# The role of smart cities in countering health threats: a review of practices

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**Abstract.** Modern cities face multiple global challenges. Despite the diversity of threats to sustainable development, public health is a priority. The authors will show, by analysing urban practices, how the integration of digital technologies, monitoring systems and data analysis can help to address the issues of disease control, environmental monitoring, access to urban medical infrastructure and health services. The article emphasises that the success of smart cities in public health is highly dependent on community engagement. Smart cities offer a set of innovative, flexible and scalable solutions that can significantly improve the situation in this area. The application of big data technologies, artificial intelligence, sensor networks and other advanced tools allows for creation of efficient mechanisms for monitoring, prediction and counteracting threats to public health. The provided conclusions and recommendations can serve as a basis for the development of sustainable development strategies for smart cities aimed at long-term improvement of people's quality of life.

**Key words:** Smart city; Health monitoring; Environmental wellbeing; Digital infrastructure.

## 1 Introduction

Intensive urbanisation increasingly raises the quality of life issue for urban agglomerations [1-6]. On the one hand, this process favours economic growth and development, but, on the other hand, it creates difficulties in management of urban infrastructure and leads to emergence of new threats. The problems of ecology, overpopulation, inaccessibility or limited high-quality medical care, the threat of new diseases and epidemics actualise the need to review the approaches to urban management [7-13]. In this context, the concept of "smart cities" is not just a technological trend, but a being-formed new paradigm oriented towards comprehensive improvement of people's quality of life, including in the sphere of public health [14].

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The smart city, in the context of public health, is an urban infrastructure that integrates different types of technology and data aimed to improve the quality and accessibility of health services, to increase the efficiency of the public health system and create a more favourable environment for the population [15-18]. Smart cities are characterised by many prospects promoting sustainable development (Figure 1). The sustainable development principles assume that urban environment should be environmentally friendly, safe, technically functional and convenient [19]. These provisions have been developed in the GLASS concept. Let us take a closer look at the "smart" component.

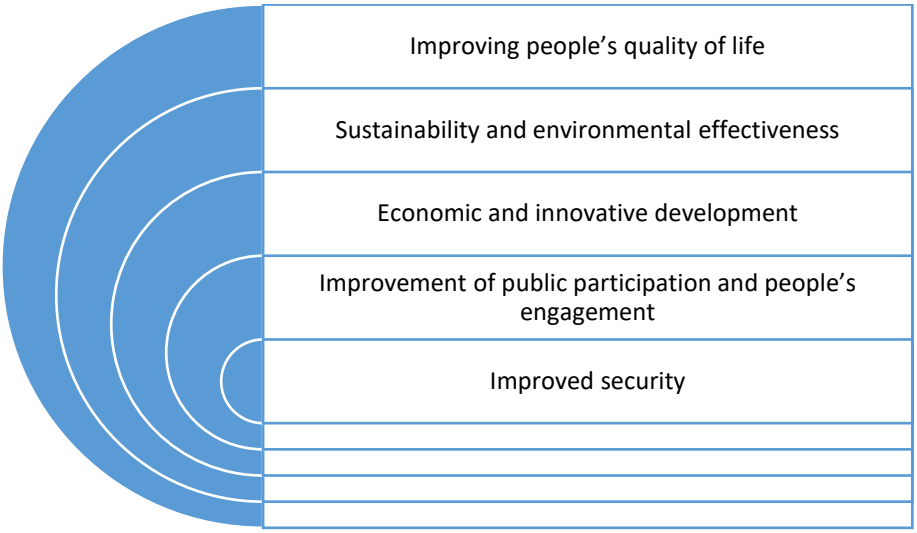


**Fig. 1**. Smart cities' advantages.

The smart city involves a broad range of technological innovations [20-23]: from data collection and processing systems to the use of artificial intelligence towards predicting and responding to different situations. The main aspects of the smart city in the public health domain are digital health services; alert and emergency response systems; improved access to public health care; environmental monitoring; etc.

The present research focuses on how smart technologies and solutions contribute to countering health threats and improving the quality of life. By analysing the current practices, it will be shown how new technologies can be integrated into urban infrastructure to ensure sustainable development.

## 2 Data monitoring and analysis

Data collection and analysis in smart cities play a key role for sustainable public health [24-25]. These technologies make it possible to identify threats in a timely manner and make informed prognostication. Below are some examples.

### 2.1 Monitoring the spread of diseases

Monitoring the spread of diseases in smart cities is becoming one of the most relevant and sought-after areas, especially after the spread of global threats such as COVID-19 [26]. This process involves collecting, analysing and interpreting data on disease outbreaks in order to

provide information that can be used for prevention, response and control of them. In smart cities, this process can be automated and optimised using the Internet of Things (IoT) and artificial intelligence [27-28]. Blockchain, BigData, geo-information systems and mobile applications can be effectively involved.

The introduction of disease monitoring systems has become a priority for many cities around the world. During the spread of COVID-19, such solutions became due tools to contain mass epidemics. Here are the most famous of them:

*Singapore:* As part of the Smart Nation project, Singapore is actively using technologies to monitor and control spread of infection. The TraceTogether application was used to track contacts of infected citizens. This application uses Bluetooth to exchange anonymised data between smartphones and helps to determine whether a user has met an infected person.

*South Korea: The* country made extensive use of mobile data, bank cards data and video surveillance to track relocation of infected people. Korea also used a rapid notification system: when a new case of infection was identified, information was posted on a specialised website and also sent via SMS to all citizens in the region.

*Israel:* Government services used mobile phone monitoring technology to track relocation of people with diagnosed COVID-19 and identify those who may have contacted them.

*China:* Chinese cities deployed face recognition systems with thermal cameras on public transport and at building entrances. Colour-coded mobile applications showed a person's health status and determined whether one could move freely or needed to be quarantined.

*USA:* Some cities used aggregated data from telecom companies to monitor social distancing. At the local level, applications were developed to notify contact with infected people.

*European Union:* Many EU countries and cities developed contact tracing applications based on decentralised approach. The application also provides guidance and advice on infection prevention.

*France:* As part of measures to combat the spread of COVID-19, the government launched StopCovid contact tracing application. This application uses Bluetooth to detect other devices in the vicinity and identify possible contacts with infected persons.

*UK:* The National Health Service (NHS) developed a contact tracking application allowing the users to record disease symptoms and learn about possible infection risks connected with their relocation. In addition, aggregated data from mobile operators were used in different regions of the country to analyse social distancing.

*Italy:* An application known as Immuni for contact tracing was launched. Using geolocation systems and mobile data, the Italian Ministry of Health tracked citizens' relocation to determine the quarantine measures effectiveness.

*India: The* Government of India developed a mobile application Aarogya Setu for contact tracing. This application uses GPS and Bluetooth to determine a person's risk of being infected as based on one's proximity to a known centre of infection and other infected person.

*Australia: The* government launched COVID Safe application for contact tracing. The application was intended to extend traditional contact tracking by automatically determining the distance between the users, and further allowed health authorities to warn a user that he/she was at a dangerous distance from some infected person.

*Russia:* A system of QR codes was developed for citizens, allowing them to move around the city during the quarantine. Each QR code was registered in a specialised system of state services, which made it possible to control relocation of citizens and reduce infection spread risks. Mobile operators' data were also used to analyse the activity of the population in different regions.

*Japan: The* Japanese government launched COCOA (COVID-19 Contact Confirming Application) to track contacts of infected people. Other solutions were developed, including temperature detection systems at entrances to public places and underground stations.

*Canada:* Contact tracing applications were introduced in several provinces. These applications helped to detect contacts with potentially infected persons and provided guidance on how to deal with possible risks.

Although the technological solutions for monitoring and tracking the spread of diseases helped in combating the pandemic, certain problems took shape as well. Such monitoring raises confidentiality issues, the problems of personal data protection, privacy and ethics, since they are critical for securing public trust.

On the whole, monitoring the spread of diseases in smart cities opens up new opportunities for more efficient and prompter response to health threats, which ultimately contributes to safer urban environment.

## 2.2 Monitoring and assessment of environmental well-being

Environmental well-being is becoming an increasingly relevant subject in the conditions of accelerated urbanisation and climate change. Many cities around the world are actively using modern technologies to monitor and assess the environmental situation [29-31]. This is primarily aimed at creating a green urban space. On the one hand, an urban greening system represents one of the levers of urban climate management. On the other hand, green infrastructure innovations have a function of supporting thermal efficiency of buildings and residential areas, reducing urban pollution and improving the psychological state of their residents. The generalisation of experience in this area will help to find most efficient solutions for its extension.

*Copenhagen (Denmark):* The city has installed a network of sensors to monitor the air quality and $CO_2$ emission. Green roof projects are being actively implemented. They not only improve the environmental situation but also serve as a place of recreation for citizens.

*San Francisco (USA):* A smart waste management system has been implemented that identifies where and when garbage collection is required, thus allowing for optimised recycling processes. The city has an extensive infrastructure for electric vehicles, including charging stations with a possibility to monitor their use. This is supposed to reduce the amount of harmful emissions into the atmosphere.

*Singapore:* The city has deployed a network of sensors to monitor the water level in rivers and canals in order to provide a timely response to threats of flooding. This mission is also performed by robotic swans used to monitor the water quality in five local reservoirs. The 'City in a Garden' programme promotes environmental initiatives aimed at creating urban green spaces.

*Stockholm (Sweden):* Stockholm Smart City application is based on integration of all basic subsistence elements on one platform. e-Stockholm focuses on providing electronic city services, including snow removal. The city uses IT technologies to monitor and optimise energy consumption in city buildings and residential houses. The city's projects to create green transport corridors for maintaining ecological well-being ensure unity with nature.

*Barcelona (Spain):* The water problems were a reason for construction of an efficient irrigation system that switches to economy mode during a drought. The city has also installed sensors to monitor air quality and noise level. The city actively implements major environmental projects, in particular, the introduction of renewable energy and modern utility networks with smart meters for analysing resource consumption and leak detection. The smart street lighting adjusted to certain time of the day and public needs reduces electricity consumption. In addition, an open-source Sentilo platform for collecting data from city sensors has been developed for Barcelona, for other cities to benefit from this experience.

*Melbourne (Australia):* The city has launched an Urban Forest Strategy project which makes it possible to visualise every tree in the city, allowing local residents and services to monitor the urban vegetation health. The application of sensors to monitor the water quality in rivers and lakes means to protect the aquatic ecosystems.

*Mexico City (Mexico):* The city has implemented sensor networks to monitor and control the level of pollutant emissions from road transport. The city is realising urban parks development and landscaping projects towards improving the air quality and providing recreational areas for the residents.

*Tokyo (Japan):* Given the frequent earthquakes and tsunami threats, the city has introduced a network of seismic sensors for their early detection and public alert. Energy conservation measures and the use of alternative power sources (hydrogen) that do not emit $CO_2$ are being realised. These and other initiatives are enshrined in Society 5.0 strategic programme.

*Kalasatama (Finland):* Kalasatama Smart City incorporates a multitude of environmental solutions such as unmanned electric buses, vacuum waste disposal system, smart litterbins, etc. It includes as well a smart power grid, a large solar panel park and electricity storage.

*San Francisco (USA):* The city is actively promoting a Zero Waste programme to reduce amounts of waste at landfills by using intelligent systems for waste sorting and accounting with a view of further recycling. In connection with the shortage of clean water, the city has introduced an automated system for monitoring the condition of water resources and prevention of water pollution.

The technologies for monitoring and assessing urban environmental well-being are becoming a standard in the modern world. This not only improves the quality of local population's life but also creates favourable conditions for economic development, tourism and investments. The smart use of resources and active interaction with the society enables the cities to face environmental challenges in a proper manner.

Environmental monitoring is also facilitated by smart solutions in the housing utilities sector. Sensors and metering systems improve the efficiency of water resources, electricity and heat utilisation. When it comes to resource use, smart systems can bring down water consumption by about one-third, electricity consumption – by about the same amount, and reduce harmful emissions into the atmosphere by about 10-15 per cent. The utilities consumption control goes far beyond the buildings and homes servicing. To provide due ecological situation within a smart city, it becomes important to take into account all aspects of housing utility services. For instance, sensors are installed in garbage containers, collecting and processing data on their fullness [32]; after that they automatically lay a route for a rubbish truck. Such technologies help to reduce vehicle fuel costs and to regulate the waste disposal system. Temperature sensors help to timely detect waste fire ignition and transmit due information to the relevant bodies.

As a result of active implementation of ecological monitoring and assessment systems, cities are able to take efficient management decisions aimed at improving the environment. This not only improves the residents' quality of life, but also contributes to the achievement of global sustainable development goals.

### 2.3 Accessibility of public health infrastructure and medical services

The integration of modern information technologies into medical infrastructure has become a key tool for many cities in their attempts to improve healthcare and meet people's needs for high-quality medical services. The availability of medical infrastructure and services in smart cities is provided through a combination of technological innovations, strategic planning and cooperation of different institutions [33].

Using advanced communication technologies, smart cities offer a possibility of remote consulting (telemedicine services), which is especially important for people living in remote urban areas or those with limited mobility. The formation of a unified digital network allows for rapid exchange of data between different institutions. This speeds up the process of obtaining information on patients' health status, providing doctors with up-to-date, real-time data. Wearable devices are also being integrated into a single digital loop. Smart watches and wristbands that have medical monitoring functions are able to transmit information to healthcare providers directly. Using the accumulated BigData array, smart cities forecast future needs in medical services on the basis of such indicators as population density in a particular area of the city, environmental condition, traffic congestion, climate, health status of the city's residents, etc. All of these parameters are incorporated into various geoinformation systems, which makes it possible to assess the demand for medical aid, to trace the location and regional distribution of medical institutions as well as to analyse and predict patient flows for optimisation of routes and to reduce medical service waiting time. Feedback from city residents can be provided through user applications that optimise navigation and provide information on the nearest hospitals, pharmacies and on availability of medical specialists. Patients can make online appointments, which reduces queues and increases the efficiency of medical institutions.

Below are some examples of smart cities' experience in this area.

*Barcelona (Spain):* mHealth – Barcelona Health Hub system gives access to a variety of remote monitoring tools to control patients with chronic diseases and to liaise with health professionals.

*Singapore:* MyResponder is an application that alerts emergency response services on incidents in order to provide first aid before an ambulance arrives. TeleHealth is a telemedicine system that allows doctors to monitor patients at a distance.

*San Francisco (USA):* SF72 is a platform to maintain communication between patients and healthcare providers in emergency situations such as earthquakes or epidemics.

*Tokyo, Japan:* Elderly Care System is a platform to monitor and support elderly residents providing them with access to health services, social services and home care.

*Canberra (Australia):* Digital Health Records has become a national electronic health records system intended to simplify access to medical information and improve coordination of health care delivery.

Seoul, South *Korea:* Seoul, South Korea Telehealth is a remote health care system that provides real-time counselling for those who cannot visit a hospital or clinic in person.

*Dubai (UAE):* Dubai Health Experience (DXH) is a platform providing tourists with information on health services in Dubai, including on specialised medical aid. Smart Pharmacy is a system of robotic pharmacies that provide automatic dispensing of medications with minimisation of human errors.

*Helsinki (Finland):* Maisa Client Portal is a system that allows efficient management of health and social services (scheduling a visit to a doctor, remote video consulting, accessing and viewing examination results, applying for social security, etc.). My KantaPages is an online service that shows details of online prescriptions. Patients can use this service to request prescription renewal and access their *medical records.*

*Toronto (Canada):* Connected Care Hub is a platform for exchange of medical data between different healthcare providers, enabling electronic counselling (eConsult) and electronic referrals (eReferral).

*New Delhi (India):* Aarogya Setu is a mobile application originally developed by the government to track and provide information on COVID-19; it also provides disease prevention tips and information on nearby health centres. India is also introducing Digital Health IDs – electronic patient records that simplify access to medical services and enhance personalisation.

These examples point to the versatility of solutions applied in smart cities to improve accessibility and quality of healthcare services for the residents.

Modern information systems make it possible to collect large amounts of data on citizens' health, including information on spread of diseases, physical activity level, air and water pollution indicators, etc. These data can be analysed to identify trends in this area, to provide early alert and take timely action.

### 2.4 Promoting healthy lifestyles

Smart cities are on the agenda in promoting healthy lifestyles [34-35]. The use of information technologies and services in this area helps cities to stimulate the population towards proper nutrition, disease prevention and training in the basics of health, physical activity.

Most often this is implemented through mobile applications. Some of them invite residents to participate in fitness challenges, tracking their progress and providing various rewards; others represent services with information on healthy nutrition, due recipes and nearby places to buy healthy food. Some applications provide physical activity recommendations, including jogging/biking routes, nutrition and meditation advice. A number of services and applications motivate people towards environmentally sustainable behaviour, in particular, waste recycling and energy saving, which also has a positive effect on health.

These initiatives demonstrate that modern technologies can be efficiently used to stimulate healthy lifestyles at the level of urban infrastructure. Using respective technologies, smart cities can influence behavioural factors, environmental and social conditions that promote health care and create a due health culture. If properly applied, they can significantly improve the quality of life and reduce public health costs.

### 2.5 Public safety

In terms of public safety, the smart city represents a set of integrated systems, technologies and methods allowing to secure safety of residents, respond to emergencies and prevent various threats specific of urban environment. Innovations in the sphere of public safety are oriented towards reducing crime rate, ensuring personal protection of residents and improving liaison between emergency services and law enforcement agencies.

The most important feature of a smart city is that all public safety solutions are based on data analysis. One of the key areas in this domain is development and implementation of a comprehensive video surveillance system. Video surveillance with data analysis is capable of recognising faces, automatically detecting fugitive citizens and stolen vehicles, identifying dangerous crowding, detecting suspicious activity or disturbance in the flow of traffic and pedestrians, controlling social distancing.

Administrative, social and cultural facilities of a smart city can be equipped with alarm buttons. Signals from them are automatically distributed among the relevant services.

To monitor urban hazards, a network of sensors can be deployed to collect data on chemical composition of air and water, on noise level, radiation and other parameters.

As concerns emergency services, intelligent transport systems are able to optimize traffic and routes for ambulance cars, fire service and police vehicles, which will help to reduce the time for them to arrive at the scene of accident [36].

The realisation of these and other similar initiatives in smart cities has become possible due to the key role of the state, local authorities and urban communities' demand [37-38]. The issues of planning, organisation, coordination and control of processes specific of transition to a smart city cannot do without participation of all interested parties [38].

## 3 Conclusion

Smart cities represent a comprehensive approach to urban space management, integrating modern technologies for improvement of their citizens' quality of life. Monitoring and forecasting systems, medical information services, platforms for promotion of healthy lifestyles – all this helps to create a safe and healthy urban environment.

However, it should be borne in mind that technologies are no more than tools; their successful application requires competent planning, coordination and consideration of socio-cultural peculiarities of a particular city. Public administration, investment and strategic partnership with the private sector and the society are key elements in the realisation of smart city initiatives.

Cities face a multitude of global health threats. In today's world, threats are becoming increasingly complex and multifaceted, including such manifestations as mass diseases, ecological problems and inequality in access to health care. Smart cities offer a set of innovative, flexible and scalable solutions that can significantly improve the situation in this area. The application of big data technologies, artificial intelligence, sensor networks and other advanced instruments promotes the development of efficient mechanisms to monitor, predict and counteract these threats at the level of cities and regions.

This study has addressed various practices of implementing urban smart technologies in different countries, aimed to improve public health service. Digital platforms for monitoring spread of diseases, along with environmental health assessment systems, promotion of healthy lifestyle and ensuring accessibility of medical infrastructure represent cumulatively a part of smart cities' systemic role in the domain of public health that needs to be further explored. Sharing experience between different cities and countries is important for public health progress at a global level, creating due prospects for further research.

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