Challenges and New Research Directions to the Development of Smart Cities: Systems-of-Systems Perspective

Saeed Al Mansoori
Faculty of Engineering and IT, The British University in Dubai (BUiD), UAE
Email: 20180829@student.buid.ac.ae

Abstract. Cities play a pivotal role in the global economy as they are the hubs of trade, industry as well as social and cultural activities. Nowadays, more than 50% of the world’s population live in cities and this number is steadily rising throughout the upcoming few years leading to a highly significant change in the world’s demography. This remarkable growth in urbanization will make cities struggling to provide the basic services to their citizens and will encounter enormous challenges such as traffic congestion, more pollution, excessive energy consumption, extreme water usage, more waste, etc. Consequently, a smart mechanism needs to be implemented in-place to effectively manage the natural resources and assets within cities to ensure the sustainability of services and to provide a high quality of life to residents. Hence, the concept of smart cities has been introduced and becomes one of the most focal and hottest research areas in recent years. Generally, smart city is a combination of urban systems that are interconnected to each other using Information and Communication Technology (ICT) along with Internet of Things (IoT). The shift from a single system to systems of systems would accelerate the development of various sectors including healthcare, education, transportation, economy, energy, housing, etc. Nevertheless, this transfer is extremely challenging due to various aspects related to infrastructure concerns, data storage, subsystems integration as well as managing data in decision support systems (DSS) for end-users. This paper elaborates on the current state-of-the-art in the Systems of Systems Engineering in the context of smart cities. In addition, it highlights some of the smart cities long-term challenges, potential solutions along with new research directions.

1. Introduction
Human population has been playing a significant role in the establishment of urban areas since they are responsible for all the activities taking place in such regions. Many people today migrate from rural areas to seek employment in urban areas which leads to the growth of densely populated and busy cities [1]. The Global Data Thematic Research projected that people living in urban areas will nearly be 2.3 billion throughout the next three decades, meaning that approximately 70% of the urban population will be living in cities by 2050 as shown in Figure 1 [2]. Unfortunately, the increasing population is accompanied by serious challenges related but not limited to the inadequate capacity of social amenities, traffic congestion, poor waste management and air pollution.

Global warming resulting in climate change and sea level rise is another dimension that need to be taken into consideration when designing the road map for smart cities since more than 570 cities are lowland by the coast and it is predicted that the sea level will rise at least half a meter by 2050 which would put the lives of more than 800 million people at risk [3].
These challenges act as a driving force for the creation of smart cities to effectively use the natural resources and to improve the citizens’ quality of life. It is extremely essential to establish a smart city that acknowledges the adoption of advanced technologies linked to the aspects of urban life. There are three principal pillars that drive the concept of smart cities [3]: (a) developing local eco-systems that are able to pinpoint city needs and provide solutions at the local level, (b) developing cloud technologies and big data applications, as decisions concerning cities could be made depending on the data that have been collected and analysed with the aid of cloud technologies and (c) suppliers of interoperability (i.e. providers of various devices, sensors, systems, etc. that are interconnected with each other rendering cities more effective and increasing societies’ quality of life).

Cities are the main hubs of data gathered from residents along with various sensors and devices fitted in all over the places. Different emerging technologies such as Cyber-Physical Systems (CPS) and Internet of Things (IoT) are effectively contributing in the management of smart cities. Yin et al. [4] define a smart city as “an integrated system of technological infrastructure, depending on advanced data processing, with the aim of making city governance more efficient, citizens happier, businesses more prosperous and the environment more sustainable”.

1.1. History of Smart Cities

The emergence of smart cities dated back to the 1970s when the first urban project relying on big data analytics was established by Los Angeles state, USA [5]. In 1994, De Digital Stad, a virtual digital city, was founded in Amsterdam as the first smart city to stimulate the use of internet. Later, the developments in this domain were accelerated in the 20th century when IBM and Cisco initiated various initiatives. In 2011, Barcelona hosted the Smart City Expo World Congress that has become later a yearly occasion attracting leaders, decision makers, experts, etc. from all over the globe to discuss recent research breakthroughs belonging to smart cities (e.g. challenges, best practices and future directions).

1.2. Components of Smart Cities

As per literature, several components have been found to be the core of smart cities. For instance, Cocchia (2014) proposed three main components of smart cities that are smart people, smart infrastructure, and smart government [6]. On the other hand, Zhang et al. [7] introduced additional five smart city components comprising smart energy, smart living, smart industry, smart environment and smart services. All these components should be profoundly investigated and effectively interconnected to successfully implement the concept of a smart city. These components are explained as follows:
1.2.1. Smart infrastructure. Involving providing services to city residents more effectively while responding to their needs. It also entails applying advanced technologies such as the connected data sensors and IoT solutions, to provide electronic services and real-time data [6].

1.2.2. Smart People: Human being is the driving force for all the developments and initiatives towards smart cities. Citizens should be up-to-date with the technology to cope with the nature of life in the cities of the future that is based on advanced technologies [6].

1.2.3. Smart Government. Involving the application of ICT as well as the available technologies to institute an electronic government as a measure for enhancing the quality and accessibility of public services and making city residents more satisfied with the services offered by the local administration.

1.2.4. Smart Energy. Entailing full exhaustion of extensively deployed sensors to monitor the amount of energy generated, transmitted, distributed and consumed. It also involves controlling utility usage, electric vehicle charging, smart grid, etc. Moreover, a smart city can minimize the amount of consumed energy in various aspects as well as preventing the blackout of the power grid and failure of individual energy usage [7].

1.2.5. Smart Environment. It helps establishing not only a comfortable climate but also a sustainable environment within the smart city surroundings. The universal sensing along with intelligent climate management are simultaneously used to promote smart environment through monitoring greenhouse gas emissions, marine pollution, forest conditions, etc. to obtain a smart sustainable development [7].

1.2.6. Smart Industry. It aims at maximizing industrial production alongside with manufacturing while meeting efficiency and robustness. Moreover, it limits the materials and resources consumption including labor, time and production lines while producing goods. It also blocks the industrial heat and gas waste from being emitted into the atmosphere. The smart industry can be developed using servo actuators, motors and robots to allow it to have a firm control on industrial production [7].

1.2.7 Smart Living. It provides city residents with an intelligent management of different domestic machines as well as utilities to construct comfortable homes while enhancing energy efficiency at the same time [7, 8]. It allows city residents to have remote control on domestic machines, climate
adjustment, consumed energy, surveillance and entertainment in addition to education. It can also be used to effectively manage the recycling of the waste products, social networking, and parking spaces to have a community of smart buildings.

1.2.8. **Smart Service.** It permits city dwellers to enjoy the benefits of the public facilities and services in various ways. For instance, intelligent transportation allows travellers to evade the problem of road traffic congestion, easily navigate different parts of the city, monitor their travel plans, etc. Deployed sensors, cameras at intersections, GPS and smartphones can be used to gather the road traffic information. The control center can be used to adjust travellers’ road plans and provide them with real-time feedbacks on their smartphones or GPS [7, 8].

2. **Smart City Concept**

The concept of smart city has not been fully comprehended yet although there is a plethora of researches exploring this domain [9]. Therefore, several factors have been put forward to help explaining the concept of smart cities: (a) management and organization, (b) technology and innovation, (c) governance, (d) policy context, (e) people and communities, (f) economy, (g) built-in infrastructure, and (h) natural environment [9]. These factors, elaborated in this section, can be used to develop the fundamental framework guiding the construction of smart cities.

2.1. **Management and Organization**

The smart city management system is concerned with designing and executing ways that allow cities to meet their full potentials while keeping their daily operations efficient. Smart cities are anticipated to be simultaneously huge and multifaceted due to the highly integrated system between the sub-branches of the city. Although control and monitoring systems are also needed to facilitate smooth management and organization of activities, limited research has been carried out on the innovation in management. The human resource is overwhelmed with tasks that might tamper with the effectiveness and efficiency of the management operations. Therefore, the emergence of smart cities will lead to the establishment of sub-management centers to reduce the burden of work on the human resource management and make its operations efficient [9].

2.2. **Technology and Innovation**

The main purpose of building a smart city is to improve the quality of urban life by reducing pollution, greenhouse effects, promote the use of renewable resources, and balance energy production and consumption. Therefore, there is an increasing need for the smart city to implement the smart grid concept as well as advanced technologies into its energy infrastructure [9]. These technologies are used to tap renewable energy such as solar and wind to save the natural resources from exhaustion. For example, the solar panel should be utilized to tap solar energy used in cooking as opposed to using gas cookers which is not an environment friendly.

2.3. **Governance**

The process of improving the quality of urban life requires proper leadership to spearhead all the smart city initiatives. Unsuitable governance arrangements for most of the cities have been linked to the most solemn impediments for an effective transformation of cities to be smart. As a result, a proper governance system is required to guide the development of smart cities through joining all forces at work, permitting the transfer of knowledge, and making the decisions which aim at optimizing the socioeconomic and environmental performance of the cities [8, 9]. Moreover, the main significance of developing new cities is to improve services offered by the government, which makes them easily accessible. For example, the electronic government (e-government) is characterized by a quick response in the provision of governmental services to the citizen [8]. Accordingly, a smart city should have governance that is accountable, responsible and transparent.
2.4. Policy Context
Without properly articulated policies, all the measures put in place to build smart cities will be in vain. To have a sustainable evolution in smart city technology, there is a need to develop and implement the smart city strategies that will protect the privacy of urban dwellers [7]. Moreover, the conflict of interests existing within public companies in the government sector would require the intervention of smart policies [8]. Generally, smart cities create an enabling environment for business activities. For example, the government can establish a market place where businesses operate within the city. In return, businesses will sell hardware, software, networks, and maintenance services to the governments for supporting smart cities.

2.5. People and Communities
People and communities are the main beneficiaries of the smart cities development. The Canadian Federal Government (2002) defines ‘Smart’ communities as the societies where electronic networks and the Internet provide a virtual platform bringing the local administrators and the general public together to innovate and extract new economic and social values [9]. Community development using smart cities aims to empower urban dwellers by equipping them with the necessary skills and information that would result in positive impacts on their communities. Consequently, the urban community within the smart cities will be comprised of people with tech knowledge to ease their access to services such as paying bills as well as connecting with friends and families through digital devices and social media platforms, etc.

2.6. Economy
A smart city should be the one that is concerned with the allocation of the limited resources to satisfy the dwellers’ needs. The contemporary “Smart City” has been acknowledged to be a significant economic role-player. It can support initiatives in addition to long-term projects focusing on constructing new ecosystems with numerous opportunities and perspectives. In this case, the concept of a smart city is specifically promising given that it assures competitiveness together with economic growth through competent city dwellers, tech companies and persistent digital connections [8]. To stimulate economic growth, a smart city should provide the city dwellers with a variety of economic opportunities, focus on balanced and sustainable economic growth, encourage sharing economy, have a flexible labor market, and promote sustainable management of natural resources [9].

2.7. Built Infrastructure
With comfortably built infrastructure, there will be more building facilities that can enhance the level of production within the city. The smart cities will attract highly competent people and increase the city dwellers’ experience. Based on data exchange, there will be a faster transmission of data communication due to the utilization of different integrated systems and common channels of communication [7]. Furthermore, controlling and monitoring environment improve the level of automation which would result in limited physical interactions among city dwellers. In addition, maintenance and operation call centers will make it easier for the city dwellers to report complaints [9].

2.8. Natural Environment
The growth of the urban population poses serious threats to the environment leading to a strain on the limited natural resources and a remarkable increase in pollution. Smart city initiatives like monitoring the quality of air in the city, optimizing energy consumption, and monitoring electricity and water wastage can produce desirable results [8].

3. System of Systems

3.1. Definition of SoS
The concept of ‘System of Systems’ (SoSs) has been introduced in the literature since 1950s to elaborate on systems comprising independent constituent systems that are collaboratively operated (i.e. interconnected) to achieve a common objective [10]. There is no unified agreed-upon definition for SoSs as it varies depending on their application domains. This sub-section highlights some SoSs definitions, stated by different scholars:

1) **First Definition**: According to Eisner et al. (1991), SoSs refers to “A set of several independently acquired systems, each under a nominal system engineering process; these systems are interdependent and form in their combined operation a multifunctional solution to an overall coherent mission” [11].

2) **Second Definition**: Shenhar et al. (1996) confirm that SoSs is “A large widespread collection or network of systems functioning together to achieve a common purpose” [12].

3) **Third Definition**: Jamshidi (2005) identifies SoSs as “the systems characterized by operational and managerial independence, geographic distribution, emergent behavior, and evolutionary development” [13].

### 3.2. Characteristics of SoS

Due to the widely spread recognition of SoSs in conjunction with the absence of a universal definition of this term, there is a massive need to identify SoSs characteristics to make it simpler to understand. Consequently, Maier (1996) proposed five main characteristics of SoS features, often remembered using the acronym “OMGEE” [14]:

1) **Operational Independence**: Each system within SoS functions independently even after disassembling the SoS.

2) **Managerial Independence**: Individual systems have the ability to effectively manage, control and validate themselves despite working together in the context of SoS.

3) **Geographic Distribution**: The interconnected systems forming SoS are distributed across broad geographical areas. These systems are characterized by being able to exchange data smoothly without minding the limits of mass or energy.

4) **Evolutionary Development**: The SoS nature is evolutionary implying that its goals in addition to its operationalities witness constant variations since they are apt to be added, adjusted, or eliminated based on experience.

5) **Emergent Behavior**: The integrated systems within SoS can achieve the ultimate goal through synergism which is not probable if any of the systems works independently.

### 4. Literature Review

So far, no city on the earth can be truly called a smart city despite all the great efforts being made in this domain, due to the fact that the existing strategies are focusing on a single system of interest instead of adopting a holistic model that interconnect the city subsystems to effectively operate in an integrated manner [1-4,8,15]. Over the past decades, many studies [5,7,9,15] have been conducted to provide state-of-the-art solutions and frameworks based on the concept of system-of-systems to overcome the challenges encountering smart cities. For instance, [16] proposed a model aiming at establishing a complex standard platform that efficiently integrates the entire systems within the city using systems engineering approach complemented by Systems Engineering Modelling Language (SysML). The proposed approach is characterized by being interdisciplinary, making it an appropriate choice to design a complicated system such as the smart city one. On the other hand, SysML is recommended by the authors to cope with the challenges related to documentation, communication as well as management. In addition, it utilizes graphics in order to support the design along with the calibration and validation of complex systems. The successful implementation of the proposed model discussed in [16] will offer extraordinary features such as (i) providing citizens with real-time information; (ii) allowing urban planners to make informed decisions without causing any negative influences on other systems within the city, etc.
Another study by [17] investigated a novel approach to build an integrated smart city system based on a Model-Based Systems Engineering (MBSE) and SysML. To examine the reaction of the proposed model under various conditions, three pre-defined scenarios are applied. The authors of this study argue that MBSE is considered one of the most practical options when modelling smart city system and exchanging information across the integrated systems within the city. In addition, there are several studies [6,7,9,10,14] agreed upon the importance of Internet of Things (IoT) considering it the key enabler to develop large scale smart city applications, each of which can be represented as SoS. These studies found that the main challenge facing the implementation of SoS is its engineering complexity, especially when it comes to the development and maintenance of smart city applications. One of the major engineering challenges that encounter the industry sector nowadays is to verify a certain SoS application at runtime. In this regard, [18] proposed an effective approach to monitor smart city systems using a model-based runtime.

5. Smart City as Systems-of-Systems

The smart city in the context of systems of systems consists of various interconnected systems each of which is in charge of solving a particular problem or dealing with a certain concern related to urbanization such as mobility, healthcare, education, security, etc. This concept has been implemented successfully in various European cities such as Helsinki, Manchester, Stockholm and Amsterdam through applying the bottom-up approach [19]. In this regard, cities are expected to be smarter via adopting decentralized projects and initiatives where each one concentrates on achieving a specific goal within the framework of SoSs.

SoSs can be viewed as a potential solution to the problems arising while building smart cities [19]. For example, a city can be defined as smart if it has a good network of roads to make each part of the city easily accessible. However, this would not be easy in a city affected by traffic jams due to the high urban population, too many vehicles and narrow roads. Moreover, for a city to be smart, environmental pollution should be minimized as much as possible. Nevertheless, this would not be possible if fuel consumption vehicles are still in use. Therefore, SoSs remain the optimal solution for improving the transportation system within cities and save their dwellers against daily problems such as accidents and time wastage due to prolonged traffic jams as well as limited car parking spaces. On the other hand, replacing fuel consumption vehicles with electric vehicles will help in limiting air pollution.

Electric vehicles should interrelate with the smart grid as both rely on electricity; however, non-smart charging schemes can be insufficient. Thus, smart interaction between the vehicles and the grid should be applied to ease smart charging approaches as well as to provide supplementary services in order to assist in the grid management, referred to as vehicle-to-grid (V2G) [20].

The smart grid gains many direct and indirect benefits from the associated technologies. In this case, vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication are applied when implementing the ITS, which aids the smart grid to consume less power in infrastructure-based lighting and traffic control systems. From another perspective, the V2I and V2V communication will indirectly help the smart grid when applying more intelligent transportation strategies consuming less fuel. This will enable citizens to navigate the city easily and reach their places within a short time [20].

6. Challenges and Potential Solutions

Viewing smart cities from the perspective of SoS is challenging especially when it comes to practice as systems by their nature are independent in terms of their design, operation, management and maintenance. It is essential to comprehend the relationships among these systems as they vary with respect to their scope, engineering as well as functionality. This section investigates some challenges that can be encountered while constructing the next generation cities based on system of systems engineering concepts. These challenges are derived from: (i) the recent studies targeting smart cities developments based on system of systems (ii) the lessons learned from the pioneering cities in their long-term journey to become “smart” [21].
6.1. Scale and Inherent Complexity
The progressive developments in embedded systems, cloud computing, wireless sensors as well as advanced networks crowning in the emergence of nowadays Internet of Things that has been the core of making the dream of a smart city a reality. Over the past decade, several physical devices are widely in operation aiming to connect people or sensing and monitoring cities. Accordingly, many advanced systems are introduced in various domains which are expected to be much more complex in functionalities compared to now. In the context of smart cities, such diverse systems should be integrated to establish a complex system to bring practical cutting-edge solutions to government, community and environment. Simultaneously, it is essential to accentuate that each of these elements are likely to be system of systems themselves, leading to increase the scale along with the complexity in the design, manufacturing and functionality of such systems. It is extremely complicated to manage the SoS complexities which require multi-dimensional organizational measures.

6.2. Multitude of Stakeholders
To ensure a sustainable, secured supply and futuristic planning that can cope with the recent city growth and development, it is pivotal to empower stakeholders to be involved in making rational decisions [22]. Generally, Single systems have a predefined group of stakeholders concerned with one specific domain. By contrast, complex systems relying on SoS have a wider range of stakeholders, comprising the ones of the single systems and the ones of the integrated SoS. This leads to: (i) a conflict of interest as each set of stakeholders have a particular interest when dealing with SoS; (ii) a conflict in relations between the constituent systems and the entire SoS because of their managerial autonomy; (iii) conflicts resulting from interactions amongst constituent systems owing to their independence in terms of operation; and (iv) a certain constituent system can be interconnected with more than one SoS at a time. Accordingly, SoS-based smart cities should cope with various stakeholders’ contradicting interests, needs and demands as well as priorities which requires effective strategies and innovative solutions to deal with various scenarios.

6.3. Heterogeneity and Interoperability
In the smart city context, reliance could be placed on the service delivery consisting of the existing systems that form the entire city. However, the challenge that encounters the engineering of such a system lies in the high heterogeneity of its single systems, characterized by being (i) independent; (ii) distributed; (iii) developed by using various technologies; (iv) provided multiple (non-common) data formats; and (v) owned by individual organizations in the city. For instance, a patient’s efficacious medical cure at an emergency unit comes as a result of a fully-coordinated interaction among numerous operational independent systems comprising telecoms, ambulance services and health centers’ management. Hence, a successful smart city should have effective measures to enrich interoperability amongst the existing single systems while conserving their operational independences. Yet, the main challenge is that most of the constituent systems within cities are not originally designed to interact with one another, which makes an interoperability solution extremely hard to establish [23]. To mitigate such obstacles, it is essential to develop a sophisticated SoS-centric middleware services for supporting system of systems’ execution within cities by establishing a platform that is more dynamic, transparent and scalable to support interoperability amongst several systems operating within the city [23]. According to [24], Middleware denotes to “a software layer between applications and the underlying communication, processing, and sensing infrastructure aimed to offer different levels of transparency, interoperability, and services for end-users and applications”. This proposed solution looks promising owing to its ability to make the system development process much easier along with its capacity to tackle the high heterogeneity. This solution also provides essential functionalities including the management of huge datasets, data analysis, privacy, etc.

6.4. Unification on Information
The key challenge in the management of smart cities data is to have common information models besides the ability to securely exchange data and information among several organizations to get a full picture of urban activities within a city [24]. For example, information belonging to streets is strewn across multiple agencies and their corresponding systems comprising mobility, urban planning, emergency services, etc. Thus, it is essential to adopt uniformed models in order to represent the handled and shared data throughout various applications and systems within the smart city. As per the literature exploring SoS, it is recommended to utilize ontologies and semantic-based approaches to have a seamless integration of the constituent systems [24-33].

7. Conclusion

A city is extremely a complex human settlement with multiple systems, technologies, tools, stakeholders and decision makers. Nowadays, many cities exerting sincere efforts towards their transformation to be smart cities. However, none of them can achieve this goal if they are still applying the traditional approach that considers only a single system of interest instead of adopting a holistic model that interconnect the city subsystems to effectively operate in an integrated manner. Therefore, SoS is considered a potential solution to solve the issues arising while constructing smart cities. The aim of this research paper is to: (i) highlight the smart city components, (ii) elaborate on the current state-of-the-art in the Systems of Systems Engineering in the context of smart cities and finally, (iii) discuss smart cities long-term challenges and suggest some potential solutions.

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References

[1] Achmad K, Nugroho L, Djunaedi A and Widyawan 2018 Smart City Model: A Literature Review Proc. 10th International Conference on Information Technology and Electrical Engineering (ICITEE) pp 488-493
[2] GlobalData Thematic Research 2020 History of Smart Cities: Timeline. [Online]. Available: https://www.verdict.co.uk/smart-cities-timeline/. [Accessed: 03 May 2020].
[3] Mamkaitis A, Bezbradica M and Helfert M 2016 Urban enterprise: A review of Smart City frameworks from an Enterprise Architecture perspective IEEE International Smart Cities Conference (ISC2) pp 1-5
[4] Yin C, Xiong Z, Chen H, Wang J, Cooper D and David B 2015 A literature survey on smart cities Science China Information Sciences 58 1-18
[5] Pellicer S, Santa G, Bleda A, Maestre R, Jara A and Skarmeta A 2013 A Global Perspective of Smart Cities: A Survey Seventh International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing pp 439-444
[6] Cocchia A 2014 Smart and Digital City: A Systematic Literature Review Smart City 10 13–43
[7] Zhang K, Ni J, Yang K, Liang X, Ren J and Sherman X 2017 Security and privacy in smart city applications: Challenges and solutions IEEE Communications Magazine 55 122–129
[8] Dlodlo N, Gcaba O and Smith A 2016 Internet of things technologies in smart cities IST-Africa Week Conference pp 1-7
[9] AL-Masri A, Ijeh A and Nasir M 2019 Smart City Framework Development: Challenges and Solutions Smart Technologies and Innovation for a Sustainable Future 54 325-331
[10] Claus B, Peter G, John F, Jim W and Jan P 2013 Systems of systems engineering: Basic concepts, model-based techniques and research directions ACM Computing Surveys 48 1-41
[11] Eisner H, Marciniak J and McMillan R 1991 Computer aided system of systems (C2) engineering IEEE Int.Conf. Syst., Man Cybern.
[12] Shenhar A and Dvir D 1996 Towards a Typological Theory of Project Management Research Policy 25 607-632
[13] Jamshidi M 2005 System-of-Systems Engineering - a Definition In Proceedings of the 2005 IEEE International Conference on Systems, Man, and Cybernetics 5 1-9
[14] Maier M 1996 Architecting Principles for Systems-of-Systems Sixth Annual International Symposium of the International Council on Systems Engineering
[15] Boardman J and Sauser B 2006 The meaning of System of Systems In Proceedings of the IEEE/SMC International Conference on System of Systems Engineering
[16] Muvuna J, Boutaleb T, Mickovski S and Baker K 2016 Systems engineering approach to design and modelling of smart cities Proc. International Conference for Students on Applied Engineering (ICSAE)
[17] Muvuna J, Boutaleb T, Baker K and Mickovski S 2019 A Methodology to Model Integrated Smart City System from the Information Perspective Smart Cities 2 496-511
[18] Incki K and Ari I 2018 Model-based runtime monitoring of smart city systems Procedia Computer Science 134 75-82
[19] Cavalcante E, Cacho N, Frederico L, Thais B and Flavio O 2016 Thinking smart cities as systems-of-systems: A perspective study In Proceedings of the 2nd International Workshop on Smart Cities 2 1-9
[20] Stephen W and Suleyman U 2015 Interaction and synergy of the smart grid and intelligent transportation systems towards smart cities In Smart Grid: Networking, Data Management and Business Models
[21] Cacho N, Lopes F, Cavalcante E and Santos I 2016 A smart city initiative: The case of Natal In Proceedings of the Second IEEE International Smart Cities Conference (IEEE ISC2 2016) pp 242–248
[22] Schleicher J 2016 A holistic, interdisciplinary decision support system for sustainable smart city design In Proceedings of the First International Conference on Smart Cities (Smart-CT 2016)
[23] Lopes F, Loss S, Mendes A, Batista T and Lea R 2016 SoS-centric middleware services for interoperability in smart cities systems In Proceedings of the 2nd International Workshop on Smart Cities: People, Technology and Data (SmartCities’16)
[24] Cavalcante E, Cacho N, Lopes F and Batista T 2017 Challenges to the Development of Smart City Systems: A System-of-Systems View 31th Brazilian Symposium
[25] Al-Ruzouq R, Shanableh A, Gibril M and Al-Mansoori S 2018 Image Segmentation Parameter Selection and Ant Colony Optimization for Date Palm Tree Detection and Mapping from Very-High-Spatial-Resolution Aerial Imagery Remote Sensing 10 1-24
[26] Al Mansoori S, Kunhu A and Al Ahmad H 2018 Automatic palm trees detection from multispectral UAV data using normalized difference vegetation index and circular Hough transform In Proceeding of High Performance Computing in Geoscience and Remote Sensing VIII
[27] Al-Mansoori S and Kunhu A 2014 Hybrid DWT-DCT-Hash function based digital image watermarking for copyright protection and content authentication of DubaiSat-2 images In Proceeding of High Performance Computing in Remote Sensing IV
[28] Al-Mansoori S and Al-Marzouqi 2016 Coastline Extraction using Satellite Imagery and Image Processing Techniques International Journal of Current Engineering and Technology 6 1245-1251
[29] Al-Mansoori S 2015 Intelligent Handwritten Digital Recognition using Artificial Neural Network International Journal of Engineering Research and Applications 5 46-51
[30] Al-Mansoori S and Kunhu A 2012 Robust watermarking technique based on DCT to protect the ownership of DubaiSat-1 images against attacks International Journal of Computer Science and Network Security 12 1-9
[31] Aldogom D, Albesher S, Al Mansoori S and Nazzal T 2020 Assessing Coastal Land Dynamics Along UAE Shoreline Using GIS and Remote Sensing Techniques IOP Conference Series: Earth and Environmental Science 540 1-10
[32] Al Mansoori S, Salloum S and Shaalan K 2020 The Impact of Artificial Intelligence and Information Technologies on the Efficiency of Knowledge Management at Modern Organizations.
A Systematic Review Recent Advances in Intelligent Systems and Smart Applications 295 163-182

[33] Bhaskar H, Werghi N and Al Mansoori S 2010 Combined spatial and transform domain analysis for rectangle detection In Proceeding of the International Conference on Information Fusion pp 1-7