglitz (Korinek 2019) distinguish two models of society's development in terms of access to information technology and, in the current reality, to artificial Intelligence. First, the wealthiest people will have access to the latest technology that will improve them and allow them to achieve superhuman Intelligence. Those unable to purchase the latest technology will be forced to rely on the public offering. Unfortunately, as the pace of innovation increases, the gap between best and public technology will increase. Enhanced humans through technology will be considered a better, separate species of AI humans. Secondly, the poorer part of the population will be marginalized and subordinated. Importantly, it will lose the fight for limited goods with artificial Intelligence - for example, it will lose the fight for electricity. In the second scenario, a world will be created for machines that will be wholly separated from humanity. The world will be created by machines, for machines. People in the second model will not be needed for this world to function.

It is assumed that a smart city is a city that not only uses intelligent technologies to generate sustainable economic growth and improve the quality of life of its inhabitants but also involves creating and using relationships and connections between human and social capital. A smart city is a set of interconnected sensors or technologies and a place where people should play the most crucial role. Smart cities are cities that should provide more space for citizens. A wide range of technology using artificial Intelligence means that smart technologies are becoming an essential part of the everyday life of city residents.

For example, Bydgoszcz introduced the Bydgoszcz Tourist Card and the Mobile Guide. Thanks to the Bydgoszcz Tourist Card, users receive several free services and attractive discounts in gastronomic, cultural, and entertainment facilities. Bydgoszcz - a mobile guide (since July 2015) helps tourists get to know the town on the Brda River. It provides information on current cultural and sports events (calendar of events) and encourages you to discover the city's secrets. Thanks to the city games included in the application, sightseeing can become even more interesting and exciting. Using the "tourist routes" module, guests can consciously explore both the Old Town and Śródmieście areas and plan a bicycle trip. Residents of the city of Bydgoszcz have also been equipped with the Dbamy o Bydgoszcz (DoB) application, which is a tool thanks to which residents can report information about irregularities, illegal landfills, barriers to moving around the city on foot or by bike, and improve the quality of life in the city[2].

[2] Based on: https://www.nist.gov.pl/rozwiazania-w-zakresie-smart-city-w-polsce

3.6. Spatial planning and urban development

Artificial Intelligence (AI) has enormous potential in spatial planning and urban development, offering new tools and methods to create more efficient, sustainable, and citizen-friendly cities.

AI can analyze data from various sources such as sensors, cameras, geospatial data, and social media to understand traffic patterns, resident preferences, and the use of urban space. This allows for better infrastructure planning, such as roads, parks, and residential and commercial areas. Using AI, it is possible to create advanced simulation models to predict the impact of various development strategies on the city. This allows for assessing the potential effects of urban plans before their implementation. AI can help manage urban resources such as water, energy, and waste more effectively by optimizing their distribution and consumption based on residents' needs and behavior.

The city of Łódź has implemented an application constituting a compendium of knowledge about the city's current spatial policy. The application always presents an up-to-date, uniform mosaic of local plan provisions. It also allows instant access to a preview extract and outline for a selected area.

4. Conclusions

The Smart Cities concept is becoming increasingly popular and essential in the operations of cities worldwide. The role of artificial Intelligence in shaping smart cities is comprehensive and dynamic. As AI technology evolves, new opportunities are opening up for more innovative, safer, and sustainable urban life. This article presented various AI applications, from traffic optimization and resource management to improving public safety and citizen health. However, it is equally important to recognize and address the challenges of implementing these technologies, including ethical, privacy, and data security issues.

The conclusions from our study emphasize that the success of smart cities depends not only on technological advancement but also on a responsible and sustainable approach to the use of AI. Policymakers, city planners and other stakeholders must work together to ensure that these technologies are implemented to serve all residents while maintaining their rights and privacy.

The future of smart cities with AI seems promising but requires continuous dialogue, research, and collaboration between disciplines and sectors. As we strive to build more intelligent and integrated cities, we must remember these technologies' human dimensions and put residents' well-being first.

Therefore, the paper takes a step towards a deeper understanding and better exploitation of the potential of AI in smart cities, encouraging further research and innovation in this exciting and rapidly developing field.

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