CHAPTER 2 / BÖLÜM 2

SMART CITIES AND INFORMATION SYSTEMS

AKILLI ŞEHİRLER VE BİLGİ SİSTEMLERİ

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ABSTRACT

Now, more than half of the world population lives in urban areas. The growth of an urban population depends on many factors such as economics, employment, and quality of life standards. People living in big cities and towns face many challenges such as high energy demand, poor air and water quality and waste disposal. Smart city is a concept that uses the information and communication technologies of information systems to create a modern city that increases the quality of life and satisfaction of people living there. The Internet of Things sensors, tags, and actuators are used for real time data acquisition. Cloud based information systems store and analyze the collected data to generate meaningful results and reports. Artificial intelligence and machine learning applications create a collective city intelligence. The inter organizational information systems allow sharing of the electronic data and documents between different organizations such as universities, hospitals and, businesses.

Information systems play a leading role in the design and implementation of sustainable smart cities. Understanding all of the components, using the required technologies and information systems correctly, facilitates the transformation of cities into smart cities. This chapter will present smart city projects, applications and future directions that require information systems as a driving force. Smart cities, their components and infrastructures, the identification of information systems and technologies that correspond to these concepts, and exemplary applications and projects in the world are within the scope of this chapter.

Keywords: Smart Cities, Information Systems, Information Technologies

ÖZ

Son yıllarda, dünya nüfusunun yarısından fazlasının kentsel alanlarda yaşadığı bilinmektedir. Kentsel nüfusun büyümesi ekonomi, istihdam, yaşam kalitesi standartları gibi birçok faktöre bağlıdır. Bunun yanında, büyük şehir ve kasabalardaki kalabalıklar, yüksek enerji talebi, kötü hava ve su kalitesi ve atık bertarafı gibi sorunlarla karşı karşıyadır. Akıllı şehir, içinde yaşayan insanların yaşam kalitesini ve memnuniyetini artıran modern bir şehir yaratmak için bilgi sistemlerinin barındırdığı bilgi ve iletişim teknolojilerini kullanan bir kavramdır. Gerçek zamanlı verinin toplanması için Nesnelerin İnterneti sensörleri, etiketler ve aktüatörler kullanılır. Bulut tabanlı bilgi sistemleri, anlamlı sonuçlar ve raporlar oluşturmak için toplanan verileri depolar ve analiz eder. Yapay zeka ve makine öğrenimi uygulamaları kolektif şehir zekasını oluşturur. Kurumlar arası bilgi

sistemleri, elektronik veri ve belgelerin üniversiteler, hastaneler ve işletmeler gibi farklı kuruluşlar arasında paylaşılmasına imkan sağlar.

Bilgi sistemleri sürdürülebilir akıllı şehirlerin tasarlanmasında ve uygulamaya geçirilmesinde öncü rol oynamaktadırlar. Akıllı şehirleri tüm bileşenleri ile anlamak, ihtiyaç duyulan teknolojileri ve bilgi sistemlerini doğru bir şekilde kullanmak, şehirlerin akıllı şehirlere dönüşümünü kolaylaştırmaktadır. Bu bölümün amacı, itici güç olarak bilgi sistemlerine kuvvetle ihtiyaç duyan akıllı şehir projelerini, uygulamalarını ve gelecek yönelimlerini sunmaktır. Akıllı şehirler, bileşenleri ve altyapıları ile bu kavramlara karşılık gelen bilgi sistemleri ve teknolojilerinin belirlenmesi ile dünyadaki örnek uygulamalar ve projeler bu bölümün kapsamı içerisinde yer almaktadır.

Anahtar Kelimeler: Akıllı Şehirler, Bilgi Sistemleri, Bilgi Teknolojileri

1. Smart Cities

Communities throughout the history of humanity have developed activities with a common purpose in order to maintain their existence. With a common purpose, these communities have kept up with numerous social, economic, and technological innovations, from family and tribal organizations to today's modern city and state governments to ensure a better life. Although people had to struggle and fight among themselves for thousands of years, they sought common solutions against the crises that would affect all humanity, from epidemics to natural disasters.

In hunter-gatherer societies, people survived with what nature offered to meet their basic needs such as nutrition and shelter with the simple but useful tools they developed in small groups. With the advent of an agricultural society, people passed from a nomadic society to an agarian society. This, in turn, paved the way for them to live in their geographic region for many years by adopting a settled life. With the industrial revolution, people benefited from the invention of the steam engine, electricity and similar technology, facilitating new production processes, increasing the interaction between human communities, and benefiting from energy more than human physical power.

The transition between the first industrial and second industrial societies took approximately hundred years much like the transition process between the second and third industrial societies. Since this period is more than the average human lifespan, very few people have been in more than one industrial society. The number of people who have experienced the third industrial, fourth industrial and information societies is too high to be underestimated.

The dazzling and rapid developments in electronics and technology have affected the life of today's information society deeply compared to the lives of other societies. It is well known that technology facilitates the transformation of societies but, there can be many negative factors that directly affect the quality of life, either from technology itself or from other reasons as well. In recent years, smart societies tend to be super-smart societies. The fourth industrial society and information society have many common features that overlap each other. The abilities of people to keep up with technological developments has been improving. Managing and controlling technology and therefore nature, depend on the speed of development of technology and the qualified transformation of societies.

People who are looking for the advantages of urbanization over rural life are interested in the infrastructure of cities (Ismagilova et al., 2019). People migrated to big cities because of the opportunities of finding a job more easily in industrial societies. People who migrate

to cities due to reasons such as economy, war, and poor living standards are increasing the population of cities day by day. More than half of the world population lives in urban areas, and it seems like the growth of the urban population will continue to increase in the near future. The United Nations, Department of Economic and Social Affairs, Population Division (2019:11) published a report named "World Urbanization Prospects: The 2018 Revision" that showed the Estimated and projected urban population of the world from 2018 to 2050. According to the report, "*during this period the urban population is expected to rise by 2.5 billion persons, from 4.2 billion to 6.7 billion, while the total world population is projected to grow by somewhat less, 2.1 billion, from 7.6 billion in 2018 to 9.8 billion in 2050*". It means that nearly 68% of the people in the world will live in urban areas by 2050. Because of this, new strategies should be developed for better city performance and sustainability by leaders of cities (Letaifa, 2015).

There are some problems caused by living in the same city in large masses. Some of these problems are inefficient use of energy resources, air pollution that negatively affects human health, traffic congestion, and limited access to water and food resources. Urbanization, technological advancement, and environmental problems motivated people to think about how to build and manage cities (Höjer and Wangel, 2015). To overcome these problems, the need for interdisciplinary studies is increasing day by day. The smart city is a multidisciplinary field (Angelidou, 2015). Economics, sociology, psychology, ecology, geography, computer science, governance, and management science are some of the prominent disciplines. In order to increase the welfare of a society, there is a need for smart systems that can bring the disciplines together, and smart cities where smart systems can work in harmony. Before defining the smart city concept, it is beneficial to understand what is meant by the term smart. According to Batty (2017:3), "*the term smart has long been associated with the fact that computers can be used intelligently for many purposes while the recent wave of devices that enable us to compute as well as remotely access data enables us to demonstrate such smartness through extremely fast access to ever increasing volumes of information*". The word "smart" in the concept of smart city is the meaning of a feature. Therefore, its antonym is "without the use of advanced information and communication technology" (Höjer and Wangel, 2015:338).

Before the use of the term smart city, the concepts of digital city, wired city, and information city were generally used (Ismagilova et al., 2019). After explaining that the concept of smart city emerged in the literature in the late 1990s, Ismagilova et al. (2019) stated that the concept was not widely used until the 2010s. But there were some researchers that dated the origin of smart cities back to the 1960s (Höjer and Wangel, 2015). There was no common

definition of smart cities (Angelidou, 2015; Letaifa, 2015; Zhu, Shen and Ren, 2022). The researchers, institutes, associations made different definitions depending on the perspective. Some definitions were citizen centric, others were technology centric and some of them were governance centric.

According to the results of the literature review and the analysis of empirical applications of smart initiatives by Dameri (2013:2546), terminology, components, boundaries and scope were three main aspects of smart city definitions. Ismagilova et al. (2019:90) searched the definitions of smart cities within the information system literature and revealed some of the common terms as Information and Communication Technologies (ICT), interaction, sustainability, citizens, and quality of life.

The Organization for Economic Co-operation and Development (OECD) defines smart cities as "*initiatives or approaches that effectively leverage digitalization to boost citizen well-being and deliver more efficient, sustainable and inclusive urban services and environments as part of a collaborative, multi-stakeholder process*" (OECD, 2018 cited by OECD, 2020:8). According to the European Union, "*smart cities are the cities that use technological solutions to improve the management and efficiency of the urban environment*" (EU, 2020). From a perspective of worldwide company Deloitte, "a *city is smart when investments in (i) human and social capital, (ii) traditional infrastructure and (iii) disruptive technologies fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance*" (Deloitte, 2015:14). A definition which emphasized citizen as a component of smart cities was given by Snow et al., (2016:92): "*A smart city uses digital technologies to improve performance and well-being, reduce costs and resource consumption, and communicate more effectively and actively with its citizens*". Marek, Campbell, and Bui (2017:41) definedsmart cities as "*cities where ubiquitous sensors and devices enable more efficient city management processes, smoother information systems flow, and/or optimized use of infrastructure. But also aware of the scarcity of natural resources".*

An information system is the collection of interrelated components that collect, process, store, and share the data and information for decision making by control and coordination. From a technical point of view, of course, the main component of the information system is advanced technology, which includes hardware, software, database management systems, a network, and telecommunications. Information systems, beyond being computer systems, are also in a strong relationship with the economy, sociology, and psychology with a sociotechnical approach. Smart cities include systems like smart building systems, smart transportation systems, smart healthcare systems, smart education systems and many others. Actually, each

of these systems refer to an information system that collect, process, store and share the data and information.

In addition to these definitions, it is useful to include another definition in which information systems (IS) are at the center and smart city elements are brought together. Ismagilova et al., (2019:90) suggested a new definition by adapting from Caragliu, Del Bo, and Nijkamp (2011), Lee and Lee (2014), and Piro et al. (2014). According to them, "*Smart cities use an IS centric approach to the intelligent use of ICT within an interactive infrastructure to provide advanced and innovative services to its citizens, impacting quality of life and sustainable management of natural resources".*

In the transition from traditional cities to smart cities, human and society-oriented approaches should be the first priority target. In this transition, technology provides the connection between existing systems and new systems. The survival of societies in smart cities can only be achieved through sustainable technology and social integration. The International Telecommunication Union published a technical report about the definition of a smart sustainable city by analyzing the definitions of smart sustainable cities from various sources. According to the definition proposed by the International Telecommunication Union (ITU), "*A smart sustainable city is an innovative city that uses information and communication technologies and other means to improve 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, and environmental aspects*." (ITU, 2014:13). Another similar definition was developed by Höjer and Wangel (2015:342). According to them, a smart sustainable city "*meets the needs of its present inhabitants without compromising the ability for other people or future generations to meet their needs, and thus, does not exceed local or planetary environmental limitations, and where this is supported by ICT"*. This definition was developed by the researchers based on the definition of Brundtland. Smart cities can meet some of the sustainable development goals of the United Nations such as good health and wellbeing, clean water and sanitation, and climate action (Ismagilova et al., 2019).

According to the literature and smart city applications, the main aspects and goals of sustainable smart cities are presented in Figure 1 and listed below.

- Economic, social, and environmental aspects
- Information and communication technologies
- Better life standards

- Competitiveness
- Innovations
- Present and future integration
- Sustainability

Even though there are different societies in different regions of the world, there is a worldwide information society that uses the same technological communication and information language thanks to the international standards of information systems. In parallel with this, the informatics literacy of societies is also increasing, and they are prone to lifelong learning. This information society, which is sensitive to environmental problems, should be able to maintain a green and liveable world that future generations of people and living things will benefit from. New generation technologies should respect nature and living things and use natural resources and energy in the most efficient way.

Today, technology is developing and transforming much faster than societies. It seems like changing technology is easier than changing societies. In order to reach better living standards, it is necessary to change the existing conditions. The innovative services, products and technologies create an opportunity for societies to reach a better life. The societies trying to keep up with innovative changes accelerates social transformation.

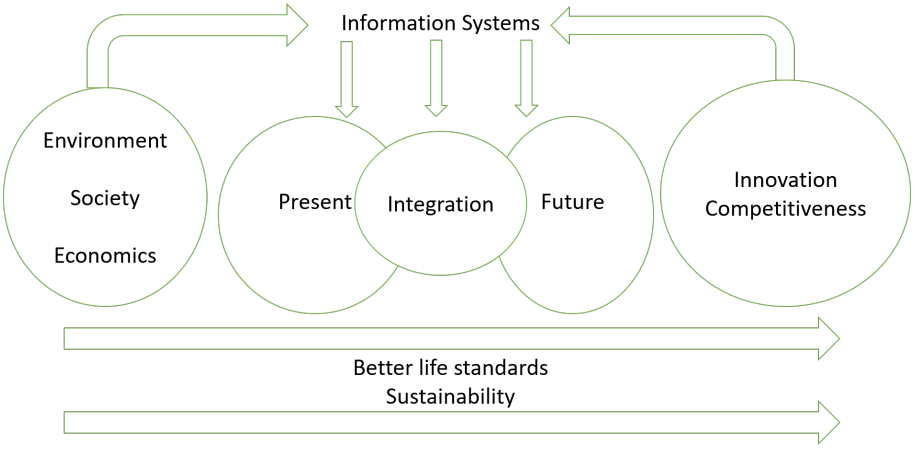


Figure 1. Sustainable smart city themes

Developments in e-commerce and internet technologies have revolutionized global economic development. While international trade has become widespread, marketplaces, market mechanisms, and market activities that contribute to the economy have become more func-

tional. "*The digital economy, also known as the Internet economy, is an economy based on online transactions, mostly e-commerce. It includes digital wireline or wireless communication networks (e.g., the Internet, intranets, extranets, and VANs), computers, software, and other related information technologies*" (Turban et al., 2018:20). Smart city is a concept that uses information and communication technologies to create a modern city that increases the quality of life and satisfaction of the people living there, and smart cities can create value for economic growth by optimizing city wide electronic transactions.

Technology, which is the most important component of smart cities and information systems, should increase the welfare of the society, protect personal and private data, and be open and accessible to the public. The reasons for using technology and information systems in a general framework are as follows:

- To understand and analyze the current situation of cities by collecting related data.
- To produce innovative information, products and services for society
- To produce new technologies for better life standards
- To gain the upper hand in a competitive environment for the motivation of smart cities
- To adapt to new technologies for future life
- To keep the information technology infrastructure ready for possible dangers and threats to smart cities
- To share valuable data and information among citizens, institutes, businesses, corporations and governments.

Integrated and inter organizational information systems facilitates data communication in a healthy way among people, businesses, and the organizations. Existing life standards can be improved with innovations and carried to the future with information systems which are adaptable and flexible to new changes. Laudon and Laudon (2020:62) emphasized that with a sociotechnical perspective, system performance can be optimized when technology and an organization mutually adjust to one another. This adjustment continues until finding a mutually satisfactory fit. Like organizations, societies and smart cities need continual and sustainable changes.

2. Smart City Infrastructure and Information Systems

The historical development of smart cities started with the applications of technology companies, developed with the use of these applications by city administrations, and chan-

ged depending on the demands of the people. In order to develop sustainable smart cities, city governments have updated their strategies and visions in an evolutionary process. All stakeholders of smart cities such as citizens, companies, and institutions have entered into harmonious interactions with each other depending on the strategies created. Studies examining the development of smart cities have divided smart cities into various periods in terms of managerial and technological aspects.

Deloitte (2015: 36) offered a maturity model that included four development stages of smart cities as initial, intentional, integral, and transformed. In this model, stages were evaluated in terms of strategy, vision, projects and solutions, data, technology, competences, openness, and ecosystem. The smart city projects evolved overtime. In the initial stage, projects were department based. In the intentional stage, cross-departmental projects were developed. In the integral stage, a cohesive citywide portfolio of cross-departmental projects was created. In the transformed stage continuous improvement of service delivery became the main approach. Angelidou (2015:103-104) referred to two main sections of the history of smart cities. The first one is urban futures, and the second one is the knowledge and innovation economy. In the first stage, technology always played an important role for approaches to the future of cities. On the other hand, recent developments in technology have provided new information management and innovation opportunities for cities in the second stage. Bashynska and Dyskina (2018, 234) classified the development of the concept of smart city into three stages as smart city 1.0, smart city 2.0 and smart city 3.0. In the 1.0 era, smart cities were designed with smart buildings, transportation networks, and energy technologies developed by leading information technology companies. In the second period, integrated urban infrastructure management was developed with the joint efforts of the city administration and technology companies. In smart city 3.0 era, the projects extended countrywide.

The evolution of smart cities from an information systems perspective can be discussed in three main stages as seen in Table 1. The prominent information systems of the first stage were geographical information systems that basically provide city maps and centralized information systems to monitor the data about the city. Using a city map for managing public transportation at municipalities without sharing information with citizens is a good example for the first stage. Another example is increasing the air quality with better decisions by measuring and analyzing the air pollution from different locations of a city.

The main idea at the second stage of smart cities was to connect data, information systems, and people. The Internet of Things (IoT) enabled millions of devices to be connected to the Internet within a city. IoT sensors, tags, and actuators can be used for real time data acquisi-

tion. The inter-organizational information systems allow for the exchange of electronic data and documents between different organizations such as universities, hospitals, businesses, municipalities, and corporations. Information systems can exchange structured data with other information systems easily.

Electronic Data Interchange (EDI) technologies have been used for data exchange between institutions for a long time. Beyond the standard data communication between devices and information systems, information systems that understand the meaning of data have strengthened communication between machines. Extensible Mark-up Language (XML) technologies itself and combination of EDI and XML technologies are used by web services to exchange the standard and semantic data. "*XML is one of the most widely-used formats for sharing structured information today: between programs, between people, between computers and people, both locally and across networks*" (The World Wide Web Consortium, 2022). XML technology is a mark-up language that facilitates standardization, interpretation and sharing of data with other systems. At the same time, Really Simple Syndication (RSS) is an XML based technology that facilitates the sharing of data and content in different forms among different websites. As an example, the data obtained by the connected devices in a public transportation information system can be shared with other information systems, mobile applications, and people in smart city via a city wide wireless and wired networking technologies.

Table 1. Evolution of smart cities from an information systems perspective

Stage	**Information systems**	**Main projects**
1	Centralized Information Systems	Visualizing city maps Data monitoring about city Geographic information systems
2	Connected Information Systems (Intra-Inter)	Connecting devices in a city Connecting information systems that can exchange the electronic data and documents. Connecting semantic data which is understandable by the information systems.
3	Decentralized Information Systems	Creating collective intelligence with crowd sourcing Developing cloud computing and ubiquitous computing applications Using cognitive computing and artificial intelligence

In the recent stage of smart cities, information systems mostly use crowd sourcing, ubiquitous computing, cloud computing, cognitive computing, and artificial intelligence. Driverless car technology which is an application of the third stage of smart cities, uses artificial intelligence to recognize objects, senses critical data with sensors, uses wireless technologies for data communication, and analyzes a huge amount of data in a very short time. Complicated

and developed information systems using artificial intelligence can make decisions on people's behalf. That is why, artificial intelligence and machine learning applications can be used to create a collective city intelligence.

Ubiquitous computing is the term which is often used together with IoT. The concept of ubiquitous computing is to provide digital utilized services, goods, facilities, and smart networks from anywhere at any time. Decentralized information systems, especially decentralized and distributed database management systems, process the data faster near the data source. Cloud based information systems can be used to store and analyze collected data to generate meaningful results and reports. Many middleware and Application Programing Interface (API) applications have been developed to connect data and reach linked data via cloud applications.

The efficient governance of smart cities to increase the quality of life standard strongly depends on the infrastructure of a smart city. The smart city infrastructure has been studied by many researchers, institutes, universities, and organizations for many years. The connection between people, businesses, and governments is managed by many different social, physical, and digital systems. "*Cities are based on a number of different systems – infrastructures, networks and environments – central to their operation and development: city services, citizens, business, transport, communication, water and energy*" (IBM, 2009:5). All these systems are interrelated as if they are subparts of a system that can be called a smart city system.

According to McKinsey (2018), almost 60 data-driven smart city applications spanning eight domains such as security, healthcare, mobility, energy, water, waste, economic development, housing, engagement, and community. Bashynska and Dyskina (2018:232) presented the smart city characteristics as smart environment, smart living, smart people, smart economy, smart mobility, and smart governance. They considered the creation of the concept of a smart city as one of the most urgent and debatable issues for the development of infrastructure of an entire city. Al Sharif and Pokharel (2022:3-6) identified the six dimensions of smart cities by reviewing the literature. These dimensions were smart economy, smart governance, smart living, smart mobility, smart people, and smart environment. In this study, risks associated with smart cities were classified under two categories as technical and non-technical risks. Technical ones involved IoT, AI and blockchain. Non-technical ones involved socioeconomic, governance; legacy, and strategic risks.

According to Bellini, Nesi and Panteleo (2022:7) smart city domain classifications were smart governance, smart living and infrastructures, smart mobility and transportation, smart

economy, smart industry and production, smart energy, smart environment and smart healthcare. Richter, Kraus, and Syrja (2015:222) described the six characteristics of a smart city as availability and quality of the ICT infrastructure and use, business-led urban development, social participation of urban residents in public services, high-tech and creative industries, the role of social and relational capital, and social and environmental sustainability. Zhu, Shen and Ren (2022:3) explained the main properties of a smart city as accessible and secured ICT infrastructure, reliable and efficient physical infrastructure, productive and innovative economy, equal and inclusive society, sustainable and resilient environment, participatory and transparent governance.

Consequently, it can be said that smart city infrastructure relies on a list of components such as smart governance, smart citizens, smart economy, and smart environment. According to the scope of smart city, the list of the components of a smart city can be extended by adding components like smart mobility, smart transportation, smart healthcare, smart production, and so forth. The list of common components to construct the infrastructure of a smart city and many different types of information systems is given in Table 2. These components should be interrelated. The linkage between them can be technically achieved with ICT. Additionally, smart cities need information systems using ICT to collect, analyze, store, and disseminate data within a city.

Table 2. Smart city infrastructure and information systems

Component	Sample Themes	Sample Information Systems
Smart Environment	Air pollution measurement Emission monitoring Waste management Resource management	Environment Monitoring Systems Air Quality Monitoring Systems Smart Waste Collection Management Systems
Smart Governance	Strategies Visions Public and social services Openness Collaboration	E-Government Information Systems E-Administration Systems E-Municipality Systems E-Voting Systems Executive Support Systems
Smart Citizen (people, society)	City life Social communications Long life learning Gamification Crowed sourcing	Learning Management Systems Content Management Systems Social Media Platforms Knowledge Management Systems
Smart Mobility (transportation)	Tracking Identifying Navigating Mapping Searching	Geographic Information Systems Intelligent Search Engine Systems Vehicle Sharing Platforms Fleet Monitoring Systems

Smart Economy	Innovation Entrepreneurship Production, logistics E-commerce, m-commerce E-marketplaces	Supply Chain Management Systems Decision Support Systems Enterprise Resource Planning Systems Customer Relationship Management Systems
Smart Living	Healthcare Electricity, gas, water supply Traffic management Cleaning Security	Smart Health Systems Smart Home Systems Traffic Monitoring Systems Expert Systems Cyber Security Systems

The main activities performed by information systems, and the technology and concepts used by information systems are presented in Table 3. As Information systems require not only a technical approach but also sociotechnical approach, the main goal of the information systems is to create value for people, services, economics, governance, and organizations in a smart city.

Table 3. Information systems' activities and technologies used in smart systems.

Activity	Technology / Concept	Information System's Role
Data Collection	Sensors, Actuators, RFID, Square code, Barcode Wearable devices Under skin chips Biometric Recognition System (finger print, retina)	Data is acquired either in a structured or unstructured format. The external data is stored in an information system to reuse. Database, data warehouse, and cloud platforms are used to store data in centralized or distributed database management systems. Data is cleaned and transformed before analysis step.
Data Analysis	Descriptive Explanatory Diagnostic Predictive	Information systems use powerful algorithms to analyze data to produce useful information and knowledge. Data analysis module of information systems presents the current situation, understands the relation between data and helps to make predictions.
Data Visualization	Tables Charts Graphics Dashboards Real time data visualization Data presentation services	Information systems use statistical and mathematical models to prepare data to be presented with, tables, graphics, charts, and dashboards. Smart city components can reach real time data from the information system visualization services.
Data Exchanging	Internet Intranet, Extranet Wireless (Local/Wide) Area Network Wireless Sensor Network EDI, XML, Jason, HTML, RSS	Data, reports or visualized data formats are exchanged between computer networks via standard protocols. APIs and Middleware solutions can be used to exchange electronic data between different information systems.
Decision Making	Artificial Intelligence (AI) Cloud Computing Services Machine Learning	Information systems using data analytics, data mining, artificial intelligence and machine learning algorithms, and scientific tools for better decision making processes.

Collaboration	Joint design platforms Joint plan platforms Joint production Innovation Crowed sourcing	New services, new products and new business models based on collaborative innovations can be created though inter-organizational information systems.
Security and privacy	Antivirus, Antispyware Encryption, Firewall, Virtual Private Networks Intrusion Prevention Systems Intellectual Property, Patent, License, Trademarks	Information systems include data administration, data governance, and data protection modules with needed hardware and software to control and manage cyber security issues.

The development of smart cities has a strong relation with information systems. The information system used in smart cities may vary due to the services used, culture of society, technology, and other factors. Information systems can be classified according to the management levels or functions of an organization. Information systems can be internal or external oriented. Integrating different information systems to each other facilitates the services used by citizens. The evolution from centralized information systems to decentralized information systems, increased the level of engagement of citizens to the smart city life.

3. Smart City Projects, Applications and Future Directions

There are hundreds of smart city projects and applications in the world. Ten of the smart cities and their projects are listed in this section. The cities were selected to present different approaches and applications for smart environment, sustainable economy and society, innovative technologies, future lives, open data platforms, artificial intelligence, blockchain technologies, and connected society and collaborations.

Climate Dashboard Oslo: Oslo-Norway is one of the smart cities that uses technology to develop environmental projects. The city of Oslo has developed a prototype for a pilot project which visualizes climate and environmental data such as bicycle counts, use of charging stations for electrical vehicles, and air quality. The real time data facilitates the presentation of predicted data based on machine learning. To engage people with climate change, climate statistics and historical data about climate change these trends are presented (Climate Dashboard Oslo, 2022).

Barcelona Digital City: The strategy of Barcelona-Spain involves providing high quality public services in a sustainable economy and society. Citizen oriented large-scale digital infrastructure deployment is one of the main characteristics of this smart city. Some of the featured projects are a digital market, 5G Barcelona, blockchain for data sovereignty and KIC urban mobility (Barcelona Digital City, 2022).

Brainport Smart District Project Brandevoort: This smart district in Brandevoort-Netherlands provides freedom to its residents for choice and control over their data. Anonymous data is generated under clear rules and laws for companies to test and develop innovations (Brainport Smart District Project Brandevoort, 2022).

Toyota Woven City Shizuoka: Woven city in Japan focused on the happiness of humankind. Toyota's projects for the mobility of people, goods and information, and the Woven City contribute to the future live, work, play, and move of the society. The living laboratory based on people's needs enables testing of new technologies for continuous developments (Toyota Woven City Shizuoka, 2022).

IMM Open Data Portal Istanbul: Istanbul, the biggest city of Turkey is committed to transparency and accountability. Istanbul Metropolitan Municipality (IMM) has an open data platform that links citizens, software developers, and the city. The platform enables the application to instantly review, compare, visualize, analyze, and share the data provided by the participants (IMM Open Data Portal Istanbul, 2022).

Smart Nation Singapore: Singapore is one of the best smart cities in the world. To transform the economy, a national artificial intelligence strategy is used to plan artificial intelligence applications. Government, researchers, and companies collaborate with each other to efficiently manage or change the possible risks outcome with the wide usage of the artificial intelligence applications (Smart Nation Singapore, 2022).

Seoul Metropolitan Government: The capital city of South Korea is the first local government using the blockchain for administration. The main policies, information system, and tasks performed in the city were analyzed in order to apply blockchain technologies for a better administration. Thus, this smart city shares an innovative administration (Seoul Metropolitan Government, 2022).

New York Smart Cities Innovation Partnership: One of the best applications of collaboration was done between the "The Governor's Office Technology & Innovation Portfolio and Empire State Development (ESD)"and "Israel Innovation Authority (IIA)." ESD and IIA aim to facilitate the development and integration of emerging technologies into public services by funding to support local projects that improve government services and resident quality of life by using smart cities technologies (New York Smart Cities Innovation Partnership, 2022).

Connected Community / Smart City TO: Toronto, a city in Canada provides new opportunities for its residents and businesses to improve navigating Toronto or accessing city ser-

vices. The recent projects are “Free W-Fi Pilot Project”, “Transportation Innovation Zones”, “Open Data” and “Automated water meters” (Connected Community / Smart City TO, 2022).

ASEAN Smart Cities Network: The Association of Southeast Asian Nations (ASEAN) is a network that uses technology to improve the quality of life for ASEAN citizens. Human rights and fundamental freedom are the core concepts of this network. It’s main purposes are facilitating the cooperation of smart cities development, catalyzing the bankable projects with the private sector, and securing funding and support from ASEAN’s external partners (ASEAN Smart Cities Network, 2022).

Recent smart city projects and applications show that every object or thing that we can perceive can be connected to a network with sensors, tags, and mobile devices for data acquisition, data processing, and data sharing. The digitalized services can be shared between communicating or collaborating parties as well. For this reason, the new projects will emphasize the human-machine and machine-machine communication.

Collaborations between the researcher, governments, companies and people contribute to the development of smart cities. Open data protocols facilitate to help reach the data and information provided by task oriented information systems. Smart cities also allow companies and governments to test and control innovative technologies. Continuous change in both society and technology lead information systems to use innovative artificial intelligence on big data and blockchain technologies.

Smart city projects and applications generate huge amount of data that is obtained from internal and external resources such as sensors, tags, actuators, and people. Information systems and data warehouses store this data to prepare predictive models for crowd dynamics in different scales. Dealing with this big data requires advanced information systems that perform powerful algorithms and analytics to analyze the data. However, there are some challenges such as variety, velocity, and volume of data when developing smart city projects using big data. To overcome these challenges, cloud computing, grid computing, edge computing, on memory computing technologies, and distributed database management systems can be used to process data in the shortest time needed. These emerging practices require specialized software, hardware, database management systems, and networking technologies to increase the performance of the information system.

There are other challenges such as security and privacy that threaten information systems. Information systems, data and networks should be protected. The governments and companies should have a cyber-security strategy and policy. Information systems should be powered by

the data administration, data governance, and data protection modules with dedicated hardware and software to control and manage the cyber security issues. The smart city projects and applications should respect the private data obtained from citizens, companies, and various information systems. Finding solutions to all of these challenges attracts the attention of big companies (Höjer and Wangel, 2015). The solutions can be listed as strategic assessment methods, mitigating measures, top down and bottom up initiatives, and competence of city governance and governance models.

Five countries (U.S., China, India, Europa, Japan) and 5 of 15 companies (Panasonic, Google, Alibaba, Verizon, Toyota) were analyzed by Kim (2022:8-9) and three important conclusions were derived. Firstly, smart city services are shifting from provider oriented and infrastructure based services to data and device oriented convergence businesses. Secondly, smart city companies can be categorized in two groups. The first group of companies such as Google and Panasonic lead the entire value chain. The second group of companies such as Amazon and Verizon provide products and services. These companies efficiently use cloud and AI platforms. Thirdly, urban operation companies are strengthening their cooperation systems. Smart cities determine their strategies focusing on components such as environment, people, governance, economy, mobility, and living. Information systems and technology will be a key point to prepare adaptive strategies. Letaifa (2015) collected data on Montreal, London, and Stockholm and created a model for strategic steps towards smart cities. In this model, the strategic steps to be followed are listed as creating a common strategy, adopting an approach that brings together stakeholders from different disciplines, ensuring that the stakeholders adopt the project, detailing the workflow of the project and determining the necessary technology.

4. Conclusions

Smart cities increase the welfare of societies living in urban areas by using information systems and technologies. In the recent stage of smart cities, information systems mostly use crowd sourcing, ubiquitous computing, cloud computing, cognitive computing, and artificial intelligence. Smart city infrastructure mainly relies on a list of components such as smart governance, smart citizens, smart economy, smart environment, smart mobility, smart transportation, smart healthcare, smart production, and so forth. Information and communication technologies are the main links between these components. Smart cities need information systems using these technologies to collect, analyze, store, and disseminate data within a city. The main target is to create value for people, services, economics, governance, and organizations.

In order to design and develop smart cities of the future, to increase the welfare of a society and to make the economies sustainable, projects that respect nature, focus on people needs and is open to innovations should be implemented. Information systems and information technologies are indispensable for smart cities that enable people, companies, institutions, and administrations to come together with collective intelligence. The continuous change of societies and technologies implies the change of information systems. Innovative information systems can easily adapt the new technologies to existing information systems and to the lives of the people in a smart city.

For improvement and sustainability of smart cities, there are plenty of applications and projects on energy consumption strategy, climate change, traffic management, health issues, and others. That is why a huge amount of data is generated as a result of the digital transactions. Dealing with this big data requires advanced information systems that perform powerful algorithms and analytics to analyze the data. The warehouses obtained from big data are the main resources for information systems to prepare predictive models for crowd dynamics in different scales. Integrating different information systems to each other facilitates services used by citizens. Grid computing, green computing, virtualization, and on demand computing are the emerging practices that need specialized software, hardware, database management systems, and networking technologies under information systems.

Information systems using artificial intelligence, machine learning, the Internet of things, blockchain, and many other innovative technologies, for the governance of smart cities, to the effective use of natural resources, increase the living standard of people living together, and ensure that smart cities are carried to the future. As the number of smart city projects increases, their quality differs, the use of the services offered becomes easier and the welfare level of societies increases, the need for and the perceived importance of information systems will increase in the future.

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