
Edited by
Wael A. Samad & Elie Azar
SMART CITIES in the GULF
Current State, Opportunities, and Challenges
Gulf Research Centre Cambridge
Knowledge for All

Smart Cities in the Gulf

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Wael A. Samad • Elie Azar
Editors

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Current State, Opportunities, and Challenges

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ISBN 978-981-13-2010-1 ISBN 978-981-13-2011-8 (eBook)
https://doi.org/10.1007/978-981-13-2011-8

Library of Congress Control Number: 2018958487

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This Palgrave Macmillan imprint is published by the registered company Springer Nature Singapore Pte Ltd.
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Acknowledgments

This volume is based on a selection of papers presented at the "Smart Cities in the Gulf: Current State, Opportunities, and Challenges" workshop, which was held on 1–4 August 2017 at the University of Cambridge in the United Kingdom. The co-editors would like to extend a warm thank you to all participants of the workshop, totaling 22 scholars and practitioners, who convened over three days to present academic papers and discuss the prospects of smart cities in the six Gulf Cooperation Council member states. The discussions held during the event greatly enriched the chapters of this volume and helped the co-editors and authors together define a number of overarching themes, challenges, and solutions relating to the topic.

The co-editors are also deeply grateful to the organizers of the 2017 Gulf Research Meeting of the Gulf Research Centre Cambridge, under the umbrella of which the workshop took place. In particular, we would like to thank Dr. Abdulaziz Sager, Chairman and Founder of the Gulf Research Centre (GRC) and Dr. Christian Kokh, Director of the GRC Foundation Geneva, as well as Elsa Courdier at the GRC Foundation, Dr. Oskar Ziemelis, Director of Cooperation at the GRC, and Sanya Kapasi at the GRC, for their tireless work and support.

United Arab Emirates
May 2018

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PART I

Introduction

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CHAPTER 1

Smart Cities in the Gulf: An Overview

Wael A. Samad and Elie Azar

Background

The notion of a *Smart City* is one of the rapidly emerging topics in modern sustainability trends, and understandably so. Although the term *Smart City* has appeared in literature as of the late 1990s, there still is some confusion with regard to its exact meaning, context, and methods of assessment and quantification. However, and irrespective of a *Smart City*'s precise definition, *Smart City* initiatives are actively being implemented in various developed cities worldwide, while their application in Gulf Cooperation Council (GCC) cities is fairly limited, and when so, often inorganic. Various challenges are ahead of GCC cities for an effective transformation toward a *Smart City* model. The dimensions of these challenges include political, socio-economic, technological, local talent resources, policy, cyber, and infrastructural aspects, with their proper integration being an essential element.

With that, the purpose of this edited volume is to expand on the current state, opportunities, and challenges related to *Smart Cities* in the

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_1

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GCC. The scope is well along the lines of the United Nation's (UN's) Sustainable Development Goals (SDGs); in particular, the 11th pillar on "Sustainable Cities and Communities". This edited volume comes as a result of the compilation of some of the insightful papers, presentations, and discussions by participants at the 8th Gulf Research Meeting, which was organized by the Gulf Research Centre and held at the University of Cambridge in August 2017. Participating authors included a diverse mix of experts from various disciplines and sectors such as policy makers, engineers, political and social scientists, architects, educators and researchers.

Cities throughout the world are facing significant urban sustainability challenges related to their various sectors such as buildings, transportation, industrial, healthcare, and education (Newman and Jennings 2012). With the worldwide current and anticipated population growth, the sustainable management of key resources including energy, water, and food has become inevitable (Albino et al. 2015). This has contributed to the recent concept of a *Smart City*: a city that creates sustainable development and high quality of life through the smart and adaptive management of its resources (Hollands 2008; Neirotti et al. 2014). Cities in GCC countries are at the front line of such increasing demands with their projected population growth being among the highest worldwide; well over 30 times that of European Union countries (IRENA 2016; IEA 2015). A transition toward smarter GCC cities is vital to an improved management of resources, a high living standard, and a knowledge-based economy. As a matter of fact, knowledge has become a key element of growth in what is often referred to as a "knowledge-based city", where innovation and information exchange are fostered into that environment to drive and lead a positive change (Ingallina 2018; Leducq et al. 2017; Carrillo et al. 2014). Such a vision is in agreement with the SDGs declared in the UN resolution A/RES/70/1 of September 2015. Specifically, the 11th goal titled "Sustainable Cities & Communities" is a confirmation of the need for immediate action toward more sustainable and *Smart City* initiatives (UNDP 2015).

In recent years, some efforts have been taken by Gulf public and private entities to make particular sectors more efficient; that is, *smarter* (Tok et al. 2015). However, such efforts have typically been segregated among the various constituents of a city, and thus failing to truly achieve the full potential of a smart and integrated city. For instance, critical resources such as energy, water, and food are intricately linked and actions in one

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area have a direct impact on the others (FAO 2014). As a result, applying a "smart" supply-side energy management platform in GCC cities will only be beneficial granted it accounts for—and adapts to—its implications on the other resources.

A common misconception is that the essence of a *Smart City* revolves around the adoption of new technologies, when the main goal is the application of such technologies in the form of means to improve the well-being of the inhabitants of the city (Nam and Pardo 2011). Moreover, and with the surplus of data being collected from numerous sensory connected devices, the challenge of a *Smart City* is now more centered about drawing conclusions and insights from data for optimal decision-making (Bessis and Dobre 2014).

In the end, each city is unique, posing its own challenges and aspirations depending on almost every aspect of a nation from location, stability, economy, political leadership, level of advancement, readiness of the citizen, and so on. What works as a framework for one city will not necessarily apply for another. Even within the GCC, and contrary to common perception, cities and their inhabitants are quite unique, which further complicates the model of a *Smart City* that Gulf cities can aspire to achieve.

Objectives and Target Audience

Filling a void in academic and governance-relevant literature on the topic of *Smart Cities* in the Gulf region, this edited volume provides a multidisciplinary analysis of the current state, key opportunities, and challenges related to realizing this goal, including infrastructure, information and communication technology (ICT), frameworks, as well as social and well-being perspectives. Eleven insightful analyses on Gulf-specific aspects of *Smart Cities* are presented, examining the current state, opportunities, and challenges, while identifying key takeaways. The editors believe that this volume is the first of its kind to address *Smart Cities* in the Arabian Gulf region. The edited volume serves as an essential reading for researchers and practitioners studying smart cities in general and the current state, challenges, and opportunities for GCC cities more particularly. The book tackles diverse topics given the multidisciplinary topic of *Smart Cities*, and as such will cater to a wide spectrum of audience. Furthermore, the book can be of great benefit for instructors offering undergraduate or graduate courses in disciplines related to City Sciences, Urban Planning, Policymaking, and Urban Sustainability, to name a few.

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CHAPTER 2

Book Structure

Wael A. Samad and Elie Azar

The book is divided into six main parts. Part I: *Introduction*—which comprises two chapters—introduces the readers to the concept of smart city both from the international and local Gulf Cooperation Council (GCC) contexts, mapping previous and current research efforts in the field. Part II: *Frameworks and Governance*—which includes three chapters—presents case studies on current smart city frameworks and initiatives undertaken in multiple GCC cities. Part III: *Resources and Infrastructure*—which comprises three chapters—covers the link between smart cities and key infrastructure sectors and resources such as energy, water, and food. Part IV: *Information and Communication Technology* (ICT)—which includes two chapters—covers key advancements of ICTs and their applications in smart cities. Part V: *Social Perspective*—which includes three chapters—offers an alternative approach to the role of smart cities in the Gulf, with insights into the socio-political dimensions of the challenge. Part VI: *Conclusion*—presents an overview of the topics covered in the various chapters

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_2

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highlighting key findings and directions for future research. The following paragraphs detail each of the chapters presented in the book starting from the chapters of Part II, which follow the current introductory chapters.

In Chap. 3, "An Impact-Driven Smart Sustainable City Framework to Address Urban Challenges: Smart Dubai Experience", the author proposes a holistic impact-driven smart sustainable city framework to address social, economic, and environmental issues. The chapter also discusses the application of the suggested framework in Smart Dubai, the smart city initiative of Dubai in the United Arab Emirates, as a short case study.

In Chap. 4, "Development of a National Smart City Initiatives Framework for the Kingdom of Bahrain: A Blueprint for Successful Smart Cities", the authors explore the National Smart City Framework (NSCF) for the Kingdom of Bahrain by examining international standards, working with the main stakeholders to identify its components, and aligning it to the national strategic plan and priorities.

In Chap. 5, "Smart-Governments for Smart Cities: The Case of Dubai Smart-Government", examines and analyzes the smart government project in Dubai in an attempt to underscore the main opportunities and challenges facing this project on the ground. The author argues that a new way of thinking about the role of government is needed in relation to other societal players.

In Chap. 6, "Linking Smart Cities Concept to Energy-Water-Food Nexus: The Case of Masdar City in Abu Dhabi, UAE", the authors investigate the link between water-energy-food nexus and a smart city in managing these resources in a more sustainable way. Masdar City in Abu Dhabi is taken as a case study.

In Chap. 7, "Sustainable Transportation Infrastructure for Smart Cities in the Gulf Cooperation Council: The Case of Electric Vehicle Charging", discusses the current infrastructure challenges for a wider penetration of electric vehicles in GCC markets. The authors then propose a new technology for a fast and wireless charging of electric vehicles.

In Chap. 8, "Intelligent Energy Management Within the Smart Cities: An EU-GCC Cooperation Opportunity", the authors focus on the energy management of buildings, where an "app-in-context" framework is presented, extending sophisticated ICT-based energy management systems in order to empower occupants to engage in energy efficiency through behavioral change.

In Chap. 9, "The Influence of Big Data and IoT on Smart Cities", several smart city applications are analyzed within the context of the IoT and

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Big Data. A novel integration framework is proposed, which can serve as a guideline for industries or stakeholders who engage in the development of smart cities initiatives.

In Chap. 10, "Opportunities and Challenges in Internet-of-Things (IoT) Deployment for Smart Cities", the author covers the security vulnerabilities of the promising technology of IoT and presents an approach to mitigate them through a vision of unification and cooperation of public safety agencies in the GCC. The chapter also discusses the economies of scale that can be leveraged by the GCC member states to secure IoT applications in their smart cities.

In Chap. 11, "Dubai Happiness Agenda: Engineering the Happiest City on Earth", presents the vision of Dubai to become the "Happiest City on Earth". The author outlines the strategy undertaken by Dubai, and the mechanisms employed to reach this vision, along with the technological and psychological tools used to ensure success, describing some actions taken to overcome such challenges, and data showing progress toward this vision.

In Chap. 12, "Smart Cities and Place Making: The "Sense of Place" in the Implementation of Smart Cities in the Arabian Gulf", the author addresses the importance of incrementing the conditions for the existence of "sense of place". Historically "sense of place" was not a planned emotional condition. It formed through lengthy processes not replicable in the conscious act of founding a contemporary city. The different implications of Smart City are analyzed here, as well as the differences between Smart City and Smart Growth, elaborating on some of the theoretical approaches.

In Chap. 13, "Transnational GCC Triple-Helix Relations for Building Smart Cities Under Globalization", the author explores the role of transnational knowledge and triple-helix relations between GCC countries and both the West and Asia for pursuing smart cities in the GCC. The author argues that the development of GCC smart cities will equally require strong transnational knowledge and triple-helix relations between local academia, business, civil society, and government with foreign counterparts crisscrossing national and sectorial borders.

Finally, in Chap. 14, "Outlook of the Future of Smart Cities in the Gulf", the book is concluded with an overview of the topics and case studies that were covered in the various chapters. The chapter includes a discussion of the key findings, insights learned, recommendations on how to address the challenges toward a more effective implementation of smart cities in the GCC, and directions for future research on the topic.

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PART II

Frameworks and Governance

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CHAPTER 3

An Impact-Driven Smart Sustainable City Framework to Address Urban Challenges: Smart Dubai Experience

Okan Geray

Introduction

Cities are projected to accommodate a high majority of human population and also economic activities. These dense and highly congested physical spaces present significant challenges as well as opportunities for humankind. Smart and sustainable city (SSC) initiatives have been positioned as potential solutions to economic, social, and environmental issues and pressures in cities. Advances in Information and Communication Technologies (ICT) enable significant transformation potential in the way cities are planned and managed.

This chapter proposes a holistic impact-driven SSC framework to address social, economic, and environmental issues. The suggested framework defines and encompasses main city constituents. Transformation examples of city constituents are briefly discussed along with sample key performance indicators (KPIs) to define the transformation. Target values for KPIs regarding various aspects of constituents, when combined together, establish a future state vision for an SSC. The difference between

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_3

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current (baseline) and target values for KPIs determine the strategic gap which is targeted to be closed through ICT-enabled strategic action items. Closure of identified strategic gap is then translated into three types of impact at the city level. The framework defines these three types of impact and discusses them. The proposed framework can be used as top-down and bottom-up approach; and may act as a strategic decision-making tool for SSCs as they undertake city-level large-scale complex initiatives.

The proposed framework is inherently designed to accommodate and encourage substantial innovation through target setting. The size of strategic gap will determine the extent of innovation required from city stakeholders. The framework can be used as a macro city-level transformation tool. This chapter briefly discusses the application of the suggested impact-driven SSC framework in Smart Dubai, the smart city initiative of Dubai in UAE, as a short case study.

Cities globally accommodate majority of human population and also economic activities. The same trend is projected to continue in the foreseeable future. Already in 2016, an estimated 54.5 percent of human population lived in urban settlements and the same figure is expected to rise to 60 percent by 2030. There were 512 cities globally in 2016 with at least 1 million inhabitants and 662 cities are projected for 2030. There were 31 "megacities", that is, cities with more than 10 million inhabitants in 2016 and the same number is estimated to reach 41 by 2030. Similarly in 2016, 45 cities had populations between 5 and 10 million and 63 cities are projected for 2030 (UNDESA 2016).

Population growth has been the crucial driver of cities' growth (McKinsey Global Institute 2016). In a sample of 943 global cities with more than 500,000 inhabitants in their metropolitan regions, 58 percent of gross domestic product (GDP) growth between 2000 and 2012 came from expanding population. Rising per capita income contributed the other 42 percent. Large cities generate about 75 percent of global GDP today and are estimated to generate 86 percent of worldwide GDP growth between 2015 and 2030 (McKinsey Global Institute 2016). Hence cities will play a crucial role economically in the future as well.

Cities as relatively dense and highly congested physical spaces are prone to significant challenges. More than 80 percent of cities in 2014 were located in areas which were vulnerable to high risk of mortality or economic losses associated with natural disasters (UNDESA 2016). Population increase, urban sprawl, climate change, environmental problems, and fiscal pressures are among the myriad challenges faced by cities (UNECE and

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ITU 2016). Additionally, demographic changes such as aging populations, volatile economic growth, unemployment, low-wage low-skilled jobs, income inequality, social polarization and segregation present threats for sustainable urban development (European Commission 2011). Furthermore, our current consumption levels in cities pose an unsustainable threat for the future.

Middle East and North Africa (MENA) region has its own urban challenges as well. In the second half of the twentieth century, the population of MENA region has increased more than any other region in the world (UNDESA 2001). Below is a summary of some of the challenges faced by MENA region (UNHABITAT 2009):

- High unemployment and illiteracy rates
- Rapid urbanization
- Severe water shortage
- Peace and political stability
- Informal settlements and slums
- Poverty
- Economic policy and governance reforms' slow implementation
- Lack of secure property rights

More recently, declining oil prices have also resulted in fiscal pressures for oil-rich MENA countries. The extent and intensity of these challenges vary from country to country, and more specifically from city to city in the MENA region. Some MENA countries and cities have undertaken significant reforms in identified areas of priority and have turned some of these challenges into opportunities.

Smart and Sustainable Cities

SSC initiatives have been proposed as potential solutions to economic, social, and environmental challenges and pressures encountered by cities. Advances in ICT enable significant transformation potential in the way city resources, services, and infrastructures are planned and managed. City data obtained from various sources can aid in identifying root causes of challenges and provide innovation potential for addressing them. More specifically, ICT can play an enabling role to address the urban challenges of twenty-first century.

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On the other hand, the concept of an SSC is relatively a new one and several working definitions have been proposed (Chourabi et al. 2012). In this chapter, the definition adopted by International Telecommunication Union (ITU) and United Nations Economic Commission for Europe (UNECE) (United 4 Smart Sustainable Cities 2017) for SSCs will be used:

> A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) 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, environmental as well as cultural aspects.

SSC initiatives tend to address multiple challenges in a city by implementing several strategic action items. Depending on particular city approach, SSCs may span a wide spectrum of action items covering economic, social, and environmental aspects among others. They harness ICT (including various subtopics under ICT such as digital transformation, data, Internet of Things (IoT), digital services) and intend to deliver city enhancements through a portfolio of action items. By their very nature, SSC initiatives impact the underlying cities. It is important to identify this impact. Identification of impact will allow for better planning, setting expectations with stakeholders, financing viable but underfunded initiatives, and will also help in communicating SSC initiatives.

Impact Management

Since SSC initiatives impact cities, it is important to take a broad perspective and assess the impact of these initiatives. International Association for Impact Assessment (IAIA) defines impact assessment as "the process of identifying the future consequences of a current or proposed action" (IAIA 2012).

Impact assessment can be used by city planners as a forward looking tool to evaluate what might happen in the future with respect to their planned initiatives. It is essential to consider both positive as well as adverse impacts during such an assessment. From its very definition, it can be seen that impact assessment can be used to balance current and future sustainability of cities with respect to conceived SSC initiatives. Sustainability is often stated as a goal by various entities including city planners; yet it is not easy to measure or assess it.

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In mid-1990s, John Elkington proposed a new framework to measure sustainability for corporates (Elkington 1994). It was an accounting framework, called the Triple Bottom Line (TBL), and went beyond usual economic measures (such as profits, shareholder value) and incorporated social and environmental dimensions (later on it was also referred to as 3Ps; namely people, profit, and planet (Dhiman 2008)). TBL was adopted by various private and public sector organizations to assess their impact with respect to sustainability. TBL is scalable to assess impact from a single corporate project to a set of initiatives implemented in a large geographical area (such as a city) (Hall 2011). The impact assessment can include various economic, social, and environmental measures. Economic measures are concerned about the flow of money and may include measures around income, expenditures, taxes, employment, and so on. Social measures are related to social fabric of a community or region and may include things like education, health, equity, safety, poverty, housing, and so on. Last but not the least, environmental measures are concerned about natural resources and their viability and may include air and water quality, energy consumption, waste, land use, and so on. The actual measures opted for a specific impact assessment will be driven by the actual scope and objectives of the projects and/or initiatives and will reflect pertinent stakeholders' views.

Impact-Driven SSC Framework

In this chapter, a holistic impact-driven SSC framework is proposed and developed. The framework encompasses four city constituents; namely:

- Government
- Economy
- Society
- Resources and Infrastructure

Government includes the city public sector organizations which govern city affairs and in general provide policies, regulations, and public sector services to the city. Economy includes businesses (in general private sector organizations) which participate in economic and commercial activities by exchanging products and services. Society is composed of individuals (and the communities) living in a city which interact and consume social services. Resources refer to city resources consumed by other city constituents

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and include among others water, energy, air, land, waste, and so on. Infrastructure refers to the fundamental facilities and systems serving other city constituents and includes among others roads, bridges, tunnels, water and electricity supply network, telecommunications networks, and sewage and drainage network.

SSC Impact Through Constituent Transformation

A two-step process is adopted for identifying impact in this chapter. SSC initiatives transform city constituents through targeted actions. The first step entails identifying transformational KPIs with respect to the above defined constituents of a city. The KPIs are associated with a baseline and a target value. Target values for KPIs regarding constituents, when combined together, establish a future state vision for transformation of a SSC. The difference between current (baseline) and target values for KPIs determine the strategic gap. The second step entails identifying impact on a city when SSC initiatives deliver the intended transformation on constituents by achieving targeted KPI values. Various potential transformations regarding aforementioned constituents are briefly explained below in a non-exhaustive manner to illustrate the concept. There is a myriad set of potential action items for each constituent and it would be beyond the scope of this chapter to enumerate each one distinctly and exhaustively.

Government Constituent Transformation

The diffusion and uptake of digital technologies enable tremendous opportunities for changing the way cities are governed and the way public sector functions and delivers services. Digital transformation initiatives are enabling public sectors to:

- provide more effective and efficient services
- streamline and improve core and back-office processes
- open up and share their data and to provide it as fuel for innovation

These changes are impacting the city inhabitants' expectations from city services. They also significantly enhance quality of life when implemented properly. City government can be simplistically thought of as providing public services to individuals and businesses through core processes

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which are supported by back-office processes. During execution of public sector services and processes, substantial amount of data is created and consumed by public sector organizations. SSC initiatives for government constituent digitize some or all of these public sector processes, services, and data.

Public Services and Core Processes

Public services are provided by city governments (in some cases by country level governments) within their jurisdictions. Public services span economic and social sectors among others; including various licensing, and permit services, as well as mobility (transportation), culture, housing, municipal services, and so on among others depending on the local context of each city.

SSCs capitalize on the enormous opportunity to avail public services and processes digitally. More specifically public services are:

- digitally provided in a convenient, and easy-to-use manner anytime anywhere easing the lives of individuals and businesses
- provided effectively and efficiently by digitizing, streamlining, simplifying and redesigning public sector core processes

However, digital public services will create actual value and have a positive impact on an SSC if and only if they are digitally adopted by the users (needless to say, city users have the alternative to utilize traditional offline, that is, non-digital services). Hence, high levels of digital adoption (uptake) should be targeted by realizing the potential of digital public services by boosting the return on investments for digital transformation by city governments.

Public Sector Shared Services

Digital transformation also poses considerable opportunities for providing shared services in the public sector. Common functions, processes (both core and back-office), infrastructure needs, and services can be digitized and provided centrally to public sector entities. This precludes the need to provision them individually by various public sector entities. For example, common back-office processes such as human resources management, financial management, and supply chain management processes can be provided as a shared solution/service through a centrally utilized

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ICT-based service (e.g. enterprise resources planning service) by public sector entities. Similarly, digital authentication, and digital payments can be provided as a shared service/solution to be used by public sector entities. The list of shared services/solutions can be extended due to rich spectrum of activities and their execution in public sector. SSCs consider providing shared services/solutions in order to create operational efficiencies through savings in public funds. They can create significant fiscal advantages for public sector organizations by leveraging on synergies inherent in them. SSC's target customer-focused (or centric) public sector shared services aiming high-levels of customer satisfaction and usage. This will allow high adoption (uptake) of public sector shared digital services which will significantly boost the likelihood of increased return on shared services investments.

Public Sector Data (Open Data)

Data has become a strategic asset fueling innovation. It contributes to openness and transparency of public sector, while allowing for novel as well as enhanced services and processes design, and improved planning and decision-making. Open data can also be used and analyzed by researchers and non-government organizations contributing to enhance its value. Innovators and entrepreneurs can re-use open data to create new digital services and channels (e.g. mobile apps utilizing open data).

SSCs should provide open data to enable easy and convenient access to city information; and to also encourage innovation and value creation by various constituents of the city, including public and private sectors, as well as academia and NGOs.

Smart Governance Strategies for an SSC

SSCs launch initiatives to digitally transform their public services, shared services, processes, and data. Historically, e-government, smart government (or city), digital government (or city), open data initiatives, among others, included various action items to avail public services, shared services, processes, and data digitally. The new public sector digital transformation initiatives can be scoped and formulated by taking into account the current state of public sector digital transformation as a baseline.

Government Constituent Transformational Key Performance Indicator Examples

The list of KPIs is given below as representative examples of KPIs that can be used to depict government constituent transformations. They are by no

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means comprehensive and exhaustive. The actual list of transformational KPIs can be identified by each city depending on its public sector priorities and preferences.

List of sample KPIs:

- Percentage of public sector services digitally enabled (alternatively percentage of highly used or priority public sector services digitally enabled)
- Percentage digital adoption of public sector services
- Percentage of core processes digitized
- Operational efficiency enhancement in core processes
- Percentage of back-office processes digitized
- Operational efficiency enhancement in back-office processes
- Percentage of digital adoption of supply chain transactions (e.g. public sector procurement, supplier invoicing, and supplier payments)
- Number of digital shared services implemented
- Percentage adoption of digital shared services
- Percentage of eligible public sector data available as open data
- Usage of open data (e.g. number of data sets downloaded, number of apps developed per open data set)

Economy Constituent Transformation

Since cities are the source of a large portion of GDP (McKinsey Global Institute 2016), sustainable and inclusive economic growth will be important for cities. Economic output in general is measured by the total value of goods and services produced in an economy and measured by GDP. GDP by metropolitan area is a monetary measure of the value of all final goods and services produced within a metropolitan statistical area during a specified period (e.g., a quarter, a year). Eurostat has defined Nomenclature of Territorial Units for Statistics (NUTS) and it has been used for metropolitan level GDP calculations by Eurostat (Europa 2017). Similarly, GDP by metropolitan area is calculated annually by the Bureau of Economic Analysis within the United States Department of Commerce for the US metropolitan areas (BEA 2017).

Organization for Economic Cooperation and Development (OECD) has analyzed economic growth with respect to four factors; namely labor, Non-ICT capital, ICT capital, and multi-factor productivity growth (OECD 2015). Multi-factor productivity (MFP) captures efficiency in the

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use of labor and capital and a substantial portion is attributable to innovations such as improvements in management processes, organizational change, Research and Development (R&D), product design, and so on. Long-term economic development studies indicate the importance of MFP in economic growth as countries exhaust the use of their labor and capital. The income level differences in countries are also attributable to differences in MFP. Furthermore, the importance of MFP is predicted to increase over time for future economic growth (OECD 2015). Innovation in general entails creation and diffusion of new products/services, processes and methods, among others. It provides the foundation for new businesses, new jobs and productivity growth; hence it is an enabler of economic growth and development. Innovation is fostered by sound policies and flourishes best in a collaborative environment involving many actors (e.g. public and private sectors, academia, non-governmental organizations (NGOs), entrepreneurs). Hence, SSCs can develop strategies, policies, and initiatives striving to accomplish high levels of innovation. Some high-level policies affecting the drivers of innovation can be stated as follows:

- An economic environment that supports investments in ICT, technology in general, and business innovations in terms of new processes, products, and services as well as business models to encourage healthy economic growth.
- An ecosystem that supports knowledge creation and transfer; and enables R&D and easy exchange of knowledge among different participants including academia, private and public sectors.
- Supply side policies to encourage start-ups and new businesses for boosting innovation in various economic sectors. It would be important to streamline regulations and pertinent public and private sector services to simplify starting a business. Additionally, inclusive, participative and skilled consumers of innovative products and services are also key for innovation uptake and sustainable success.
- A skilled labor force equipped with requisite knowledge for innovation to enable practical applications and to turn their knowledge and ideas to real-life products and services.

The actual and right mix of these policies will differ from city to city.

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Business Regulations

World Bank annually publishes "Doing Business" reports to measure 11 areas of business regulation for a majority of countries globally. These areas of business regulation have direct and indirect impacts on economic dynamism, growth, and innovation. Simplifying regulations help remove barriers for entrepreneurship and innovation. These regulations affect businesses throughout their life cycles from their inception to expansion and even termination. Simpler regulations are easier for businesses since they require less documents and also require shorter timeframes to obtain results. This allows for easier and faster compliance with government (public sector) regulations. As a result of most of these regulations, businesses can increase their revenue potential (e.g. starting a business to enable revenue generation, trading across borders—exporting to generate revenues) and also make new investments for expansion (dealing with construction permits and registering property for facilities expansion, labor market regulations for employment, etc.) or even divest to avoid financial losses (resolving insolvency).

Digital Business Services

Having digital public and private sector services available for start-ups and SMEs will ease doing business in the city (e.g. digital start-up services, digital recruitment, digital taxation, digital permits, digital business and professional services, digital procurement). Availability of digital services will increase the efficiency of conducting business in a city by enabling time and cost savings for companies. Digital services enable conducting business transactions anytime and anywhere circumventing the need for physical visits and submission of manual paperwork and documents. Businesses can obtain results faster and in a more convenient fashion. These expedited and convenient results enable faster innovation for businesses since process cycle times tend to shorten through effectively implemented digital services.

Business Incubators and Accelerators

Incubators and accelerators prepare companies for growth by providing guidance and mentorship in slightly different ways and at different stages in their lives. Incubator programs tend to assist businesses in their start-up phase by potentially offering office space, business skills training, and access

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to financing and professional networks, among others. These programs aim to get the businesses on their feet in their start-up phase and may last variable amount of time depending on business.

Critical to the definition of an incubator is the provision of management guidance, technical assistance, and consulting tailored to young growing companies. Incubators usually also provide clients access to appropriate rental space and flexible leases, shared basic business services and equipment, technology support services and assistance in obtaining the financing necessary for company growth. On the other hand, accelerator programs in general tend to last for a certain period of time and aim to accelerate growth rapidly (hence the name accelerator). They aim to help develop necessary skills for entrepreneurs through mentoring, formal training, informal peer learning, and advice, among others. They target existing businesses and may potentially take a holistic advisory approach to enable rapid growth (Cohen 2013; OECD 2013).

Smart City Initiatives and Innovation

Challenges identified by cities create significant innovation opportunities and in some cases even flourish new economic sectors. Leading edge innovative ICT solutions (e.g. IoT, blockchain, and artificial intelligence (AI)) are required to address some of these challenges. In some cases, innovative industry and sector-specific solutions are implemented (e.g. energy, water, logistics, mobility). These innovations solve city challenges while creating new sources of GDP and employment opportunities, and enhance workforce skills.

Economy Constituent Transformational Key Performance Indicator Examples

Below are some non-exhaustive examples of KPIs that can be used for economy constituent transformations. The actual list of transformational KPIs can be identified by each city depending on its economic priorities and preferences.

List of Sample KPIs:

- City GDP
- City labor productivity
- City multi-factor productivity
- Percentage contribution of small and medium enterprises (SMEs) to city GDP

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- Percentage of SMEs in businesses
- Percentage of start-ups
- Percentage of new sectors' contribution to city GDP
- Digital transformation rate in economic sectors
- City unemployment (possibly city youth unemployment)
- City R&D to GDP ratio
- Number of patents in 100,000 city capita
- Rank in World Bank doing business reports

Society Constituent Transformation

SSC solutions ultimately address and meet the needs of people (individuals) and communities living in a city (as consumers of services) and tend to have a fairly wide scope encompassing various social and daily needs. Furthermore, these solutions are formulated and provided by people working in related public and private sector organizations (as providers of solutions). Creating an optimum city experience for the people and by the people is quite important. Hence, SSCs by definition need to be people-centric while utilizing technology as an enabler. Technology and data are used as tools while putting people in the center of solutions to shape how cities should function.

Hence, SSCs can aim to:

- equip its people with the right skills and capabilities to ensure their well-being and prosperity as city residents;
- deliver inclusive city solutions by ensuring high levels of stakeholder participation and engagement;
- provide easily accessible social services including health, education, transportation, culture, housing, community and volunteering services among others.

Skills Enhancement

Skills of people in cities are key enablers for SSCs. Rapid advances in technology and innovation necessitate continuous skills refinement, enhancement, and upgrading. Building an appropriate pipeline of skills is essential to meet cities' future skills needs to ensure sustainability. The requisite skills may vary depending on purpose (e.g. consumption vs. production of city solutions, services) and segment (age group, interest, profession, etc.) within the city. Hence, SSCs can launch initiatives and projects to ensure sustainable availability of requisite targeted skills and capabilities for

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intended groups of citizens in the cities. These initiatives and projects usually target a certain segment of the citizens and provide pre-defined skills and capabilities programs reflecting various needs within the city. The specificity and specialization of programs may vary considerably depending on the spectrum of skills needed. Following are some sample skills related programs illustrating the concept and are non-exhaustive.

- Digital literacy boosting programs aiming to bridge the digital divide in SSCs. SSC services tend to use digital technologies. It is imperative to ensure citizens can access and consume these digital services confidently and easily. In this context, digital literacy should not become a barrier for consuming SSC services. Digital literacy programs can target citizens who are left behind in some cities such as seniors, low income groups, less educated ones, and disabled individuals.
- Coding skills programs targeting kids, young people, and even adults (e.g. Apple's Everyone Can Code program, Google Computer Science First program, CoderDojo, a global movement of community-based programming clubs for young people).
- Workforce and employment-related skills enhancement programs aiming to bridge the gap between required and available skills, to build capacity and to promote lifelong learning. Participants in these programs may be provided with support schemes such as grants, incentives, funding schemes, and certifications (e.g. Singapore Workforce Skills Qualifications; a national credential system that trains, develops, assesses, and certifies skills and competencies for the workforce. As a continuing education and training system, it supports the SkillsFuture movement; National skills development program in India supported by Skill India Portal which was conceptualized to provide a collaboration platform that helps empower all stakeholders including citizens, training partners, trainers, and training infrastructure providers to freely connect with each other).
- Placement or financial assistance programs help potential students and employees to gain real work experience, exchange knowledge, and obtain financial assistance (e.g. scholarship programs, internship programs, exchange programs, matching live projects with available skills).

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Digital skills enhancement services can be used by people to enhance their skills (e.g. digital libraries, virtual classrooms, massive online open courses (MOOCs), and e-learning courses).

Participation and Engagement

People-centered SSCs naturally entail extensive engagement and participation of their citizens. Digital technologies provide abundant opportunities for citizen engagement through participatory inclusive decision-making, and SSC solutions design and implementation (barring digital literacy as a barrier). The sustainable development goals (SDGs) call for participatory decision-making. United Nations (UN) publishes biannually e-Government Surveys and ranks countries for their e-participation performance with respect to e-information, e-consultation, and e-decision-making.

SSCs can launch initiatives and programs to ensure inclusive and participatory engagement of citizens in the cities. The nature of programs may vary considerably depending on the particulars of the city. The participants may consist of citizens (individuals living in the city), businesses, NGOs, and other organizations. Following are some sample programs illustrating the concept.

- Programs launched by cities to tap into its citizens' collective knowledge of city-related issues. Citizens can report issues such as broken streetlights, potholes, and abandoned cars.
- Programs created to propose, comment, debate, and vote on ideas to improve various aspects of the city. Some cities have implemented digital suggestions and complaint mechanisms to improve various aspects of the city.
- Programs created to engage citizens and businesses during the design of digital public sector services. Various online and off-line mechanisms can be used to improve public services design through a dialogue between producers and consumers of digital public services.
- Programs created to crowdsource city-related ideas and to vote on them to influence the city budgeting process in a participatory manner.
- Programs designed to create a common community/city vision for the future by engaging community/city members through digital deliberations and discussions.

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- Programs created to engage citizens for solving problems defined by city authorities, using digitally available tools to debate SSC ideas and solutions, and decide which of them get implemented (rather than simply asking for suggestions).
- Programs created to utilize available city open data by citizens to provide innovative ideas to address city challenges and to propose SSC solutions.
- Programs created to engage citizens to collect various city-related sensor information from different locations across the city (crowd-sourcing city sensor data).

It is important for cities to gain the trust of their citizens as they engage them. Hence, SSCs need to put in place clear and transparent policies to ensure that they get the most benefit from the citizen involvement. The basis of the data provided, and the uses to which they may be put, should be clear to citizens and will increase their willingness and commitment to support innovative initiatives.

Social Services

Social sectors and services have been transformed in the past by harnessing digital innovation and the same trend still continues. Healthcare, education, housing, culture, entertainment, transportation, community and volunteering, sports are all potential social sectors for enhancement by utilizing ICT. ICT can render social services more accessible, convenient, and efficient for their consumers. Hence, cities can prioritize their social sectors implementations and enable better city experiences for their citizens by capitalizing on the potential of ICT.

Society Constituent Transformational Key Performance Indicator Examples

Below are some non-exhaustive examples of KPIs that can be used for society constituent transformations. The actual list of transformational KPIs can be identified by each city depending on its social priorities and preferences.

List of sample KPIs:

- Percentage of city population participating in city governance
- Adult literacy rate (digital literacy rate)

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- Number of higher education degrees per 100,000 population
- Percentage of digitally enabled education institutions and/or education processes
- Percentage of city population participating in lifelong learning (or e-learning)
- Average life expectancy
- Percentage of digitally enabled healthcare institutions and/or healthcare processes
- Percentage of population with electronic health (medical) records
- Percentage of social services digitally enabled (depending on city particulars, various social services can be included in this KPI)
- Percentage of public transportation trips (or shared trips)
- Percentage of autonomous (driverless) trips

Resources and Infrastructure Constituent Transformation

SSC initiatives transform city resources such as water, energy, air, and land as well as city infrastructures such as water and energy supply network, drainage and sewage network, roads, buildings, bridges, and street lighting. ICT enablement of city infrastructures through sensors and actuators (also referred to as IoT) enable reliability/availability as well as efficiency enhancements. For example, outages in water and electricity can be immediately sensed and faster service recovery can be achieved. Similarly, leaks in water and electricity networks and their locations can be detected in a much more reliable manner to minimize such unintended losses. City residents can monitor their resource consumptions, such as water and electricity, on the spot and can be provided with the right information to make choices for reducing their consumptions. Sensors can detect air quality in different locations across the city. Clean resources such as air, water, and energy are essential for city residents to lead healthy and productive lives. A low-pollution and low-emission environment coupled with clean resources ensures a sustainable development path for cities in the longer term. Air quality can be kept in allowable safety limits through continuous monitoring in terms of GHG (green house gas) emissions, ambient noise, and also electromagnetic radiation. GHG emissions can be reduced through targeted programs (e.g. building regulations formulation, retrofitting existing buildings, switching to renewable/clean energy alternatives, power and water tariffs adjustments; water reuse and efficient irrigation techniques, smart lighting systems, green transport alternatives).

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Environmental concerns compounded by severe water shortages, reliance on hydrocarbon based energy sources, and global climate change (among others) pose significant stress on cities across the MENA region.

Resources and Infrastructure Constituent Transformational Key Performance Indicator Examples

Below are some non-exhaustive examples of KPIs that can be used for resources and infrastructure constituent transformations.

List of Sample KPIs:

- Percentage of city infrastructures ICT (IoT) enabled (can be calculated separately for different city infrastructures)
- Drinking water quality
- Percentage of renewable/clean energy consumption
- Air quality index
- Water/energy consumption per capita
- GHG emissions per capita (or per GDP)
- Percentage loss in water/energy supply network
- Customer minutes lost (for water and electricity)

Strategic Action Items and Constituent KPIs

Specific KPIs selected by a city determine the transformation which will be applied to various constituents in the city. Various city KPIs and sustainable development goals defined by international organizations such as ISO (2017), ITU (2017), and UNDP (2015) may provide assistance to cities in selecting their own specific KPIs; however, each city's own strategic priorities would determine the final selected set of KPIs. Furthermore, the strategic gap is identified by the difference between the baseline and the target values for KPIs selected by a city. The strategic gap is closed through a set of well-defined targeted SSC strategic action items.

SSC Impact Management

The triple bottom line (TBL) concept introduced in the section "Impact Management" can be applied to SSCs for impact management. Impact can be assessed along the social, economic, and environmental dimensions. Impact assessment can be used to understand the changes foreseen by SSC initiatives. It can also be used to identify and circumvent the

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negative and unintended impacts while capitalizing on and enhancing the positive and sustainable impacts further.

Social Impact Assessment

Social impact assessment (SIA) identifies and analyzes the issues which impact people and their lives in cities related to SSC initiatives. Social impact captures issues related to how people live, their culture and traditions, their communities, their well-being and concerns and aspirations among others (Vanclay 2003; IAIA 2015). It is important to indicate that social impacts can be experienced both in perceptual or in real sense, or both (unlike environmental impacts which are experienced in real sense). As SSC strategic action items transform city constituents along selected KPIs, social impacts can be assessed through an inclusive process by involving and engaging stakeholders. SSC initiatives purposely and also inadvertently introduce changes in people's lives by utilizing ICT and digital transformation.

For example, digital public services may introduce skills barriers for their users (e.g. digital literacy); they may also encounter cultural barriers whereby people may prefer physical face-to-face interactions. Similarly, new disruptive and emerging technologies in city economy may press existing businesses to reduce employment opportunities. Leading edge ICT skills may be scarce in the city and may pose skills divide in the labor force for employment. Digital city services, whether in the public or private sector, may cause security and privacy concerns and may adversely impact trust and confidence in them if not addressed properly. Economic development projects, especially at large scale in certain sectors, may cause anxiety and concerns in people due to adverse environmental impacts; they may also cause concerns in terms of rising living expenditures and reduced well-being. On the other hand, economic prosperity and new job opportunities may have positive impacts on people and communities in the city. Rising living standards and disposable income may render city residents more confident about themselves and about their futures. People can empower themselves and enhance their well-being through various means in their city lives. These are some non-exhaustive examples to illustrate the concept. The actual SIA for a given city would be an exhaustive list regarding the specific SSC strategic action items for that city. SIA may utilize qualitative and quantitative methods. OECD framework for measuring well-being and progress (OECD 2017) and The World Happiness

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Report (Helliwell et al. 2017) include examples of quantifying people aspects which can be used by cities in their SIA processes.

Economic Impact Assessment

Economic impact assessment identifies and analyzes the economic effects and contributions of SSC initiatives in cities. Economic impact can be viewed in terms of business (economic) output, value added or city GDP, wealth, personal income, jobs and labor force among others (Weisbrod and Weisbrod 1997). Cities can qualitatively and quantitatively analyze economic impacts incurred by SSC strategic action items. As SSC strategic action items transform city constituents along selected KPIs, economic impacts can be assessed concomitantly.

For example, digital adoption of public services and data saves time of businesses as well as public sector entities; which in turn can be translated into financial savings (cost savings). Total time savings for businesses regarding public service transactions can be estimated by Eq. 3.1 below:

$$\begin{aligned}&\text{Total businesses time savings}\\&= \text{Business time saved per public service transaction}\\&\quad \times \text{ Number of transactions conducted}\end{aligned} \tag{3.1}$$

Similarly, total time savings for public sector entities can be estimated by Eq.3.2 below:

$$\begin{aligned}&\text{Total public sector time saved}\\&= \text{Public servant time saved per public service transaction}\\&\quad \times \text{Number of transactions conducted}\end{aligned} \tag{3.2}$$

City public sector entities cumulatively conduct on the order of at least hundreds of thousands or millions of number of transactions annually. Hence, the time savings amount to significant values when summed up over a long period of time (e.g. annually). The cost savings for businesses can be estimated by Eq. 3.3 below:

$$\begin{aligned}&\text{Estimated total businesses cost savings}\\&= \text{Total businesses time savings}\\&\quad \times \text{Average compensation per business employee per unit of time}\end{aligned} \tag{3.3}$$

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Note that in Eq. 3.3, the business employee is assumed to be the one conducting public sector transactions on behalf of the business. Similarly, the cost savings for public sector can be estimated by Eq. 3.4 below:

$$\begin{aligned}&\text{Estimated total public sector cost savings}\\&= \text{Total public sector time saved}\\&\quad \times \text{Average compensation per public sector employee per unit of time}\end{aligned} \tag{3.4}$$

In Eq. 3.4, the public sector employee is assumed to be the one dealing directly with businesses on behalf of the public sector. Additionally, public sector shared services also create financial efficiencies by circumventing the need for individual public sector entities to implement those services on their own. Substantial cost savings can be achieved through economies of scale and economies of scope through implementation of shared services. Hence, cost savings can be projected by estimating how much it would cost public sector entities to implement those services on their own versus implementing a shared service and using it (avoids replication of investments by public sector entities while simultaneously expediting implementation). Cost savings (i.e. operational efficiencies) clearly enhance the fiscal sustainability of cities. Digital transformation of public services creates surplus demand for various ICT sectors. Hence it can contribute in boosting their competitiveness by supplying services and solutions to meet public sector demands.

The impact will be felt positively by both public and private sectors if and when ICT-based solutions are implemented correctly. It will increase the productivity of public sector through achieved cost savings; it will also increase supply of ICT products and services by the private sector. Consequently, it is expected to boost the GDP contribution of ICT sector and help create new subsectors. It will benefit innovation as well and boost entrepreneurial activity in the economy. Economic policies and regulations supporting innovation and entrepreneurship will be conducive to economic growth, resulting in added economic value. Their successful implementation will enable new products and processes; new companies and business models; new industries and sectors; which in turn will enhance the economic competitiveness of smart cities. They will enable cities to become more productive, economically resilient, and agile. Successful innovation will also create new job opportunities and help reduce unemployment rate in an economy. Furthermore, innovations in a

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city will also uplift labor force skills for future sustainability. Economic impacts of innovation can also be quantified based on specifics of SSC strategic action items selected by a city.

Additionally, transformations in city resources and infrastructures may also yield significant economic impacts. For example, losses due to unaccounted water may be reduced through IoT deployments. These reductions will be direct savings in terms of actual water supplied to the city. The total water savings can be quantified in monetary terms by multiplying with appropriate tariff rates (the same argument also applies for energy savings due to reductions in energy losses in the supply network). Similarly, total reductions in water and energy consumptions (demand side reductions) can be quantified in monetary terms by multiplying with appropriate tariff rates and converted into savings.

Savings mentioned under economic impact correspond to financial efficiencies created in a city. These efficiencies create economic benefits which may be diverted or reallocated for other uses in both public and private sectors.

Environmental Impact Assessment

Environmental impact assessment (EIA) identifies and analyzes the issues which impact urban environment in cities related to SSC initiatives in order to promote sustainable development. Environmental impact captures anticipated effects and consequences on water, energy, air, land, and in general on urban natural environment and resources in a city. As SSC strategic action items transform city constituents along selected KPIs, environmental impacts can be assessed through a well-structured process (IAIA 1999, 2007) by addressing potential impacts on city flora and fauna, soil, water, air, climate, landscape, and city architectural, archeological and cultural heritage (EPA 2002). For example, digital adoption of public services has multifold indisputable positive impacts on certain city resources and infrastructure. Digital adoption of public sector interactions (e.g. public services and data-related interactions) will avoid physical travel by vehicles to public sector entities; which in turn will also circumvent related GHG emissions. GHG emissions savings can be estimated by Eq. 3.5 below:

$$\begin{aligned}&\text{Estimated GHG emissions savings}\\&\quad=\text{Total public sector trips avoided through digital interactions}\\&\qquad\times\text{Average GHG emissions per public sector trip}\end{aligned}\tag{3.5}$$

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Similarly, the number of trips avoided can be estimated by Eq. 3.6 below:

$$\begin{aligned}&\text{Estimated city trips avoided}\\&= \text{Total public sector digital transactions}\left(\text{interactions}\right)\end{aligned} \tag{3.6}$$

Circumvented GHG emissions contribute to cleaner air whereas avoided city trips also reduce the stress on city transportation infrastructure and also potentially enhance quality of life perception by city inhabitants. Additionally, ICT deployment across SSCs (e.g. IoT devices in the form of sensors and actuators) will enable monitoring and controlling through timely identification and intervention (e.g. air pollution, noise, water cleanliness) to protect the environment. Similarly, ICT deployments in city resources and in their related infrastructures (e.g. smart grids) aid in monitoring resources distribution and consumption; and taking actions to enhance their efficiencies (e.g. reduction of unaccounted water losses, electricity line losses, excessive user consumption). Such efficiency enhancements are critical for scarce resources such as water and energy.

Clean and renewable energy projects reduce GHG emissions in the city resulting in cleaner air and will slow down climate change. On the other hand, certain economic development projects may cause adverse impacts on the environment by increasing GHG emissions. Tourism and culture-related SSC strategic action items may positively impact architectural, archaeological, and cultural assets of a city. Public parks and landscaping projects enhance overall urban experience of city inhabitants and will lead to an improved quality of life perception. These non-exhaustive examples illustrate the concept. The actual EIA for a given city would depend on the specific SSC strategic action items selected by that city.

Application of Impact-Driven SSC Framework to Smart Dubai

Dubai's technological journey began in 1999 with the announcement of its first ICT strategy which was followed by the launch of Dubai Internet City, Dubai e-government, Dubai Smart Government, and, more recently in 2014, the Smart Dubai initiative. During the past two decades, the numerous digital transformation initiatives in Dubai drove public acceptance and adoption of ICTs in all aspects of life. Today, Dubai, a city of 2.5

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million inhabitants and one of seven Emirates of the UAE, has one of the highest levels of ICT adoption in the region. Outlined in His Highness Sheikh Mohammad Bin Rashid Al Maktoum, vice-president and prime minister of the UAE and the ruler of Dubai's vision, technology, as the platform for solutions, is simply to play the role of an enabler, rather than the principal goal. The Smart Dubai initiative fulfills the vision of His Highness "to make Dubai the happiest city on earth". Numerous implementations ranging from massive IoT systems, data analytics, blockchain, hyperloop projects, innovative 3D printing initiatives, to experiments on autonomous vehicles and drones, robotics, and artificial intelligence applications were developed and trialed as part of Smart Dubai initiative.

Dubai has in 2017 launched its 5-year strategy called Smart Dubai 2021 (SDO 2017). The new strategy explicitly shifts the strategic focus from mere enablement to significant positive impact on the city through digital transformation. Smart Dubai 2021 has adopted the impact-driven SSC framework as described in this chapter.

Different constituents in Dubai, such as government, businesses, and individuals, interact daily through exchanging products, services, and even ideas and experiences. Hence each and every one of them is a producer and also a consumer. Smart Dubai 2021 aims to ensure happy city experiences in these exchanges. Hence, the first impact area is the customer impact achieving happiness for Dubai residents and visitors in their daily urban lives (customer impact corresponds to social impact in the framework presented in this chapter). This is clearly stated in Smart Dubai vision to become the happiest city on Earth. Happiness as defined by Smart Dubai is an umbrella concept which captures various aspects of quality of life and well-being among others. Please refer to Chap. 11 for more on this topic.

Smart Dubai has identified two more impact areas. Smart Dubai 2021 strategy has been formulated to achieve financial savings while delivering simultaneously happiness to city inhabitants. Hence, Smart Dubai has opted to achieve happiness while simultaneously achieving tens of billions of UAE dirhams in financial benefits (which corresponds to the economic impact introduced in this chapter). The third impact area is the overall city environment including Dubai resources and infrastructure. Smart Dubai has charted a course whereby it intends to create positive impact on its city environment by ensuring clean and sustainable resources and enhanced infrastructures. Sixteen percent GHG emissions reductions are targeted by

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2021. City air and drinking water are targeted to have worldwide leading quality compliance levels. Seven percent of its energy consumption is targeted to come from renewable sources by 2021. Smart Dubai 2021 explicitly aims at creating positive impact with respect to all three impact areas mentioned in this chapter.

In order to achieve this impact, Smart Dubai 2021 has identified 42 strategic and 58 additional KPIs amounting to 100 in total. These KPIs are transformational KPIs regarding Dubai constituents including government, economy, society, city resources, and infrastructure. The intended positive impact relies on achieving the 2021 target values for various KPIs. Smart Dubai has compiled a rich set of strategic action items from both public and private sector entities to close the strategic gap, which derives from the difference between baseline and 2021 target values of KPIs.

Conclusion

SSC initiatives are complex large-scale initiatives which involve a large number of stakeholders. Given the large scope and spectrum of city activities they entail, a holistic all-encompassing framework is highly beneficial. In this chapter, an impact-driven framework has been proposed for the same purpose. The proposed framework is intentionally formulated as a generic one to ensure applicability to different city contexts. Identification of impact is highly important for city officials to understand the positive and the adverse consequences of their SSC initiatives including costs and benefits. It can also be used as a communication tool for city stakeholders.

The proposed framework accommodates city innovation through target setting of KPIs with respect to various city constituents. Bottom-up strategic action items aim to close the top-down strategic gap stemming from the difference between baseline and target values of KPIs. Hence, city constituents' transformation can be captured by the proposed framework. Three areas of impact, namely social, economic, and environmental, aim to have a broad-spectrum and complete perspective of the effects and consequences of SSC initiatives at the city level. The proposed framework has been applied successfully by Smart Dubai initiative for planning its 5-year strategy. Further research is required to identify, and especially to quantify and model all three proposed impact areas in the context of SSC initiatives.

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CHAPTER 4

Development of a National Smart City Initiatives Framework for the Kingdom of Bahrain: A Blueprint for Successful Smart Cities

Hesham M. Al-Ammal and Maan M. Aljawder

Introduction and Background

Various smart city projects are springing nationally in different sectors in the Kingdom of Bahrain. Owing to the multidisciplinary and multidimensional nature of smart city initiatives (SCIs) undertaken by all sectors, it is vital that a conceptual model exists that ensures that these initiatives are integrated, complement each other, and are aligned strategically. This can be achieved through the adoption by the major stakeholders of a common vision, framework, or maturity model.

The aim of this study is to develop a National Smart City Framework (NSCF) for the Kingdom of Bahrain by examining international standards, working with the main stakeholders to identify its components, and aligning it to the national strategic plan and priorities. The proposed study is a joint project between the University of Bahrain (UOB) and the Information and eGovernment Authority (IGA) in the Kingdom of

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_4

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Bahrain. However, the framework is designed through consultation with the major stakeholders from the private and public sectors as well as the relevant non-governmental organizations (NGOs).

The methodology relies on evaluating existing SCI frameworks and models, selecting a model which is relevant to the Kingdom of Bahrain, and communicating with major stakeholders in the public sector, private sector, and relevant NGOs to customize it and align it with national strategy, stakeholder needs, and local priorities. In the second stage, the study evaluates the status of some of the existing SCIs within the Kingdom of Bahrain, both in the government and private sectors using the developed NSCF. This step ensures the validity and effectiveness of the model, as well as its utility as a tool for measuring the maturity of the various initiatives proposed by different entities and sectors. The resulting NSCF will then be raised to the major stakeholders for adoption and use in evaluating future projects.

Faced by the ever-growing population within urban areas (United Nations 2007) and the advances in information and communications technology (ICT) and engineering technology, the concept of *smart cities* emerged among city planners, governments, and engineers. However, the term "smart city" itself remains elusive due to the wide range of technologies, disciplines, and stakeholders that share this label. The concept is related to many other concepts such as economics, sustainability, urban planning, data science, environmental engineering, as well as citizen participation and good governance, which makes it quite hard to define (Albino et al. 2015).

Although many researchers investigated the evolution of the concept "smart city" from 1993's Digital City to Intelligent City, and then eventually to "smart city" (He et al. 2014), its vagueness and inconsistency continued to grow along with its popularity. Yet, the dominant strategic goal of these cities remained the same, which is to achieve sustainability, efficiency, and high quality of life (Monzon 2015; ISO 2014; Albino et al. 2015). Thus, to keep the focus on this goal, the research community produced several models that put together some aspects of the cities in the form of dimensions and components (Meijer et al. 2015) to create a unified understanding among a city's stakeholders. The survey conducted by the Centre of Regional Science at the Vienna University of Technology identifies six dimensions of smart cities (Giffinger and Gudrun 2010) which include:

- smart economy,
- smart environment,
- smart mobility,

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- smart governance,
- smart people, and
- smart living.

These dimensions, which were earlier proposed by Boyd Cohen (see Fig. 4.1), entail sustainable economic growth, wise management of resources, a high quality of life, participatory governance, and diverse urban transportation. These dimensions are accompanied by key enablers that lead to the achievement of the state of being smart. For example, the integration of ICT with development projects will change the urban landscape

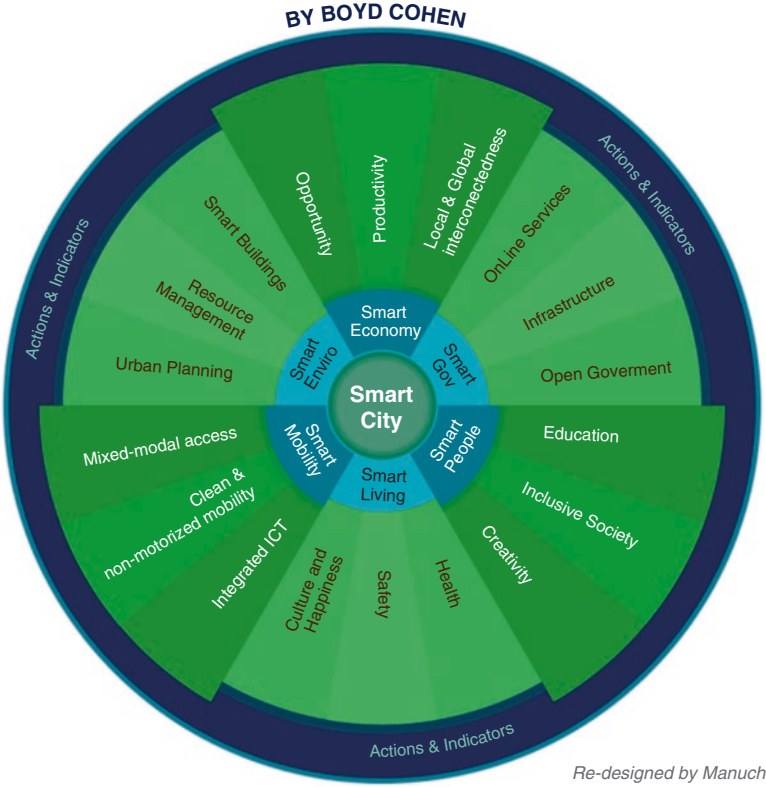


Fig. 4.1 The smart city wheel model proposed by Boyd Cohen. (Reprinted with permission.)

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of a city, improve the management and functionality, and enhance the quality of life (Giffinger and Gudrun 2010).

The aim of this study is to present a means of developing an NSCF for the Kingdom of Bahrain by examining international standards, working with the main stakeholders to identify its components, and aligning it to the national strategic plan and priorities. The proposed study is a joint project between the UOB and the IGA in the Kingdom of Bahrain. However, the framework is designed through consultation with the major stakeholders from the private and public sectors as well as the relevant NGOs.

SCIs and Trends

There are various cities in different countries around the world that have successfully achieved the state of being smart and hence named as smart cities. In the Gulf Region specifically, several projects and activities like "Lusail" in Qatar, Masdar in Abu Dhabi, and Dubai Smart City constitute most recent examples of smart cities in the region (Tok et al. 2014).

Various smart city projects are springing nationally by different sectors in the Kingdom of Bahrain. Due to the multidisciplinary and multidimensional nature of SCIs undertaken by all sectors, it is vital that a conceptual model exists that ensures that these initiatives are integrated, complement each other, and are indeed aligned strategically. This can be achieved through stakeholder adoption of a common vision, framework, or maturity model.

Among all of the numerous models that were suggested for smart cities (Bakıcı et al. 2013, Chourabi et al. 2011, Joshi et al. 2016, Mahizhnan 1999, Neirotti et al. 2014, De Santis et al. 2012, Shichiyakh et al. 2016) and after the development from Intelligent Cities to the current state, it is clear that there is a trend toward approaching smart cities from a holistic point of view and a clear shift from concentrating on technology to enabling citizens and communities in establishing the smart city model. This came after a lot of criticism toward models that emphasized technology-driven solutions that were the result of commercialization of the smart city concept (Hollands 2008).

For companies such as IBM, Cisco Systems, Siemens, and Huawei, the technological component and the branding is most important in their vision of smart cities (Albino et al. 2015). This approach has been highly criticized by several authors.

Another trend among smart cities was the inclusion of "people" as a key component in any SCI. This is increasingly seen as a major component

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that enables the success of any such project (Albino et al. 2015). The social infrastructure including the intellectual, social, and cultural capital of a city is a major component of any smart city framework. This has to be integrated with the technological part in order to have a sustainable and effective SCI. From this viewpoint, education is seen as a major factor in the success of smart cities. Education contributes to change management and also can be used as an indicator of the success of such projects (Winters 2011). This includes skilled workforce, educated citizens, and the contribution of higher education in research and development of the city.

The Role of Higher Education in Setting the Agenda

In smart societies, institutions such as government, businesses, and NGOs work collaboratively to make conscious decisions about the effective use of technology to transform life and work in their ecosystem. Conceivably, universities are a common constituent among these institutions and are essential role players in those societies. Historically, universities served as a driving apparatus of knowledge generation and change diffusion in societies (Castells 2002). Its elite academics upheld continuous ideological expressions and arguments beside their traditional role of producing highly skilled workforce and practicing research and innovation. Together, these roles result in manifold solutions and projects that serve a society's economy, urban planning, safety and security, and effective information technology, to name a few.

Thus, it is obvious that institutes of higher education and universities are important contributors to building smart societies. These contributions can be made at different levels of each element of a society; we here highlight two levels that are related to the aforementioned roles.

The first level is "knowledge creation". The field of smart cities is composed of a complex ecosystem that is relatively new; and its various areas of research depend on factors such as stakeholders, components, infrastructures, processes, and contexts. An independent critique of these areas and the delineation of their impacts and benefits are essential for city leaders and stakeholders. Higher education institutions, with their vast intellectual capacity and possessed knowledge stock, are considered a fertile soil to ignite such an independent discussion in the various areas of smart cities. The organized effort of scientists and intellectuals results in

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the generation of new ideas, revisiting current ideas and concepts of smart cities, coming up with innovative solutions for problems, and predicting future changes. In addition, when partnered with other constituents of societies, they can effectively participate in the planning and development of regulatory, governance, economic, systemic, policy, and organizational smart initiatives. This collective effort creates a common and comprehensive global understanding of smart cities and their appropriate applications. Unfortunately, many cities are struggling with their existing smart projects because of the lack of such a comprehensive thinking (Falconer and Mitchell 2012). Universities are, presumably, the most capable institutions, with the public and private sectors partnership, to develop comprehensive frameworks and set standards that will guide cities to effectively manage its scattered intuitive smart projects in a clear structured manner.

The second level is "technology and capacity building". Research cohorts and centers at universities work to generate breakthroughs and smart generations of integrated hardware, software, and network technologies that are capable of transforming life and work of societies (Nam and Pardo 2011). Technologies such as smart interfaces, smart control systems, smart database resources (Al-Hader et al. 2009), and smart mobility are essential for enabling advanced analytics and real-time awareness about a society. On the other hand, universities invest in redeveloping their academic curricula to ensure that their graduates are capable of innovating in their work whether pertaining to the technology inventions or their innovative use and applications.

As an example of such initiatives, the college of Information Technologies at the UOB started a Smart Cities Research Group which kick-started two main research projects: transforming the campus of the UOB to a Smart Campus and the development of an NSCF for the Kingdom of Bahrain. For the latter, the UOB in partnership with the IGA of Bahrain started this project to build a common vision for all SCIs around the country. Both organizations are trusted by the private and public sectors and play a major role in coordinating ICT and research agendas in the country. The UOB has also recently organized a Smart Cities Research Hackathon which rejuvenated interests and gathered stakeholders from all sectors (http://uobhackathon2017.wordpress.com/).

The experience with the organization of the Smart City Hackathon proved to be a great success for a higher education institute (such as the

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UOB) in acting as a mediator between the major stakeholders including the public sector, private sector, and civil society. The event, which was supported by donations from the private sector, included eight organizations from the stakeholders who played the following roles:

- Stakeholders identified challenges
- University experts and students proposed solutions
- Private sector and public sector organizations adopted initiatives

The results were 18 project proposals, and the best three winning proposals received financial awards. However, the most interesting result of the hackathon was the success in putting all these smart city stakeholders together, and allowing access and coordination for researchers to the data.

The contribution of higher education in SCIs has the following success factors:

- Independent input from cutting-edge technology experts
- Links and partnerships with public and private sectors
- Formation of interdisciplinary teams

The latter was reflected in the Hackathon through teams that were formed from four different colleges: Science, Engineering, Information Technology, and Health Science. The feedback received from the public and private sector organizations that participated in the Hackathon was highly positive and encouraging.

Why a Smart City Framework?

Cities and communities around the world face intractable challenges such as:

1. *Increased population:* More than 50% of the world's population lives in cities, placing massive pressure on city infrastructures. This includes pressure on transportation, housing, water, power, and city services. Many of these services require enormous redesign and capital expenditure.
2. *Polarized economic growth:* The 600 largest global cities will contribute 65% of global GDP growth from 2010 to 2025.

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3. *Increased greenhouse-gas emissions (GHGs):* GHGs are forcing cities to develop sustainability strategies for energy generation and distribution, transportation, water management, urban planning, and eco-friendly (green) buildings. In addition, the economic climate continues to place huge budgetary constraints on cities, which are becoming limited in their ability to respond to these pressures.

These issues, among others, can be mitigated through the adoption of scalable solutions that take advantage of ICT to increase efficiency, reduce costs, and enhance the overall quality of life (Falconer and Mitchel 2012).

Ensuring sustainable development and quality of life in complex social ecosystems such as cities and urban areas are important concerns. Cities are increasingly aware of these concerns and are actively developing strategies and initiatives toward the goal of becoming "smart" in managing city resources more efficiently while addressing development and inclusion challenges (Joshi et al. 2016).

At its core, a smart city framework is a simple decision methodology that enables both the public and private sectors to plan and implement SCIs more effectively. Most cities actually undergo this process in an intuitive way rather than in a clearly structured manner. A structured method not only will enable efficiency in city infrastructures, but also transparency into how cities work (Falconer and Mitchel 2012).

Setting a smart city vision and effectively moving toward it with a system-based approach is imperative to ensure optimum resource efficiency and security, along with preserving socially inclusive growth. A framework explains in a more coherent fashion the relationships between many factors including social, management, economy, legal, technology, and sustainability. Each of these factors enables both the public and private sectors to plan and implement SCIs more smoothly and with minimum conflict. These elements provide a basis for matching how different cities are envisaging their smart initiatives, employing shared services, and tackling related challenges.

The framework also analyzes the actual impact of different factors on the success of SCIs. The framework constructs an abstract relationship among the major factors in a sustainable smart city. It also identifies the more influential factors depending on the context and the national

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priorities. The framework can be bifurcated in many levels reflecting on the different impact of these factors on the SCIs (Joshi et al. 2016).

The Kingdom of Bahrain has several well-established systems, and there are a number of SCIs. However, most of these initiatives stem from a certain organization's (from the private or public sector) ideas and priorities. The creation in 2014 of a government committee for studying the smart city concept and its implementation was a first step in ensuring that these initiatives are integrated and follow the same strategy and goals. However, a national conceptual framework that is based on the national economic strategy and government plan is essential. Once a comprehensive framework has been agreed upon and existing projects are inventoried, existing systems should be redeveloped and integrated. The government should apply the NSCF on all the new initiatives.

Framework Methodology

As this is intended to be a national framework that guides the SCIs across the private and public sectors, the design of the framework includes eight main stages. These are listed in the following summary of the project methodology, which ensures benchmarking with international standards and stakeholder consultation.

Stage 1: Research the Literature and Current Initiatives in Smart Cities

At this stage, the team members will identify the major frameworks and models existing in the literature. Frameworks and models vary in their components and covered areas depending on the proposing author/body; some are developed from a very specific technical perspective, such as the infrastructure, while others are developed from a broad generic perspective, which aims to encompass as many as possible of a city's areas. Existing (successful and unsuccessful) initiatives from around the world will be studied and lessons learned will be extracted to be accounted for in the development of the proposed national framework. The team members will critically evaluate these researched frameworks and initiatives and will eliminate unsuitable ones. A shortlist of frameworks and models' components/areas will be produced as a deliverable of this stage and will be used in the next stage.

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Stage 2: Development of a Prototype Framework and Alignment with the National Strategic Plans

This stage will synthesize the results of the previous stage and develop a prototype framework and align it with the National Strategic Priorities (NSPs). The alignment exercise will entail studying and mapping the components of the proposed framework with the plans' priorities and their sub-priorities. A mapping matrix will be the deliverable of this stage.

Stage 3: Involvement of Stakeholders

Major stakeholders who are linked to the national priorities and SCIs in the NGOs, public and private sectors will be identified and contacted. Meetings and site visits will be held to obtain information about and catalog existing national SCIs/projects. Other stakeholders will be surveyed to collect useful data from them through several methods (i.e. semi-structured interviews, questionnaires, etc.). Major stakeholders include:

- Public sector organizations, including:
  - IGA
  - Ministry of Works and Municipalities
  - Ministry of Housing
  - Electricity and Water Authority
  - Ministry of Health
  - Ministry of Telecommunications and Transport
- Private sector organizations such as:
  - Bahrain Petroleum Company (Bapco)
  - Bahrain Aluminum (ALBA)
  - Bahrain Telecommunications Company (Batelco)
  - Zain Telecommunications
  - Microsoft Corporation
  - Huawei Corporation
- Civil society organizations such as:
  - IEEE Bahrain Chapter
  - Bahrain Engineers Society

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IGA's feedback will be required for the selection of the stakeholders. This stage will commence in parallel with stage 2.

Stage 4: Development of the NSCF

The NSCF will be an overarching umbrella for all the smart initiatives/projects (existing and future) in all areas of the Kingdom. The team will use the decided components of the framework as ultimate goals. Detailed and defined enablers for each goal will be constructed. This will include the introduction of further measurement indicators, which are tracked down to the very specific project under each goal. Additionally, a roadmap can be developed, at a later stage, to guide its use and implementation.

Figure 4.2 shows a possible proposed framework. This is a tentative design, which will of course have to be reviewed by the stakeholders and validated. Note that the first layer is a general classification of the various initiatives proposed by public and private sector entities within the smart city framework. However, levels 2 (enablers) and 3 (indicators) will be directly mapped to an existing national plan (i.e. the *National Strategic Priorities* document) that was approved by the Bahraini government. This alignment is important as it ensures consistency, coordination, and integration among all of the SCIs proposed by the different stakeholders.

One of the major contributions of this framework is the alignment that will be done through this stage with the *NSPs* document. The researchers with the IGA have already started going through the NSPs document and finding enablers and key performance indicators (KPIs) to be included within the framework.

As an example of this alignment, Tables 4.1 and 4.2 show how enablers within the SCIs framework can be aligned with the national strategy. Please note that this is shown for illustration purposes only and is not a full example.

As an example, consider the case of an initiative entitled "Upgrade of the capacity and quality of the public bus system". The example shows how the introduction of an e-ticket system, Wi-Fi enabled buses, and GPS trackers can benefit one of the SCI goals, namely "smart mobility". Although this is just an example, other enablers within the framework will similarly be aligned with the NSPs. This again will ensure coherence and integration of the initiatives. It will also give us a way for measuring progress through the KPIs.

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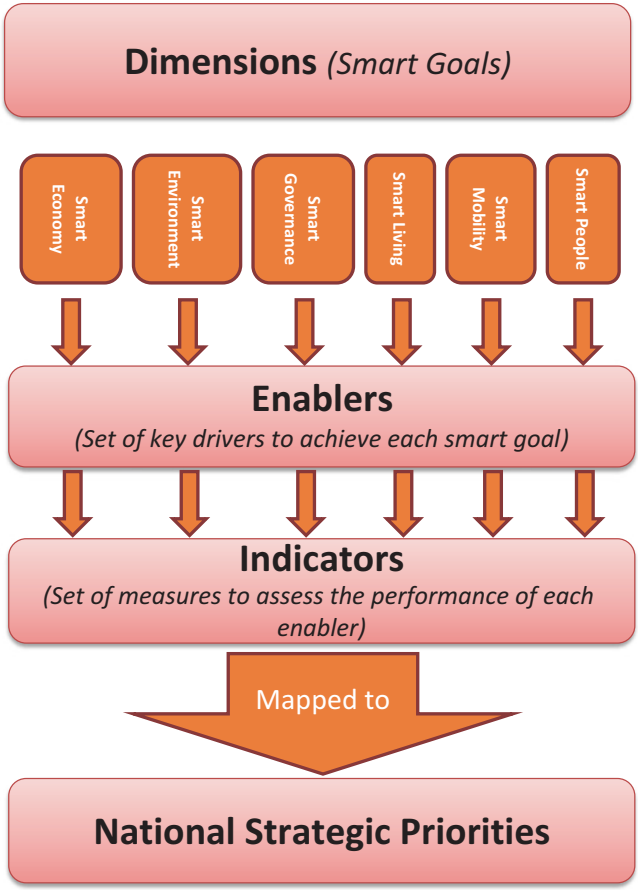


Fig. 4.2 A draft SCI framework

Table 4.1 National strategic priorities

NSP1. Maintain a safe and pleasant environment
NSP2. Enhance the quality and accessibility of social services
NSP3. Achieve sustainable quality growth
NSP4. Ensure fiscal sustainability to fund the future
NSP5. Ensure excellence in infrastructure
NSP6. Ensure sustainable development of strategic resources
NSP7. Ensure government performance and efficiency

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Table 4.2 Possible mapping between enablers and NSP

Goal	*Enabler*	*NSP*	*Sub-NSP*
Smart economy	Entrepreneurship and innovation	NSP2	NSP2.6
		NSP3	NSP3.1, NSP3.2, NSP3.3,
	Productivity	NSP4	NSP3.4, NSP3.5, NSP3.6
	Local and global	NSP5	NSP4.1, NSP4.2
	Interconnectedness	NSP6	NSP5.1
		NSP7	
Smart environment	Green buildings	NSP1	NSP1.1
	Green energy	NSP2	NSP2.2
	Green urban planning	NSP3	NSP3.6
		NSP5	NSP5.2, NSP5.3, NSP5.4
Smart governance	Enabling supply and demand side policy	NSP3	NSP3.1, NSP3.4, NSP3.6
		NSP7	
	Transparency and open data		
	ICT and e-government		
Smart living	Culturally vibrant and happy	NSP1	NSP1.1, NSP1.2, NSP1.3,
	Safe	NSP2	NSP1.4
	Healthy		NSP2.1, NSP2.4, NSP2.5
Smart mobility	Mixed-modal access	NSP1	NSP1.3
	Prioritized clean and non-motorized options	NSP2	NSP3.2, NSP3.6
		NSP3	NSP5.1, NSP5.2, NSP5.3,
	Integrated ICT	NSP5	NSP5.4
Smart people	Twenty-first-century education	NSP1	NSP1.4
	Inclusive society	NSP2	NSP2.3, NSP2.4, NSP2.5,
	Embrace creativity	NSP3	NSP2.6
			NSP3.1, NSP3.5

Stage 5: Proof of Concept Case for a Successful Initiative in the Government

The team will select one of the successful SCIs for further analysis and design it as a case study. The team will work closely with the entity involved to further study the initiative by interviewing, collecting data, and analyzing all the aspects of the initiative. The team will write a detailed report that outlines all the different aspects of the initiative, what makes it a successful initiative, and what are the lessons learned. The case will serve as a catalyst example for the rest of the stakeholders and their projects.

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Stage 6: Review and Adjust the Framework with Stakeholder Consultation

The NSCF will be presented to the stakeholders for feedback and review. The team will meet major stakeholders to discuss the details of the framework and get the stakeholders feedback. The NSCF enablers and drivers will be refined based on the feedback and discussions. These refined enablers will serve in the development process of the maturity assessment model in the next stage.

Stage 7: Develop a Smart City Maturity Assessment Model

Several assessment systems have been proposed in the literature to come up with a representative metric of comparison. This requires the development of synthetic quantitative indicators. Giffinger et al. (2007) used a set of indicators for each dimension in their proposed model. The Intelligent Community Forum proposed five factors: broadband connectivity, a knowledgeable workforce, digital inclusion, innovation, and marketing and advocacy (Forum n.d.). For instance, the "Smart City Index", which was developed by Lazaroiu and Roscia (2012), was used in the 2020 strategic plan of the European fund. Zygiaris (2013) identified seven layers of a smart city: city layer, green city layer, interconnection layer, instrumentation layer, open integration layer, application layer, and innovation layer. Another system is the modified version of the triple helix model proposed by Lombardi et al. (2012).

This stage is essential to evaluate the current state and assess the achievements level, in other words, are they "good enough"? The team will analyze the purpose of each component, set the desired expectations, and develop a corresponding target with an appropriate scale. The deliverable of this stage will be a five-level maturity assessment model (similar to the popular Capability Maturity Model), which will be used, in the next stage. Possible maturity levels could be Beginning (Level 1), Emerging (Level 2), Conforming (Level 3), Leveraging (Level 4), and Leading (Level 5).

Stage 8: Evaluate Current National SCIs Using the Developed NSCF

The team will evaluate all SCIs in the Kingdom with the cooperation of IGA and stakeholders involved using the smart city maturity assessment

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model. The assessment will be used to guide IGA and involved stakeholders on the status of the initiatives in Bahrain and what needs to be done in later stages. A final report will be presented to the Bahraini IGA summarizing the key findings of this effort.

Conclusion

The methodology presented in this chapter is a flexible process where government, private sector, and NGOs can work together to establish a framework for SCIs within a certain city or country. The structured approach that involves all stakeholders was presented as a guideline for community leaders to establish a common term of reference for smart city projects.

The success of efforts in building a common framework depends on several factors including:

1. Support from the top governing entities
2. A common shared future vision within the city or country, usually led by governments (in the form of a government plan or strategy)
3. Open data and transparency
4. Government coordinating body such as the IGA in Bahrain, which is responsible for leading smart city efforts
5. A clear understanding of the main pillars in the model and the priorities depending on the community of these pillars
6. A holistic view of a smart city and one that does not focus only on technology, but extends to community participation, among other factors
7. Stakeholder acceptance, including government, private sector, and NGOs

The proposed project in the Kingdom of Bahrain for establishing a smart city framework among all stakeholders was met with a lot of enthusiasm from the different parties, including the IGA, public sector ministries, and private sector partners. The plan is to work with these stakeholders and use the Kingdom's Economic Strategy 2030 as a reference point for establishing Bahrain's framework. The plan is expected to be shared with the stakeholders and tested on some SCIs to ensure its validity as a blueprint for unifying efforts within the field. The project is expected to be completed by 2018. It is hoped that the procedure for establishing this

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framework can be implemented elsewhere to guide efforts for SCIs, especially within the Gulf Cooperation Council.

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CHAPTER 5

Smart-Governments for Smart Cities: The Case of Dubai Smart-Government

Ahmed Badran

Introduction

Contemporary society is highly dependent on utilizing smart applications and technologies for communicating and delivering services to citizens and for improving the quality of life in general. Despite the potential advantages of putting in place such new smart tools, the introduction of the notions of smart cities and smart-governments pose many challenges for governments. From regulatory and policy perspectives, a whole set of legal, social, and technical issues come into play. In this regard, this chapter argues that having conducive regulatory and policy frameworks is a prerequisite for the smooth and successful transition towards smart cities. This chapter examines and analyses the smart-government project in Dubai, in an attempt to underscore the main opportunities and challenges facing this project on the ground. The chapter builds on an extensive research and empirical material developed by the author while he was working with the Dubai government on the issue of smart-government governance. The analysis of the Dubai smart-government has indicated that the Government of Dubai was keen from day one on putting in place the required incentive schemes and major milestones for the successful

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_5

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implementation of the project. Nonetheless, the full transformation towards smart cities requires a new way of thinking about the role of government in relation to other societal players, in addition to providing all the new technology and infrastructure needed. Furthermore, the notion of smart cities introduces a new set of issues that governments have to deal with and pay attention to via formulating smart regulations and sound policies. Chief among those issues is the matter of information security and privacy.

Smart-Governance: A Theoretical Framework

The notion of smart-governance is closely related to the idea of e-governance, which revolves in particular around the ways in which governments around the globe handle their affairs and manage their societal resources. To govern from this angle is to exercise power and influence in allocating societal resources in addition to managing interrelationships between government units and non-state actors in the society (Cornforth 2003). Relying on smart information technology (IT) applications is key for the success of the implementation of e-governance. In this context, the Economic and Social Commission for Western Asia (ESCWA) has underlined the importance of utilizing IT for the purpose of reaching out to citizens and delivering faster, better, and more cost-efficient government services (ESCWA 2014). Advancements in the area of IT and smart applications also allow governments to become more transparent and enhance the notion of accountability and due processes in public services delivery (Kumar et al. 2014). E-governance has been perceived in a broader fashion by the Council of Europe as a means for enhancing citizen participation and a better way for managing the state–society relationships (Council of Europe 2016). From this perspective, the utilization of IT smart applications should allow for better access to decision-making processes by citizens and non-state actors. IT smart applications should also enable citizens to take part in designing public services and express their opinions about the quality of services delivered by government entities.

Considering the aforementioned definitions, it can be noticed that e-governance provides a new method for managing state–society relationships and resources by relying on IT and smart applications. The idea is that citizens as well as other non-state actors can collaboratively work with government institution in order to better manage and fully utilize the available resources. In that sense, e-governance extends to cover a

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whole web of relations including government to government, government to business, government to citizen (Savic 2006). Consequently, smart-governments focus primarily on one aspect of the smart-governance that is, the way in which services are designed and delivered to citizens. The idea is to move away from the traditional top-down approach for public services design and delivery towards a citizen-centric government mode wherein citizens are actively engaged in designing public services and evaluating delivery processes and quality. Smart-governments then bring citizens to the core of government businesses and reduce time as well as space limitations (Okot-Uma 2004). In the words of Safeena and Kammani (2013), smart-governments reduce the distance between the centre and the periphery. To this aim, governments try to capitalize on and modernize their infrastructure and practices by making a good use of IT smart applications in order to improve administrative practices as well as public service design and delivery via citizen participation (ESCWA 2014).

The Digital Era Governance: Digitizing Government Services

The notion of digital era governance as presented by Dunleavy and Margetts is paramount in understanding the transformation from the electronic-government model to what is known today as the smart-government (Dunleavy and Margetts 2010). The discussion of the digital era governance is an attempt to bring back the utilization of IT to the heart of government business but in a way that differs from the IT applications under the New Public Management (NPM) era. According to Dunleavy et al. (2005), the way in which IT was used under the NPM reform approaches has resulted in the fragmentation in public services delivery. Many agencies were created with different and sometimes conflicting mandates. This trend is known in the regulatory governance literature as the "agencification" process. Hence, the call was for reintegrating the processes of service delivery using a holistic approach and with the aid of the new advancements in IT. The idea of redesigning and reintegrating government service delivery forms the backbone of the smart-government discourse. Instead of having separate websites for government agencies, a unified platform via which all users can access all government services around the clock has become the end of many smart-government initiatives.

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A glance at the literature reveals that the concept of e-government has been extensively examined by scholars. Nonetheless, there is not an agreed upon definition of the concept. Most of the e-government definitions revolve around the utilization of IT and the internet to arrive at better access to the processes of public services design and delivery. As noted by Al-Hosh, e-government provides means for transforming the interrelationships between the government and the rest of the societal actors including citizens and end-users (Al-Hosh 2006). In his conceptualization of e-government, Forman (2005) has focused on the notion of effectiveness and efficiency in government's operations. From this angle, e-government provides the necessary tools for arriving at better public services and more efficient governmental operations and activities. In the same vein comes the definition coined by the ESCWA, which perceived e-government as a tool for improving the overall performance and functions of the government (ESCWA 2014). Added to this, the Organisation for Economic Co-operation and Development (OECD) has highlighted the integrative role the IT and the internet can play by linking all governmental services and operations in a coordinated fashion (OECD 2001). The World Bank in several occasions has also underlined the role of e-government in fighting corruption and enhancing a participatory approach for services, design, and delivery (World Bank 2016).

Taken together, all the above-mentioned definitions underscore the benefits of using IT applications and advancements in order to improve the overall performance of governmental units. The aim is to arrive at better quality, more accessible, faster, and easier service delivery modes. The efficiency and effectiveness of government operations were among the major deriving forces of e-government implementation. Furthermore, the core principles of good governance in terms of accountability, integrity, transparency, and accountability were cornerstones in the e-government initiatives and projects worldwide. In that sense, e-government has never been perceived as an end, but as a means for improving the relationship between the government and the rest of the stakeholders in the society, as well as, providing better public services designed and delivered in a collaborative fashion (Hussein 2013).

Implementation wise, the e-government model has gone through three main phases. In phase one, governments have tried to reach out to the users by providing information about the services, forms required, fees, procedures, and so on. As can be seen, the communication at this stage was in one direction from governments to the users and all government

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units were required to establish their own websites via which end-users can access the information needed about the public services they deliver. The e-government model was further improved due to the advancements in the IT and the internet and a more interactive model was introduced wherein the user can have a dialogue with government institutions and submit forms in addition to making some transactions online. At this interactive stage, the users were also able to provide feedback regarding the quality of the services provided and the delivery methods. The smart applications and smart devices have paved the way for the third phase of e-government evolution, known as smart-government.

Defining Smart-Government

According to Gartner, smart-government refers to the way in which governments utilize smart tools and applications as core-integrated parts in their functions and operations at all administrative and decision-making levels (Gartner 2010). The aim is to add new value to the governmental operations and activities and to make sure that citizens as well as the other societal non-state actors are actively engaged in the processes of designing and delivering public services. This conceptualization of smart-government has a lot in common with the notion of e-government previously defined. Nonetheless, the emphasis here is on the smart gadgets such as smartphones and tablets as facilitating tools enabling better interaction between government units and the wider society. In this regard, smart applications provide the way forward in order to improve availability, accessibility, and the quality of public services. Having said that, it is important to indicate, and contrary to the common belief among many scholars, that smart-government is no more than a new phase of the e-government evolution journey. It is not as many like to introduce it a new paradigm. It is not totally disconnected with the origins and evolution of the e-government notion.

This is not to say that e-government and smart-government both refer to the same thing. There are still some fundamental differences the advocates of smart-government underline. Accordingly, the notion of smart-government is not just about developing smart applications and using smartphones. Deep down, moving from e-government to smart-government calls for a comprehensive strategy to restructure and integrate government services provided through the websites of public institutions and bodies. In this context, users can rely on a single platform to access all

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government services without the need to visit the individual websites of government agencies. Such an integrative platform requires a great deal of collaboration and coordination among all governmental agencies in order to make sure that their services are timely accessible and compatible with the services provided by other agencies. As such, the smart-government model brings government institutions one step closer to the societal non-state actors and citizens. It also allows government units to make a better use of the information available in designing and delivering better public policies and services. In the era of big data, the challenge is not about the lack of information, but rather the way in which information is extracted and used to serve the overall policy objectives.

Based on such an understanding of the smart-government, one can summarize the main features of this notion as being social, mobile, built on analytics, and based on trust and radical openness. The social aspect of the smart-government appears in the way that government units communicate and timely respond to demands from societal actors based on the information received through instant communication channels. The smart-government is mobile in the sense that it is flexible, adaptive responsive and reflective. That means the processes of service design and delivery methods depend on concurrent information flows. Additionally, a mobile government will reach out to societal actors and provide them with its services at a fingertip rather than asking users to come all the way to governmental organizations. The smart-government is also analytic in the sense that all operations, decisions, and activities are evidence-based and derived from a deep analysis of existing databases. It is worth mentioning in this regard that one of the major challenges facing smart-government is how to make a good use of the wealth of information they have at their disposal in improving the processes of services design and delivery. Trust and openness are paramount for the success of the smart-government. Unlike the traditional government model of government wherein distrust between the government and the rest of the societal actors was the name of the game, smart-governments build up and maintain a trust relationship with private and non-state actors (Mat and Tib 2014). Keeping open communication channels is essential for building up and enhancing trust relationships between smart-governments and society. In other words, smart-governments reject the traditional organizational culture of information hoarding that used to prevail in traditional government organizations.

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Trust: The Institutional Foundation of Smart-Governments

Whereas in the context of single hierarchal government organizations, the legal-rational authority represents the cohesion factor that holds the different parts of such organizations together, in the less hierarchical and dispersed organizational forms including the smart-government models such a cohesion factor is subject to different interpretations. In this regard, Agranoff identified trust as an impermanent cohesion factor in networked settings such as smart-governments (Agranoff 2003). The importance of trust as an institutional foundation of smart-governments becomes evident if we consider the level of ambiguity and uncertainty in policy and administrative arenas. For instance, a functional model of smart-government calls for the integration of public services provided by a number of separate government units. Such an integration in turn requires a huge deal of cooperation among those government units in order to redesign public services and delivery mechanisms. If trust were lacking, collaboration among government units would be vulnerable to different forms of opportunistic behaviour, which might affect the overall functionality of the model.

From this angle, many scholars regard trust as a prerequisite for any cooperative or collective sort of action, including networking government agencies and gearing them up towards smart-government models. Hudson, for example, has noted that, as an institutional characteristic, trust can facilitate and promote several kinds of social processes that can lead to the development of synergistic relationships (Hudson 2004). In the same vein, Eggers and Goldsmith observe that successful networked organizational settings rely, at least partly, on trust. Without trust, government units will be unwilling to share knowledge, and coordination will be more difficult (Eggers and Goldsmith 2006).

With the importance of trust identified as a major cohesion factor in smart-governments, the question that begs itself is how trust relations can be built. To answer this question is to address two main aspects of trust: psychological and institutional. At a general level, trust can be perceived as a two-way relationship that can be built, fostered, or eroded as a result of many factors. From a psychological point of view, trust between government units on the one hand, and between those units and the citizens on the other can be built based on historical relationships, previous experience, and reputation. Given the long history of distrust between governments and citizens in the Arab world, this aspect of trust has to be properly

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addressed and the right measures need to be put in place for the new smart-governments to function effectively. In other words, the reputational and psychological aspect of trust has to be complemented with the required institutional guarantees including formal policies, laws, and regulations. This institutional element of trust is particularly important for smart-government projects in the Arab World because of the weakness of the psychological element.

To sum up, trust building appears to be among the most important foundations that are needed for successful implementation of smart-government projects. Trust relations need to be built and fostered among government units and between those units and the users of smart-government's services. At the same time, institutional guarantees in terms of the required legal and regulatory frameworks need to be fully developed and enforced in order to prevent opportunistic behaviour and protect weak parties and stakeholders from those with more power. Sharing information and having the same processes and techniques among government agencies and between those agencies and the citizens can be a first step on the route of building and enhancing trust. Furthermore, trust can be seen as the cement that helps to keep the different elements of the smart-government together.

A New Smart-Culture for Smart-Governments

The notion of smart-government as previously conceptualized emphasizes the importance of changing the traditional organizational culture in governments as well as the top-down approaches and mechanisms of decision-making. In other words, the success in the implementation of smart-governments initiatives relies heavily on changing the mentality of civil servants and the way they conduct their daily business and activities. Furthermore, the process of service design and delivery mechanisms should be reconsidered to reflect an integrative approach in public service delivery. Such an integration should facilitate the information flows among all governmental units and between those units and the societal non-state actors (Rubel 2014). Added to this, the patterns of interaction between the state and non-state actors should be studied carefully in order to capture the personal preferences of the customers with respect to service quality and delivery methods.

The above discussion on smart-government has indicated that the implementation of this model is not about all or nothing. To put it another

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way, on the ground, the application of smart-governments may take different approaches and may result in different models with different levels of maturity. The mobile-government model is case in point. This intermediate phase of smart-government applications is quite vague but carries the first seeds of the smart-government notion. The idea was to benefit from the modern applications of smart mobile phones in developing and delivering public services. With the maturity level increased, the model has moved from just using smartphones to access government services to focus more on the idea of service integration and more citizen-centric governments. In this context, Rubel has indicated that the level of smart-government maturity can be measured against three main criteria: the level of citizen participation, the level of transparency, and the level of cooperation and coordination among government units. Consequently, a mature model of smart-government should reflect a high level of citizens' participation in the processes of designing and delivering public services. Additionally, mature smart-governments are characterized by a high-level transparency in information dissemination, but not just that, advanced smart-governments also tailor information to the needs of its customers. Finally yet importantly, mature smart-government models are built on full cooperation and coordination of all government activities and services. The higher the level of coordination and cooperation, the more likely for the implementation of smart-governments to be a success. The ultimate level of maturity of the smart-government model is reached when what is known as 360 degrees citizen service is realized. That means the smart-government has become highly responsive to the demands and needs of end-users and responds almost immediately to any change in their taste and demands.

Regardless of the level of maturity, the transition from the electronic-government model to the smart-government model calls for an action plan which clearly identifies the main prerequisites, timeline, resources as well as the phases on implementation. In this regard, the centre for electronic-government studies has identified the main requirements for the successful smart-government implementation as follows (Egovconcepts 2018):

- Making use of existing governmental information and databases in redesigning public services and developing new smart applications.
- Developing an overall framework for data gathering and organization in a way that facilitates the immediate response to changes in customers' preferences.

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- Developing partnerships among the state and non-state actors in the society in order to develop smart applications for services. For example, use of the databases available to government agencies in the economic, social, health, and transport and communications by making them available to developers of smart applications. That would enable them to develop useful applications for customers with government agencies.
- Providing smart-government users with guidelines and frameworks that demonstrate how to access those services through smart applications.
- Developing guidelines and frameworks for government agencies on how to convert public services into smart services, while allowing each of them to develop what they consider appropriate applications and technologies to transform into the smart-government model.
- Investing in the development of smart applications and providing financial incentives to software and applications developers in order to update existing applications or to develop new ones.

The fulfilment of this long list of requirements is far from being an easy task. In other words, moving from the existing applications of e-government towards the more advanced and mature models of smart-governments entails fundamental changes in the way traditional and even e-governments used to conduct their businesses. That includes rethinking the existing electronic infrastructure in terms of making good use of the available technologies in the development of new tools and smart applications. This should enhance better communication among the stakeholders in the society and provide quality public services to end-users. To put it in another way, the transformation to the smart-government model does not mean the recycling and reproducing the existing ministries' and government agencies' websites. It goes way beyond the use of smart mobile devices to include major restructuring and redesigning of government services and operations using an integrative approach. Added to this, smart-governments should not be considered in isolation of the overall picture of smart cities. It is highly unlikely to have a smart-government in an environment of backwardness and retrograde. In other words, the smart-government model is flourishing in smart cities that seek sustainability in economic growth by providing a modern information and communications technology (ICT) infrastructure through which the government provides citizens with high quality economically efficient public services.

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To recapitulate, it is clear from this discussion of smart-government models that the success in providing integrated public services to end-users using smart electronic gadgets depends, among other factors, on the way in which government offices interact with the electronic users interface used by individuals and private companies. In other words, success on the smart transformation level is preceded by a very important requirement, namely, the development of the wheel of work within the government agencies and ministries, in a way that eliminates overlapping of competencies and redundancy in the services provided. It is inconceivable to find a successful smart-government work in cyberspace or cybernetics and backed by a rigid paper-based bureaucracy.

From the e-Government to Smart-Government: The Experience of Dubai

This part of the study deals with the analysis of the smart-government model in the Emirate of Dubai. The aim is to identify the phases of implementation and regulatory lessons learned from the process of transformation to the smart-government. Before talking in detail about the Dubai smart-government, we need to clarify the reasons for choosing the case study and to give a quick overview of the evolution of the UAE e-government concept and applications as a prelude to analysing the experience of the emirate of Dubai.

Why Dubai Smart-Government?

Academic and methodological norms require a clarification of the reasons for selecting the case study. In this regard, it is possible to say that the focus on the experience of the smart-government of Dubai was driven by several reasons, including, but not limited to, that Dubai is one of the smartest cities in the Gulf region and the Arab world (Kippreport 2013). According to estimates by the Economic Council of Dubai, the gross domestic product (GDP) growth rate increased by 4.7% during the second half of 2013. In addition, Dubai has a modern ICT infrastructure built on government communication networks and planning systems that are the best in the world. In addition, the Dubai smart-government has received an international recognition of the Emirate's efforts to transform into the smart-government by winning the United Nations Government

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Services Award on June 23, 2013. The prize was awarded to the Dubai smart-government Task Force for their outstanding role in promoting electronic smart applications in various departments of government organizations. UN Secretary-General Ban Ki-moon said in his inaugural speech to the United Nations Public Service Day that the winners of this award provide a model for developing service delivery processes and achieving higher standards of accountability and transparency within the government organization (Talwar 2013). Thus, Dubai has presented the first model in the area of smart-government applications in the Arab region and has been a leader in this field (Dubai Economic Council 2018).

The Development of the Smart-Government Model in the United Arab Emirates

The United Arab Emirates (UAE) has been at the forefront of implementing e-government in the Arab region since the early 2000s. According to the studies conducted by Google, the UAE is taking the lead in terms of using smartphones by 62%, and with an annual increase of 18%. The UAE is ranked seventh in the world in terms of providing government services through e-gates. This situation is expected to improve significantly following the implementation of the smart-government initiative and the use of smart technologies to find solutions to problems related to public service design delivery processes (Emirates247 2013).

The smart-government journey commenced in the UAE at the beginning of the millennium. In 2001, the Council of Ministers issued a decision to assign the Ministry of Industry and Finance at that time the responsibility for developing the strategic plan for the implementation of the e-government. In the same year, the Ministry of Finance provided the first e-service in the federal government, the E-Dirham service. In order to achieve coordination between the various activities included in the e-government programme, a committee was set up under the leadership of the Minister of Finance and Industry in the federal government in 2011. The federal government in the UAE has assigned the task of assessing the current situation in government agencies and proposing a plan for implementing the e-government programme for the IBM Company. In 2004, a Memorandum of Understanding (MoU) was signed with Etisalat (the national telecommunications services operator) to develop the necessary infrastructure for e-government applications at the federal level. In 2005, the first e-platform was launched in collaboration with Etisalat. In

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2006, the task of managing the e-government transformation programme was transferred from the Ministry of Finance and Industry to the Ministry of Public Sector Development. The government also issued a ministerial decree in 2010 authorizing the Telecommunications Regulatory Authority (TRA) to develop an information plan at the state level as a whole. Subsequently, in 2011, the TRA embarked on the task of managing the e-government programme. In 2012, the Cabinet approved the Government's Strategic Plan (Al-Khouri and Ali 2012).

This brief and quick overview of the evolution of e-government efforts at the federal level shows that the Government of the UAE has taken the issue of e-government transformation seriously since the first years of implementation and has continued to develop and implement the programme at a steady pace by providing an environment conducive to implementation. The emirate of Dubai has benefited from developments in the field of e-government application at the federal level. The development of the necessary infrastructure for the utilization of ICTs to serve the citizens and the business community was essential to Dubai for developing its own e-government model. Following the initiative of His Highness Sheikh Mohammed bin Rashid Al Maktoum launched at the 2013 Government Summit all government organizations in Dubai were on the quest to transform their e-services into smart services using smart applications and technologies (TRA 2018).

The Dubai Smart-Government Initiative

In the launch of the Dubai smart-government Initiative, His Highness Sheikh Mohammed bin Rashid Al Maktoum said that Dubai has succeeded in introducing a modern and sophisticated concept for the innovative applications of e-government. He also added that it is time for Dubai to continue its progress in this field of innovation by seeking a creative government—a smart-government built on the world's best telecommunications infrastructure and serving 14 million subscribers with an average of two mobile phones per person (Emirates247 2013).

The Ruler of Dubai has set the goal of launching this initiative in order to facilitate communications and interactions between users and government agencies in an attempt to achieve higher levels of satisfaction and happiness. This focus on improving public services was confirmed by His Highness Sheikh Hamdan Bin Mohammed, Crown Prince of Dubai. In this regard, the Crown Prince stressed that the transformation to the

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smart-government model provides a qualitative leap in the process of providing government services (Awad 2013). The initiative also emphasized the importance of reaching all sectors within the society, regardless of their level of culture and electronic awareness. In other words, the crux of Dubai smart-government initiative was to make government services available to citizens around the clock 7 days a week and 365 days a year. Thus, the smart-government facilitates access to government services from anywhere using smart technologies and helps to raise the quality levels of provided integrated government services government services. With regard to the timeframe of the implementation process, the initiative has been set for two years from the date of announcing the initiative, during which all government departments will review and develop their services and search for smart applications to develop the process of providing these services to customers.

At the implementation level, the initiative encouraged competition between service providers in the area of developing smart applications. The idea was to redesign the existing electronic applications and to develop new ones that help in providing more integrated and easily accessible services. The Government of Dubai has allocated AED 200 million via the ICT Fund to support the initiative and to encourage the development of smart applications. The ICT Fund also contributes to the initiative by providing technical support and advice to the other parties involved in the implementation process (Emirates247 2013). In this context, the initiative has focused on three main areas of implementation:

- Activating all government services through smartphone applications
- Developing new smart services through advanced applications using mobile phones
- Demanding government agencies to cooperate in order to develop a unified strategy to implement the idea of smart-government on the ground

In addition to the previous implementation pillars, the initiative emphasized the necessity of establishing a new legislative and regulatory framework that includes a definition of smart electronic services as well as unified standards for the provision of these services by government departments. An executive framework for the initiative as well as a plan for the implementation phases was required for the successful execution.

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Dubai Smart-Government: Application Models

In light of the government's smart initiative and the directives of the political leadership, many government agencies have sought to develop their services in line with the idea of smart-government as outlined above. In this chapter, it is not my contention to provide a comprehensive review of all smart-government models and applications in the Government of Dubai as this narrative goes beyond the boundaries of one study. Hence, this section of the chapter will focus on a brief presentation of some of the smart models developed to enhance transparency in the dissemination of government information, as well as to improve the delivery of services, build a citizen-centric government, and increase citizen participation in public policy-making.

Developing Government Services Using Smart Technologies: Towards a Citizen-Centric Government

There are many smart-government applications in Dubai, which aimed at achieving integration between government departments in addition to designing and delivering high-quality public service to citizens and end-users. Due to the difficulty of focusing on all applications, the discussion in this section will be limited to three applications: MyID, the Mobile Electronic Payment System, and the Dubai Smart Prosecution.

MyID Smart Application

This smart application was developed and launched through the collaboration between Dubai smart-government and Emirates Identity Authority. The application aims to facilitate the procedures of login for customers using smart devices so that each user has a unique single electronic identity to connect to all government departments at once. There is therefore no need for registration procedures with each individual government entity (Khaleej Times 2013). The first phase of this application witnessed the launch of 50 smart e-services provided by five government agencies. The next stages of implementation are expected to cover all government departments and services. The application of MyID makes it easier to access and use some of the already implemented electronic services such as e-payment system and e-payment services as well as electronic complaints service system.

From this perspective, the application of MyID helps to achieve the idea of integration among the Dubai government departments. Such an

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integration is an important element in the successful implementation of the smart-government. The MyID application also helps to avoid the creation of many personal accounts for the same user as it allows access and interaction with all government agencies in a timely and safe manner. As reported by the Emirates ID department, E-entry is subject to strong security standards based on standard technologies that conform to the standards applied to the government services integration platform of the Government of Dubai. The system was built using standard techniques and standards based on secure and open source standards (Emirates Identity Authority 2018).

Updating the Application of Electronic Payment System via Mobile Phones

The Dubai smart-government Department has reviewed the application of the electronic payment system (Mpay) with the aim of updating it to avoid delays in payments by customers and to make the payment process easier. The new application is now integrated with the services of all government websites, which accelerates the payment process and makes it more suitable to customer needs. The new online payment service has been downloaded 13,000 times from the iPhone and Android app stores. The revised application was also used to collect AED 15 million for government departments through 53,000 payment processes. A number of government agencies such as the Roads and Transport Authority (RTA), Dubai Police, and Dubai Electricity and Water Authority (DEWA) are also participating in this smart application by offering their own payment services through Mpay. For instance, the user can add credit to the Salik card, a service provided by RTA. Users can also pay traffic fines or electricity bills electronically through this smart application (Dubai Smart Government 2018).

Dubai Smart Public Prosecution

The Dubai Public Prosecution was one of the first departments to respond to Sheikh Mohammed's initiative to transform into smart-government. In this regard, after the completion of the necessary infrastructure for the transformation of the provision of legal services through smart devices and after the training of its employees the Smart Prosecution Project was introduced in the public prosecution. The Smart Prosecution, according to the concept of the Attorney General of Dubai, is a prosecution system that provides its services to clients through smart applications. These

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applications can be downloaded to smart devices such as mobile phones or electronic tablets (Dubai Legal Magazine 2013). The early start of Dubai public prosecution in the area of services digitization has allowed a smooth transition to the Smart Prosecution model in 2009. The new smart system provides round-the-clock service to lawyers, prosecutors, and citizens.

The Smart Prosecution system includes many applications that enable the users to access legal frameworks and legislation as well as giving them access to legal services via smart media. One of the most prominent of these applications is the electronic prosecution, which is directed to prosecutors, as well as the application of the smart lawyer, through which lawyers registered with the Public Prosecution can submit more than 125 types of applications without the need to attend to the headquarters of the prosecution in person. Another important application within the Smart Prosecution Project is the application of the smart bag, through which the statements of victims or offenders can be obtained remotely, in the event that they cannot be transferred to the Office of the Public Prosecution. There is also the smart clock app and the smart line app that enable the users to identify the branches of the prosecution and its various services. These applications also allow users to book an appointment so that the service is delivered to them upon arrival at the prosecutor's office without having to wait in line (Alkhaleej Economic 2015).

The Brainstorming Initiative: Activating Citizen Participation in Policy-Making

The UAE brainstorming initiative launched by His Highness Sheikh Mohammed bin Rashid Al Maktoum, Ruler of Dubai, provides a model in the use of e-governance and new technologies as a means to increase citizen participation in the decision-making processes. The aim was to activate stakeholders and citizens' participation in public health and education policy-making. The idea came from the belief of the political leadership in the importance of activating the role of citizens and all stakeholders to seek creative solutions in the health and education sectors. "Health and education are key national issues for the UAE and their development is a shared responsibility of the people and the government. Despite the country's progress in many important sectors, the development of these sectors does not fully meet our ambitions and our expectations", said HH Sheikh Mohammed bin Rashid Al Maktoum. "We want to unite on these two issues and create new ideas for development" (Alkhaleej Newspaper 2018).

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The initiative emphasized the importance of participation and representation of all relevant parties from teachers, doctors, parents, and students. The door has also been opened to everyone's participation by communicating through other social media. A wide range of UAE nationals accepted and welcomed the idea of the initiative. During the first three days, participants provided about 50,000 interventions, most of which represented ideas on how to tackle the problems of education and the health sector. These posts and contributions placed a burden on ministers and government officials who are required to consider these ideas when designing policies for their sectors and to respond to those demands through decisions that fulfil the aspirations of participants (Sharjah Library 2018).

Considering the brainstorming initiative in the field of education and healthcare, it can be noted that the political leadership has tried to maximize the use of smart technologies and electronic governance to activate citizen participation in political decision-making and public policy-making. This initiative also highlights the government's willingness to work transparently with the citizen and allows various societal parties to present their ideas and proposals interactively through the means of social and electronic communication. Additionally, the positive reactions from stakeholders and citizens have enhanced the notion of formal and informal accountability of public officials. On the one hand, the Prime Minister can judge the extent to which the ideas and proposals of the participants have been reflected in the decisions and policies of the government bodies. Informally, public officials and ministers were also held responsible to the wider public, which can evaluate and provide feedback of their decisions and policies via the smart applications.

Conclusion

This chapter considers smart-governance as a tool to reshape state–society relationships and to achieve a quantum leap in the use of IT to redesign government services. As such, smart-governance can be perceived as a means to promote citizen participation and achieve accountability and transparency in the work of government bodies. Moreover, digital governance and its modern and smart technologies help to develop the design and delivery of government services. That in turn helps to achieve the objectives of administrative development efforts in terms of the improvement of public services. In this context, the chapter reviewed the case of

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the Dubai smart-government in order to shed light on the lessons learned from that experience. The chapter also aimed at making some policy recommendations on the how to successfully achieve the transformation to the smart-government model.

A recent account on smart-government suggests that governments' ability to govern in the future depends to a large extent on their success in achieving greater outreach to community actors through smart-government applications (Badran 2014). This observation is quite evident in the study and analysis of the smart-government experience in Dubai. The vision of the political leadership is that the successful government should reach out to its users wherever they are, and not wait for their users to come. In other words, government organizations should deal with the challenges posed by the electronic environment. They also should benefit from the opportunities provided by modern technologies in the field of ICT in order to create a more communicative, responsive, and integrative smart-government. To this end, decision- and policy-makers should develop an integrated strategy for the process of transformation towards smart-government models. They also should develop smart technologies and tools that suit their local communities and meet the needs of customers. In this context, and in light of the analysis of the smart-government experience in Dubai, a number of recommendations can be made on the aspects to be considered to ensure a successful transition from the e-government phase to the smart-government model:

- *Continuous support and follow-up by the political leadership.* One of the most important factors in the success of the smart-government's experience in Dubai is the support of the smart-government initiative from the highest level of the political leadership within the emirate. The launch of the initiative by Sheikh Mohammed bin Rashid, Ruler of Dubai, has had a significant impact on the fact that many government institutions have taken the initiative seriously and have endeavoured to implement the Ruler's directives in light of the vision provided through the initiative. The follow-up by the Ruler and the Crown Prince of the process of transforming the smart-government model and setting a timeframe for completing the process within 24 months has also confirmed the determination of the political leadership to successfully complete the transition process and not tolerate those who will fail to do their job.

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- *Changing the mental image prevailing in many governmental institutions about the nature of public services and ways of delivery.* The smart-government is primarily related to providing smart solutions to problems associated with service delivery, not just developing smart applications. Therefore, to transform into smart departments, government departments need to think smartly and change the mental image associated with the service delivery process and its relationship with customers. The smart-government also requires higher levels of integration, coordination, and collaboration between different government agencies in a way that enables more integrated, easier, and more user-friendly services. In other words, enabling the user to access more than one service at the same time and with the same quality and efficiency.
- *Increasing connectivity with the internet.* Smart services can only be accessed by the customer if they are connected to the information network. Consequently providing such access via increasing users' connectivity to the internet through hotspots is paramount for the success of the smart-government efforts.
- *Developing an information security framework.* Such a framework should include technical standards and regulations for the security and safety of information related to electronic services provided. The smart-government users should be protected from piracy and other electronic crimes and risks including the theft of personal and banking data. This step is of critical importance in the direction of building trust between citizens and smart-government. This recommendation is even more important considering that many of the technologies used to protect the safety and security of customers are outdated and are not up to the speed with the rapid expansion of hackers who develop modern software that can infiltrate users' personal accounts.
- *Developing the legislative framework.* As noted by the ESCWA, this legislative framework is necessary to legitimize the smart-government and its transactions. Modern legislations are important in order to ensure that existing rules and regulations do not hinder the transition from the electronic-government to the smart-government model (ESCWA 2014). The efforts in this regard include ensuring that all legislation and legal frameworks are in place. This legal environment is necessary to guarantee the integrity of transactions carried out through smart-government applications. It is also needed

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to protect the rights of individuals and enterprises against any violations such as abuses of intellectual property rights. The institutional framework must also be developed through the establishment of regulatory bodies to monitor and implement electronic legislation and to provide regulators with the necessary expertise and powers to fulfil their duties and undertake their jobs (Al-Said 2011).

- *Achieving a citizen-centric government.* This can be done by increasing users' awareness of new smart applications and their benefits. Additionally, feedback processes can be very beneficial in the development of new service delivery mechanisms. At the heart of this process comes trust building with customers via guaranteeing confidentiality of data and system security safeguards. It is also required that smart-government units should achieve higher levels of coordination and collaboration with internal customers (other government departments) and external customers (private sector and users) to develop integrated electronic services.

In this regard, the chapter emphasized the need to employ smart ICTs as a strategic entry point for administrative development and the development of the delivery of government services. The chapter emphasized that many countries worldwide, have taken various forms and applications of e-governance and have tried, in one way or another, to employ ICTs to improve government service delivery and improve the quality of public services. Nevertheless, by comparing the smart-government model with the initial applications of the e-government concept, it is clear that smart-government is a more advanced step in e-government applications. It represents a new way of looking at the design and delivery of government services. In other words, smart-governments entail re-engineering and redesigning government services in a way that makes citizens and end-users at the heart of the design and delivery processes of public services. The successful implementation of the smart-government model will create a customer-oriented and a citizen-centric government that sets policies and services in line with the needs of its customers. This should increase the level of customer satisfaction with regard to the government performance.

Following up on the above discussion, it can be concluded that the new model of smart-government represents a shift in the philosophy of government in terms of the way it performs its core functions. In other words, smart-governments call for a full reconsideration of the existing

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methods of public services design and delivery mechanisms in order to gear them towards a more integrated model. Additionally, smart-governments revolve around citizens and other stakeholders in the society and use smart technologies and applications to bring them closer to the centres of policy and decision-making. Under the smart-government models, the societal stakeholders are no longer passive recipients of public services. Societal non-state actors have become the designer of many public services through their ongoing interaction with the administrative apparatus of government agencies. The government of the future is a government directed by customers. That means the government apparatus is at the service of the users around the clock and seek to provide their services in the best way possible. From this perspective, it can be mentioned that the smart-government and its applications can contribute to the realization of administrative development goals through the introduction of fundamental changes in the method of government work.

Finally, we conclude by quoting Sheikh Mohammed bin Rashid Al Maktoum, Ruler of Dubai, who describes the future government as "a government that does not sleep, operates 24 hours a day, 365 days a year, hospitable as hotels, fast in its dealings and strong in its actions" (Al Harthy 2018).

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PART III

Resources and Infrastructure

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CHAPTER 6

Linking Smart Cities Concept to Energy-Water-Food Nexus: The Case of Masdar City in Abu Dhabi, UAE

Mohamed Alzaabi, Zeinelabidin Rizk, and Toufic Mezher

Introduction

The UAE is situated on the southeastern coast of the Arabian Peninsula. It is characterized as an arid climate where temperatures can reach 46 °C in summer. Rainfall is scarce (~78 mm/year) and the evaporation rate is high (~3 m/year). Since 2000, the country has witnessed very rapid population growth, fast economic development, and increased agricultural production, which have led to a sharp increase in demand for energy, water, and food. In its effort to meet the ever-increasing stress on its natural resources, the UAE has increased its energy and desalination capacities, in addition to taking water conservation measures. Furthermore, it has adapted diversification strategy across energy sources that extend beyond oil and gas, embracing renewable and nuclear power capacities. The UAE

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_6

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federal government Vision 2021, Abu Dhabi Vision 2030, Water Conservation Strategy, and the Green Growth Strategy are all calling for a well-preserved natural environment in which the efficient management and conservation of energy and water resources are crucial. Based on that, the related public institutions are working on reforms in energy, food, and water policies; the regulatory institutional structure; and the operation of energy and water resources in the country.

In the UAE, most of the population lives in cities, mainly Abu Dhabi, Dubai, and Sharjah. These cities have witnessed a rapid urbanization with an ongoing economic growth since the 1970s. Along with that growth, demand for water, energy, and food increased substantially. So far, the UAE government was able to meet the increasing demand through building more water desalination plants for the cogeneration of potable water and electricity and through the importation of food. However, the Water-Energy-Food (WEF) Nexus approach remains unclear in the urban planning policies of UAE cities. The objective of this chapter is to investigate the link between WEF nexus and the role of a smart city in managing these resources in a more sustainable way. Masdar City in Abu Dhabi is taken as a case study.

The WEF nexus approach is a common and major focus of countries' sustainable development strategies. By 2050, the world demands for water and food are estimated to increase by over 50%, and the global energy demand will double (Ferroukhi et al. 2015). In 2014, more than half of the global population lived in urban areas and it is projected that their share will reach 66% by 2050. More sustainable challenges will be expected in urban areas, especially in middle-income countries where fast urbanization is taking place (UN 2014a). In these urban areas, most of the economic activities and their corresponding flow of resources are more complex. Urban management of water, energy, and agriculture resources cannot continue in such an isolated way in order to avoid wasteful trade-offs and fragmentation. An integrated approach is more needed for a sustainable development of both rural and urban areas to manage these interdependent resources efficiently.

There are a number of cities in different parts of the world that recognized the WEF nexus approach in their urban planning strategies. Some even went further by integrating transportation, housing, employment schemes, energy production from waste and handling sanitation with social aspects and biodiversity. These innovative policies enhanced the

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joint efforts between the different sectors and their relative stakeholders, including the different levels of the planning and execution stages (Vogt et al. 2014). In addition, most big cities are converging toward smarter cities, where sectors and resources can be integrated and managed more efficiently, contributing toward a more sustainable infrastructure.

The objective of this chapter is to investigate the relationships between the WEF approach and the smart city concept. The chapter will highlight smart city definitions, initiatives framework, modeling approaches, and benchmarking tools. The WEF nexus dynamics in the Gulf Cooperation Council (GCC) countries will be analyzed. The link between the smart city concept and the WEF nexus approach will also be investigated taking Masdar City in the UAE as a case study.

Smart City

There are a number of definitions for smart cities since the term was first used in the 1990s. At that time, the emphasis was mostly related to Information and Communications Technology (ICT) (Albino et al. 2015). The term from a technology perspective is defined as "a city with a great presence of ICT applied to critical infrastructure components and services" (Albino et al. 2015). Even a recent review of the literature indicates that there is no specific "smart city" template frame that can fit all concepts and definitions (O'grady and O'hare 2012). The term is also used nowadays in urban planning by governments to indicate the strategic direction of their policies and programs to achieve sustainable economic development and provide a happy living environment for their citizens (Ballas 2013). Caragliu et al. (2011) defined a smart city as "when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance." The Smart City Initiatives Framework to make a city more efficient, effective, attractive, competitive, sustainable, equitable, and livable included eight core pillars which are technology, management and organization, policy, governance, people and communities, economy, built infrastructure, and natural environment, as shown in Fig. 6.1 (Chourabi et al. 2012).

With the aim to have a better understanding of smart city initiatives, a study was conducted on four North American cities: Philadelphia and Seattle in the US, Quebec City in Canada, and Mexico City in Mexico. The study

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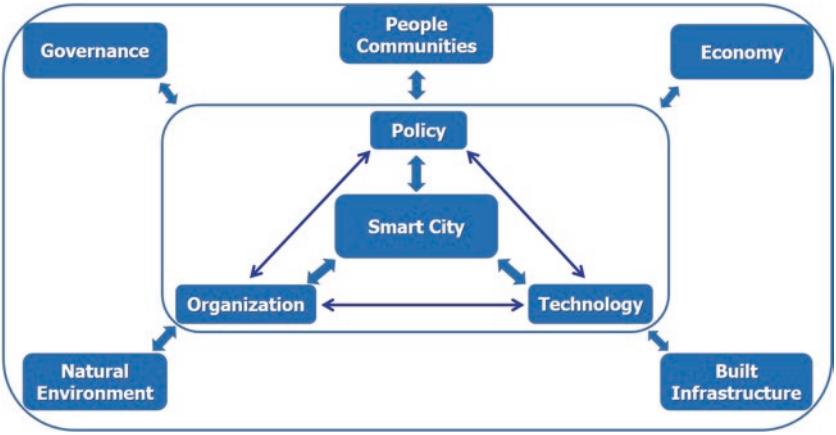


Fig. 6.1 Smart City Initiatives Framework

highlights a new understanding of smart city initiatives and suggests insights and lessons that cities can share with one another (Alawadhi et al. 2012). The main findings were:

- Information technology (IT) infrastructures enable and facilitate various smart city initiatives.
- Technological challenges of government IT projects are mostly organizational rather than technical in nature.
- The role of communication and interaction is central to managing and organizing smart city initiatives.
- The practical meaning of a city's smartness refers to successfully achieving the city government's goals and objectives despite some unfavorable conditions.
- Interdepartmental agreements are considered as policy requirements for interdepartmental workings for smart city initiatives. The mutual agreements stipulate measurable service.
- There are diverse models for governance and thus different types of a governance body. Stakeholders of smart city initiatives include various actors such as governments in other jurisdictions, nonprofits, companies, schools, universities, and individual citizens.
- Smart city initiatives are using mobile technology, social media, and other technology-enabled innovative solutions to enhance citizen participation in city governance.

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- A smart city intelligently combines its resources to provide the best economic and social conditions.
- Smart city initiatives help create desirable conditions for a livable and sustainable city by preserving and protecting the natural environment.

A number of models have been developed to understand and conceptualize smart cities, which aim to define their scope, objectives, and architectures. Anthopoulos et al. (2015) analyzed the existing smart city modeling approaches and benchmarking tools. These models included the International Business Machines (IBM) Corporation Nine Pillar Model, which links planning, management, infrastructure, and human services with the transformation of urban phenomena into data, the interconnection of the data and the intelligence of the software used (Söderström et al. 2014). The International Telecommunications Union (ITU) used key performance indicators similar to the dimensions of the United Nation Habitat to indicate smart sustainable cities which include the environment, productivity, quality of life, equity, and infrastructure (ITU 2014; UN 2014b). International Organization for Standardization (ISO) established ISO 37120 as a standard for city services and quality of life (ISO 2014). Anthopoulos et al. (2015) and Neirotti et al. (2014) developed similar domains for smart city that included natural resources, transportation, living, government, and people. Lee et al. (2014) presented a framework for smart city analysis, which involved service innovation, partnerships, and city governance. Table 6.1 summarizes various smart city modeling approaches.

Various benchmarking methods for comparing smart cities initiatives with each other have also been developed. These methods cover smart cities from different perspectives. The United Nations (UN) Habitat describes the effectiveness, equity, participation, accountability, and security as good urban governance indicators (UN Habitat 2014). Other researchers focused on different indicators such as local sustainable development (Pires et al. 2014), global city performance measurement indexes (Kourtit et al. 2014), resilience city evaluation and implementation framework (Desouza and Flanery 2013), sustainable local government scorecard (da Cruz and Marques 2014), competitiveness parameters (Singhal et al. 2013), urban intelligence assessment (Lazaroiu and Roscia 2012), and digital city assessment framework (Duarte et al. 2014). Table 6.2 summarizes common smart city benchmarking tools.

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Table 6.1 Smart city modeling approaches (Anthopoulos et al. 2015)

	Model	*Description*
IBM (Söderström et al. 2014)	Nine Pillar Model	Planning and management services, infrastructure services
	Smarter city equation	Human services Instrumentation (*the transformation of urban phenomena into data*) + Interconnection (*of data*) + Intelligence (*brought by software*)
ITU (2014)	Smart sustainable city key performance indicators	Environmental sustainability, productivity, quality of life, equity and social inclusion, infrastructure development
UN Habitat (2014)	Dimensions of city prosperity	Productivity and the prosperity of cities, urban infrastructure: Bedrock of prosperity, quality of life and urban prosperity Equity and the prosperity of cities, environmental sustainability and the prosperity of cities
Anthopoulos (2015)	Smart city dimensions	Resource, transportation, urban infrastructure, living, government, economy, coherency
ISO (2014)	ISO 37120 Sustainable development of communities Indicators for city services and quality of life	Economy, education, energy, environment, finance, fire and emergency response, governance, health, recreation, safety, shelter, solid waste, telecommunication and innovation, transportation, urban planning, wastewater, water and sanitation
Neirotti et al. (2014)	Smart city domains	Natural resources and energy, transport and mobility, buildings, living, government, economy, and people
Lee et al. (2014)	Framework for smart city analysis	Urban openness, service innovation, partnerships formation, urban proactiveness, smart city infrastructure integration, smart city governance

The Water-Energy-Food Nexus

Many scholars approached the WEF nexus from different angles based on the nature of the institutions they are affiliated with and according to their specific research areas (Biggs et al. 2015; FAO 2014; Bizikova et al. 2013; Mohtar and Daher 2012). A recent study by Saif et al. (2014) analyzed the current state of water in the GCC countries using a WEF nexus approach. The study emphasized the importance of this approach in the formulation of the water, food, and energy policies, taking into consideration the interconnection of these policies to achieve water, energy, and food securities.

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Table 6.2 Smart city benchmarking tools (Anthopoulos 2015)

	Benchmarking tool	*Description*
Pires et al. (2014)	Local sustainable development indicators	21 ECOXXI Indicators, grouped in the following sectors: Sustainable, development education, marine and coastal environment institutions, nature conservation and biodiversity, forest planning, air, water, waste, energy, transport, noise, agriculture, tourism
Kourtit et al. (2014)	Global city performance measurement indexes	Economy, research and development, cultural interaction, livability, environment, accessibility
Desouza and Flanery (2013)	Resilience city evaluation and implementation framework	City components: Resources and processes (physical) people, institutions, activities (social)
da Cruz and Marques (2014)	Sustainable local government scorecard	Social, economic, environmental, and government *criteria*
Singhal et al. (2013)	Competitiveness parameters	Physical environment, social capital, finance, development, investment, user potential
UN Habitat (UN 2014b)	Good urban governance indicators	Effectiveness, equity, participation, accountability, security
Lazaroiu and Roscia (2012)	Model for computing "the smart city" indices	Economy, mobility, environment, people, living, governance
Duarte et al. (2014)	Digital city assessment framework	Connectivity, accessibility, and communicability

These three sectors are highly interdependent in the GCC countries, since these countries are all relying heavily on fossil fuel energy in their water and food security plans. Figure 6.2 illustrates the WEF nexus dynamics in the GCC countries and demonstrates how it is crucial to analyze the dynamics of water scarcity in the region and how it can be dealt with in both a cost-effective and sustainable way through a WEF approach. It also demonstrates the ways in which present and future GCC's water, energy, and food needs can be sustained. Figure 6.2 also highlights the necessary financial, political, and utility-based resources needed such as freshwater

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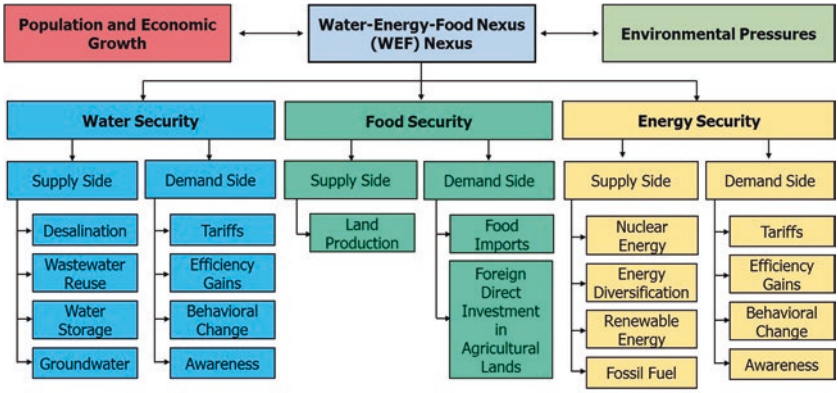


Fig. 6.2 WEF nexus dynamics in the GCC countries

and energy. The GCC nexus approach presents the food security policies that involve local food production, food imports, and the investment in foreign agricultural lands, and highlights the issues to be considered for these food policies (e.g., stress on energy/water/land, subsidies, capital, and political agenda). It also reflects the supply and demand sides of the water and energy security policies. Water supply side involves desalination, wastewater reuse, water storage and groundwater, and their respective issues. The water demand side involves tariffs, awareness, efficiency gains, and behavioral changes, and their related issues. The energy supply side involves energy diversification, renewable energies, nuclear energy, and fossil fuel extraction and imports. On the other hand, the energy demand side covers tariffs, awareness, efficiency gains, and behavioral change with their related issues. The approach also illustrates the population, economic growth and the environmental pressures that affect and are affected by the WEF nexus approach.

Linking WEF Nexus Approach to Smart City Concept

The link between smart city concept and WEF nexus approach was investigated in a number of studies. A recent study, demonstrated that by applying WEF nexus within a city through integrated urban planning process, cities can mitigate and adapt to climate change more effectively (Gondhalekar and Ramsauer 2017). In that study, the authors use a neigh-

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borhood of the City of Munich, Germany, as a case study, and found that intensive urban agriculture, wastewater recycling and reuse coupled with rainwater harvesting, and biogas generation from human sewage can provide part of the food needed, save water and electricity supply to the City of Munich. Such an approach could be relevant to other cities in other parts of the world.

Another study discussed the major factors behind the present reluctance of African cities in adopting the water-food-climate-energy nexus approach as an option for building sustainable regions and cities (Chirisa and Bandauko 2015). They used four African cities as case studies, which included Bulawayo (Zimbabwe), Cape Town (South Africa), Dar es Salaam (Tanzania), and Cairo (Egypt), to investigate the issues and factors related to the adoption of the water-food-climate-energy nexus in the sustainability and resilience agenda for these cities. The study indicated that the nexus approach is particularly enlightening for developing sustainable solutions when considering, for instance, water constraints in energy production, water-smart and energy-smart food, and impacts of biofuels on food security. The study also concluded that African cities need to develop strategies that effectively integrate WEF and climate nexus for sustainable and resilient cities.

A third study emphasized the need for establishing a broader nexus—"water-energy-pollution"—that includes the implications of energy production, related water consumption and environmental pollution (Kumar and Saroj 2014). They indicated in their study that the use of highly efficient non-carbon based renewable energy production systems such as solar, carbon dioxide (CO_2) capture and storage, and water recycling would entirely change the equation in the water-energy-pollution nexus of megacities. The study suggested that the adoption of this nexus approach can be very useful for a systemic assessment of the production and consumption of energy in growing urban environments.

In an attempt to find out pathways to sustainability in food, energy, and water systems in post-industrial urban settings, another study reported the findings of a workshop held for two compelling cases: Detroit, Michigan, and Baltimore, Maryland (Treemore-Spears et al. 2016). The workshop focused on sustainability of the food-energy-water nexus within the context of transitioning urban landscapes, economies, and governance processes associated with post-industrial cities. They reported that the issues of environmental, economic, and social sustainability and adapting WEF nexus approach were very challenging in these aged and deteriorating

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post-industrial cities. The study highlighted a number of measures that need to be taken in the two cities in order to promote sustainable food, water, and energy nexus. These measures involve the developments of effective partnerships and governance structures, addressing longstanding racial justice issues, adapting integrative WEF metrics to evaluate alternative models, and identifying suitable ways for renewal and development in transitioning urban landscapes.

Finally, not many studies were conducted related to smart cities and the WEF nexus in the Middle East region, especially in GCC. Therefore, this chapter will try to investigate this potential in Masdar City, Abu Dhabi Emirate, the UAE.

Smart Cities in Emirate of Abu Dhabi: Case of Masdar City

Masdar City Background

Masdar City is a sustainable urban development and economic free zone located about 17 km from downtown Abu Dhabi City, the UAE, with a total site size of 700 ha (7 km^2). The city provides a "green print" for cities of the future, with traditional Arabic architecture blending seamlessly with state of the art modern technology to maximize energy efficiency. It is an emerging global hub for knowledge, business, research and development, embodying Abu Dhabi's commitment to a sustainable future, and pioneering best practices in sustainable urban planning, design, development, and operation.

Masdar City delivers high-quality living and working environment with the lowest possible ecological footprint, striving to be a model of sustainable development where residents will want to live, work, and play. Designed as a cleantech cluster with special economic zone incentives, the city attracts companies to commercialize and deploy new energy technologies in the Middle East. Masdar City uses a number of green building rating systems to determine and verify the sustainability attributes of selected buildings. One such rating system is the Estidama Pearl Rating System (PRS), which is a mandatory requirement for all new buildings designed and constructed in Abu Dhabi.

In addition to the Estidama PRS, Masdar has used more internationally known green building rating systems such as Leadership in Energy and

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Environmental Design (LEED) in some cases. Masdar City hosts Masdar Institute of Science and Technology (now part of Khalifa University), Incubator building, International Renewable Energy Agency (IRENA) Headquarters, which has Estidama 4 pearl rating, Siemens Building, which was officially certified LEED Platinum for core and shell. The corporate sustainability enablers in Masdar are governance, culture, stakeholder engagement, performance management, management tools and systems, and reporting and communications. The sustainability performance themes of Masdar are workforce, economic development, products and services, environmental performance data, supply chain management, and community involvement (Masdar 2014).

UAE Context

The UAE is located in the southeastern part of the Arabian Peninsula, which is characterized arid climate, high temperatures (40–50°) and evaporation rates (2000–3000 mm/year) and scarce rainfall (<100 mm/year) (Alsharhan et al. 2001). On the other hand, the per capita water consumption in the UAE (364 liters per day) is among the highest in the world (UAE Ministry of Climate Change and Environment 2015), given the fact that UAE population increased from 4.5 million in 2008 to 9.6 million in 2015. Rapid economic development, population growth, and rising standard of living pose a great pressure on water, energy, and food resources in the UAE, especially that the country has limited natural water resources and limited local food production.

The challenge of meeting the growing water, energy, and food demands is further complicated by the impact of climatic change. The total water consumption in the UAE in 2013 was 4.2 billion m^3, of which 44% groundwater, 42% desalinated water, and 14% treated sewage water (UAE Ministry of Climate Change and Environment 2015). Between 2008 and 2012, the installed electricity capacity grew by 37%, and in 2012, the total installed capacity in the country reached 27.2 gigawatts (GW). In order to meet the growing demand of energy, the UAE has adapted diversification strategy across energy sources that extend beyond oil and gas, embracing renewable and nuclear power (UAE Ministry of Climate Change and Environment 2015). The UAE produced 21.2% of food demand and imported 78.8% in 2012 (Alpen Capital 2015). The Emirate of Abu Dhabi has seen its population grow rapidly from 212,000 in 1975 to 1.4 million in 2005. As of 2015 this figure stands at 2.8 million. The majority of these

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people live within Abu Dhabi City, an urban area. The urban population in 2015 was estimated at around 1.7 million inhabitants (Statistics Center-Abu Dhabi 2017).

The city of Abu Dhabi made many accomplishments over the last 50 years in support of the Emirate's urban vision. The initiation of the Plan Abu Dhabi 2030 and the establishment of the Abu Dhabi Urban Planning Council (UPC) in 2007 were key milestones that are now providing a strong foundation for sustainable urban planning within the city. Following the launch of the plan, the government issued the Abu Dhabi Vision 2030 in 2008, which has established a clear directive for the promotion of sustainable living and the implementation of sustainable practices. The primary objective of the vision is the diversification of the economy away from fossil fuel dependence. To enable this vision, the UPC is implementing the Capital 2030 Urban Structure Framework Plan, in an effort to optimize the city's development through a 25-year program of urban evolution.

Other key government strategic initiatives include the Maritime 2030: Abu Dhabi Coastal and Marine Framework Plan, which will establish a safe, secure and sustainable maritime domain for Abu Dhabi; the Abu Dhabi Economic Vision 2030, issued by the Abu Dhabi Council for Economic Development, in addition to the Abu Dhabi Environment Vision 2030, which has been issued by the Environment Agency-Abu Dhabi (EAD).

Estidama

Estidama, which means "sustainability" in Arabic, is the initiative which aims to transform Abu Dhabi into a model of sustainable urbanization (Abu Dhabi Urban Planning Council 2010). Its goal is to create more sustainable communities, cities, and global enterprises to balance the four pillars of Estidama: environmental, economic, cultural, and social.

The aspirations of Estidama are incorporated into Plan 2030 and other UPC policies such as the Development Code. Estidama is the first program of its kind that is tailored to the Middle East region. In the immediate term, Estidama is focused on the rapidly changing built environment. It is in this area that the UPC is making significant strides to influence projects under design, development, or construction within the Emirate of Abu Dhabi. One of Estidama's key initiatives is the PRS.

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The PRS for Estidama

The PRS for Estidama aims to address the sustainability of a given development throughout its lifecycle from the design phase through construction to operation. The PRS provides design guidance and detailed requirements for rating a project's potential performance in relation to the four pillars of Estidama (Abu Dhabi Urban Planning Council 2010).

The PRS is organized into seven categories that are fundamental to more sustainable development (Abu Dhabi Urban Planning Council 2010). These categories are as follows:

- *Integrated Development Process*: Encouraging cross-disciplinary teamwork to deliver environmental and quality management throughout the life of the project.
- *Natural Systems*: Conserving, preserving, and restoring the region's critical natural environments and habitats.
- *Livable Communities*: Improving the quality and connectivity of outdoor and indoor spaces.
- *Precious Water*: Reducing water demand and encouraging efficient distribution and alternative water sources.
- *Resourceful Energy*: Targeting energy conservation through passive design measures, reduced demand, energy efficiency, and renewable sources.
- *Stewarding Materials*: Ensuring consideration of the "whole-of-life" cycle when selecting and specifying materials.
- *Innovating Practice*: Encouraging innovation in building design and construction to facilitate market and industry transformation.

This rating system is mandatory for all proposed new developments in Abu Dhabi. The projects designed according to PRS criteria are expected to see reduced material, energy, and water consumption, as well as lowered carbon emissions and a decrease in construction waste, that keeps solid waste away from landfills. Since its launch in 2009, the Estidama Pearl Rating Program has awarded over 1400 buildings and 14,800 villas a Pearl Design Rating. The total areas covered by the program reached more than 22 million square meters as shown in Fig. 6.3, as well as training over 12,750 building professionals on the scheme and qualifying over 1900 professionals as Pearl Qualified Professionals (PQPs).

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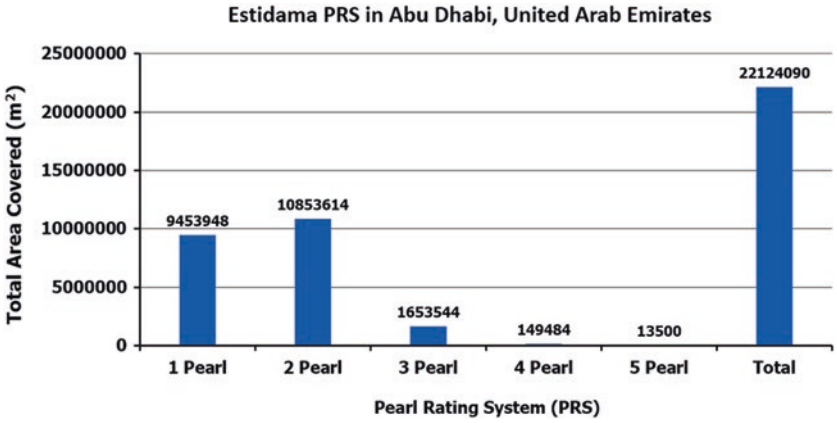


Fig. 6.3 Modified from Estidama statistics overview 2017 (UPC 2017)

Masdar City

Building on the Smart City Initiative Framework that was presented by Chourabi et al. (2012) and linking them to Masdar City sustainability enablers and performance themes, it can be seen that there are many similarities. In fact, WEF nexus in Masdar City is also in line with the framework in many ways. For example, in term of management and organization, smart city initiative is stressing on the need for clear and realistic goals, defined milestones, good communication, and measurable deliverable. Similarly, Masdar City is measuring the organization's sustainability performance against its stated objectives using Key Performance Indicators (KPIs) and using internal and external reporting and communications. From a technology perspective, ICT plays a vital part in both critical infrastructure components and services. Masdar City is using the latest ICT tools to manage and monitor the sustainable operation of the city.

Governance is important in both smart and sustainable cities. Currently at Masdar City, governance is relying on different committees in its decision-making mechanisms. Some of the committees include Masdar Executive Committee, Masdar Investment Committee, and Masdar Tender Committee. From a policy perspective, current Masdar City policies are mostly related to investors and the well-being of its residents and stakeholders, and do not currently include clear ICT policies. From the

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people and community perspectives, Masdar City is a leader on both higher level education (MIST), and stakeholders and community engagement (Sustainability Week, Zayed Future Energy Prize, and Young Future Energy Leaders program).

Economic competitiveness such as innovation, entrepreneurship, trademarks, productivity, and flexibility of the labor market and the integration in the national and global market is well defined in the smart city initiative. Masdar City plays an important role in the economic development of the country where high-tech companies, incubators, research and development institutions are hosted in order to create highly skilled workforce, and high-tech product and services. From the natural environment perspectives, the city is putting strong emphases on renewable energy, in addition to paper, energy, water, and waste management. Also, the Estidama PRS helps in the preservation of natural resources in the city especially in energy, water, and food. The use of a modern ICT infrastructure supports Masdar City's sustainability goals in the management of its natural resources, as detailed next.

Masdar City is working to position itself as a sustainable and livable city by connecting the physical, the ICT, the economic and social infrastructures. All these factors fit into the working definitions of a smart city (Albino et al. 2015). The use of technology to sustain and protect natural resources can also be linked with all other seven factors of the smart city initiative framework and also to WEF nexus approach since water, energy, and food are the major resources. Table 6.3 provides a comprehensive comparison between a smart city framework and that of Masdar City, in addition to linking these two concepts to the WEF Nexus.

While Masdar City is well known as a sustainable city, as shown in Table 6.3, it does fit the classifications of smart city framework. Since its establishment, Masdar City strategy was emphasizing both energy and water nexus. Recently, the food element became also important by initiating the Sustainable Bioenergy Research Consortium (SBRC) project. This project by itself links the food component to the already existing water-energy nexus approach. Masdar City, as a sustainable city, does meet most elements of a smart city while at the same time taking into consideration the WEF nexus. Masdar City can set a good example for future cities in the UAE and the Gulf Region.

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Table 6.3 Linking Masdar City to smart city concepts and WFE nexus approach

Smart city Initiative Framework Chourabi et al. (2012)	*Concepts*	
	Masdar City (Masdar 2014)	*Water-energy-food nexus in Masdar City*
Management and organization Project team skills and expertise, IT leader, clear and realistic goals, identification of relevant stakeholders, end-user involvement, planning, clear milestones and measurable deliverable, good communication, previous business process improvement, adequate training, adequate and innovative funding, and current or best practices review	**Performance management** Measuring the organization's sustainability performance is comprised of: Objectives, Key Performance Indicators (KPIs), and Targets **Reporting and communications** *Internal* The Masdar Times —published quarterly and distributed stakeholders The Source—this intranet platform for Masdar employees *External* Press releases, features, press, op-ed conferences, Q&As, forums, and interviews	Masdar City has the needed management skills and IT leadership and capability to apply the nexus in the city. In addition, one project, Sustainable Bioenergy Research Consortium (SBRC), is unique because it combines all the elements of the nexus in collaboration of all the stakeholders
Technology A collection of smart computing technologies applied to critical infrastructure components and services. Integrated hardware, software, and network technologies. Information and Communications (ICTs) are key drivers	**Management tools and systems** **SoFi**—Sustainability Management Tool **SafeQ**—Print Management Tool **CAFM**—Computer Aided Facilities Management Tool **EDMS**—Enterprise-Wide Document management system **Oracle Fusion**—Talent Management Tool **PDMS**—Masdar Program Development Management System **Tejari**—The Masdar e-Procurement Portal **ESRI ArcGIS**—Geographic Information System	ICT technologies are applied to the overall value chain of energy, water, and food nexus

(*continued*)

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Table 6.3 (continued)

Smart city Initiative Framework Chourabi et al. (2012)	*Concepts*	
	Masdar City (Masdar 2014)	*Water-energy-food nexus in Masdar City*
Governance Collaboration, leadership and champion, participation and partnership, communication, data-exchange, service and application integration, accountability, and transparency	**Governance** Masdar Executive Committee, Masdar Investment Committee, Masdar Tender Committee	Masdar City, Abu Dhabi Municipality (UPC and Estidama): Abu Dhabi Electricity and Water Authority (ADWEA) (energy and water utility) Environment Abu Dhabi (EAD) (environment) Abu Dhabi Food Control Authority (ADFCA) (food)
Policy Institutional readiness such as removing legal and regulatory barriers is important for smooth implementation of smart city initiatives. The understanding of the use of information systems in appropriate ways	**Sustainability policy** Drive innovation and operational efficiency Foster the growth and well-being of people Engage and respond to stakeholder expectations Invest in communities and people that support business Act as a responsible global citizen	Increase use of renewables for power and water desalination. Net metering and grid connection Estidama Pearl Rating System Using ICT to manage energy, food, and water sustainably
People and communities Digital divide(s), information and community gatekeepers, participation and partnership, communication, education, quality of life, and accessibility	**Culture** 100% ICT accessibility, Mubadala code of conduct, risk management, stakeholder engagement, community involvement, Masdar Institute, Abu Dhabi Sustainability Week, Zayed Future Energy Prize, The Young Future Energy Leaders (YFEL)	Using ICT in order to increase awareness and change behavior of city population toward sustainable management and monitoring of water, energy and food consumptions

(*continued*)

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Table 6.3 (continued)

Smart city Initiative Framework Chourabi et al. (2012)	*Concepts*	
	Masdar City (Masdar 2014)	*Water-energy-food nexus in Masdar City*
Economy **Economic competitiveness** Innovation, entrepreneurship, trademarks, productivity and flexibility of the labor market and the integration in the national and global market **Economic outcomes** Business creation, job creation, workforce Development, and improvement in the productivity	**Economic development** High tech companies, incubators, research and development, highly skilled workforce, and high-tech product and services	Economic growth Building renewable and water desalination sectors. In addition to biofuel and inland fishery resources
Built infrastructure IT infrastructure, security and privacy operational cost	Modern and advanced ICT infrastructure and competitive operational cost	To manage energy and water production, distribution, storage, consumption, billings
Natural environment The use of technology to increase sustainability and to better manage natural resources The protection of natural resources and the related infrastructure	Paper management Energy management Water management Wastewater management Construction waste management Operational waste management Solar power Sustainable transport solutions The Personal Rapid Transit System (PRT) Mitsubishi Electric Vehicles (EV) Biodiversity management Compliance management The Estidama Pearl rating system	Water use, efficiency, and recycling; renewable energy and energy efficiency; monitoring of climate, water, and soil data

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Conclusion

This chapter discussed the smart city framework and WEF nexus approach. In addition, it covered the linkages between smart cities and WEF nexus. Masdar City was taken as a case where its sustainability enablers were compared to a smart city initiative framework and the WEF nexus approach. The lessons learned from Masdar City can be a good guide for future smart cities in the Gulf Region. However, more efforts are still needed to make the city smarter and to improve the WEF nexus.

From the management and organization perspectives, more efforts are needed in having clear and realistic goals in ICT, business process improvement, adequate training, and current or best practices review. From the technology aspect, smart computing technologies linked to the critical infrastructure components and services are needed. Also, the integration of hardware, software, and network technologies in all the structures of the city are needed for the enhancement of ICT utilization to meet smart city requirements. To improve the governance in the city, more collaboration is needed between all the stakeholders in addition to communication, data-exchange, accountability, and transparency. Additional legal, regulatory, and other institutional amendments are needed to transform Masdar City into a smart one. The ICT infrastructure in Masdar City is modern and up-to-date but still needs to be enhanced to meet the requirements of a smart city, which in turn will ensure its efficient utilization in developing the sustainability aspect of the city.

Filling the above gaps in Masdar City will help its transition from a sustainable city into a smart city and will enhance the integration of the WEF nexus in the city. Masdar City is realizing the importance of WEF nexus where several research projects are initiated covering not only energy and water but also the food dimension.

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CHAPTER 7

Sustainable Transportation Infrastructure for Smart Cities in the Gulf Cooperation Council: The Case of Electric Vehicle Charging

Ashwin Kumar Balaji and Prashant Kumar Soori

Introduction

To date, there is no common consensus on the definition of smart cities. However, cities around the world are relying on information and communication technology as well as data analytics to solve various problems related to their development. The transportation sector has been under the radar for quite some time now, and major efforts are being put forth to diversify the type of fuels used to power vehicles. The global automobile industry encompasses both conventional as well as non-conventional powered vehicles. The market share of electric vehicles (EVs) is slowly increasing with companies like Tesla releasing cars that reach speeds and driving range comparable to gasoline-powered vehicles. Though EVs are

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_7

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touted as the next replacement for gasoline vehicles, widespread acceptance of EVs is still lacking as many concerns persist. Even though the market share of EVs has risen steadily over the years, its success in terms of mass adaptation highly depends on the availability of charging infrastructure and eliminating "range anxiety". This chapter focuses on eliminating these bottlenecks by introducing a proof-of-concept fast charging wireless system, which can provide a convenient and a safe way of charging EVs. Moreover, there has been a great deal of criticism regarding the use of fossil fuels such as natural gas for providing electricity for charging vehicles. This chapter seeks to address critics' views by attempting to implement this charging infrastructure via solar panels, a move that works well with a "Smart City" infrastructure plan.

EVs have been described as a "green" replacement for gasoline-powered vehicles and are placed at the helm of many smart city initiatives. However, falling prices of oil and high costs of owning and maintaining EVs have deterred many consumers from accepting EVs as an alternative mode of transport. In recent times, government subsidies in some countries have increased the market share for EVs. It has been calculated that it costs approximately six Arab Emirates Dirhams (AED) to travel 100 km in an EV with the current tariff in the UAE (Leon 2015). Even though the market share of EVs has risen steadily over the years, its success in terms of mass adaptation highly depends on the availability of charging infrastructure and eliminating "range anxiety". However, a major problem that still concerns current and potential EV owners is the lack of charging stations. As a result, most owners must invest in a wired charger that is installed in their personal garage space. Wired chargers can be problematic especially in harsh climatic conditions, where broken cables could cause leakage and damage essential Ground Fault Circuit Breakers.

As a result, unique charging technologies like an Inductive Power Transfer (IPT) system would be extremely useful and can eliminate the inconvenience caused by wired charging as well as make the charging process much safer regardless of weather conditions. This chapter focuses on eliminating these bottlenecks by introducing a fast charging wireless system, which can provide a convenient and a safe way of charging EVs. A software stack in the form of a mobile platform is also presented in addition to the charging infrastructure, as it provides an element of additional convenience to users. This is done by implementing a method of communication between the user, charging station and the EV. In the past, this technology has been utilized in wired charging stations such as Charge Point and WINSmartEVTM (ChargePoint 2016; Chynoweth 2015).

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Critics of EVs often point to the fact that the electricity used to charge EVs is produced from coal-fired and other conventional power plants. Since the UAE and a majority of Gulf Cooperation Council (GCC) nations are strategically located to receive sunshine for a majority of the year, solar energy is a viable alternative. The unveiling of the Shams-1 plant has helped the UAE move in the right direction toward powering homes using solely renewable energy (Shams 2016). However, most policy regulations in the GCC nations have historically focused on subsidizing fossil fuels or on large scale centralized generation of renewable energy. Recently, Silicon Valley giants, Tesla, officially launched their vehicles in the UAE. This move is a strategic one and will incredibly help the country push toward a "smart city" concept. In addition to launching their vehicles in the region, Tesla has also brought its supercharger network online in cities such as Abu Dhabi and Dubai (Lambert 2017).

Importance of Transportation in Smart Cities

For years, the term "smart city" has been used by policymakers, engineers, academics and public alike. But a clear term that encapsulates the essence of smart cities has not been decided upon till date. However, this indecision is most probably by design. The idea of a "smart city" is focused toward investments to upgrade or construct new infrastructure that can potentially give a city a competitive advantage over others (US Department of Transport 2014). With different cities having vastly different infrastructures and enjoying varying degrees of economic revenues, a standardized list of measures or upgrades cannot be reasonably applied in order to dub it a "smart city". Nevertheless, any city is designed with a simple goal in mind—to efficiently facilitate the movement of people, goods and ideas from one location to another in order to collectively improve the local or global economy.

As cities have grown, municipalities and urban planners have found it more challenging to offer efficient mobility services for the public. According to the United Nations, 70% of the world's population will be residing in city centers by 2050 (Dameri 2014). Assuring seamless mobility for the movement of people, goods and services will be key in order to realize the dream of a smart and eventually connected city. However, congestion and gridlock continue to be a hurdle in the growth of transportation in urban environments. A study conducted by the Centre for Economics and Business Research finds that congestion, on an average, is

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projected to cost the USA nearly US$150 billion by 2020 in addition to an increased unemployment rate due to the loss in productivity (Centre for Economics and Business Research 2014). In fact, the figures are not the best either for the GCC. In 2015, Dubai's traffic chief estimated an annual loss due to congestion in the UAE's emirate as AED 3 billion or roughly US$820 million (Badam 2015). Similarly, a report by the Qatar Mobility Innovations Center (QMIC) estimated an annual loss of 6 billion Qatari Riyals or US$1.6 billion in 2015 (Varghese 2016).

This increase in productivity losses due to increased congestion points to a particularly unsettling trend that could consequently harm the environment. With every passing moment spent stuck in a traffic jam, vehicles that are powered by conventional fuels release further harmful emissions. In current vehicles, constant acceleration and braking in a stop-and-go traffic jam situation result in burning more fuels, thereby releasing more emissions. On an average, residents in Qatar seem to spend almost four and a half days per year stuck in traffic, according to a report by the QMIC (Anderson 2017). Unfortunately, there is a human cost associated with this increased pollution, as people would need to invest more in healthcare as a result. This is normally estimated in overall traffic costs for any given country within indirect congestion costs. Direct costs, on the other hand, are attributed to a greater frequency in refueling costs due to an increased vehicle idling time while indirect costs are also likely to include other productivity losses.

In order to reduce these problems, smart engineering solutions that combine technology and data analytics are sought after. For instance, research is being conducted in Carnegie Mellon University on a smart adaptive system for traffic lights depending on a connected system of sensors to estimate real-time traffic flow through any junction (Carnegie Mellon University 2017). Preliminary unpublished results show that this system could potentially reduce vehicle wait time by 40% while simultaneously reducing tailpipe emissions from these vehicles. However, one particular technology is gaining increasing traction in the transportation industry—fully autonomous vehicles. Given the interest from high profile companies such as Google, Tesla and Uber, autonomous vehicles (AVs) have become the latest trend, combining data analytics, robotics and computer vision to safely transport people from one place to another—essentially becoming the new face of the transportation industry.

In this chapter, AVs refer to Level 4 vehicles as described by the National Highway Traffic Safety Administration (Kearns 2016). Intuitively, it is

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natural to think that by eliminating human input, AVs are bound to improve vehicle efficiency, decrease emissions while also improving fuel efficiency and air quality. However, there is an element of uncertainty associated with the use of AVs. Even though AVs are potentially an ideal solution for a connected smart city in the GCC region, certain fundamental issues do need to be taken care. As the opportunity cost of driving falls, rebound effects can potentially arise that drastically affects the vehicle miles traveled (VMT). Since more people realize the convenience associated with commuting by a mode of transport that allows an individual to get to their destinations hassle free and with minimal effort, more trips can be taken that in turn affects the VMT. Consequently, all or a majority of vehicles in use in a future GCC smart city should be either automated or possess a vehicle-to-vehicle communication system in order to truly reduce the effects of congestion. This is because, initially, low penetration of AVs may actually increase congestion because the AV would have to respond to behaviors of other non-automated vehicles on the road. So policymakers and manufacturers need to determine an ideal timeline for introducing these vehicles in normal roads if the harmful effects of congestion are ever to be removed in any future GCC smart city. Currently, Masdar city in the UAE uses driverless pods to transport people to various locations in the city. While this is a promising sign for the region, these pods operate in a controlled environment and real-world effects of this technology have still not been put to test.

Currently, since AVs are essentially vehicles without any or minimal human input, there is absolutely no direct effect on the type of fuel being used to power the vehicle. While the advent of AVs can certainly improve fuel efficiency, efforts would need to be taken to diversify fuel sources in order to truly reduce emissions. For many scientists and policymakers, driverless vehicles and alternative fuels go hand in hand. According to research conducted by Greenblatt and Saxena, Battery Electric Vehicles offer the least Greenhouse Gas emission intensities followed by Hydrogen Fuel Cell Vehicles, Hybrids and then Petroleum-powered vehicles (Greenblatt and Saxena 2015). Thankfully, this trend seems to be catching on in the GCC with more manufacturers making their versions of an EV available in the region. Unsurprisingly, the cost of ownership of an EV over the lifespan of the vehicle is a lot lower than its gasoline counterpart. Assuming a car travels nearly 15,000 miles (24,140 km) every year over a period of 15 years, the normalized cost of ownership per mile traveled over the years would be lesser for an EV as compared to its gasoline counterpart

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after taking initial capital, average fuel/electricity, insurance and maintenance costs into account (this analysis would remain consistent for the GCC region).

This transition to diversifying the fuel mix for transportation is going to be an important policy decision governing the smart city movement in the GCC. However, transitioning to any alternative transportation fuel entails building infrastructure that can sustain growth and operation. This chapter focuses on an innovative wireless charging infrastructure for EVs since these systems can potentially improve the charging experience for an EV user while being robust enough to cater to autonomous vehicles in the future as well. The following sections deal with how these systems work and then transitions into how a wireless charging infrastructure can play a role in smart cities in the GCC.

Importance of Charging Infrastructure for Market Adoption of EVs

As observed from previous sections, EVs provide a wealth of benefits and are bound to play a key role in the future of smart cities in the GCC. However, in order to ensure successful market adoption of EVs, one must look into issues that keep the general public from transitioning to an EV today. One common factor that pops up in a majority of perception surveys for EVs is the lack of charging infrastructure. The game changer in this scenario is that the gas station model, which is numerous and dispersed, will have to be slowly transitioned to a series of "plug points" that a nation's grid infrastructure powers. It is unclear whether an outburst in charging stations helps increase EV adoption, or if an increase in EV adoption warrants a more intricate network of charging infrastructure. What is clear is that when the transition to electrified vehicles does occur, this would involve considerable adjustments on the part of the user. Currently in today's market, the following type of chargers/charging standards exist:

(i) *Level 1 charging* (*home charging*): This is the most basic charging standard available in today's EV market. Vehicle owners would have to simply plug their car into a standard household outlet. This particular charging standard is the slowest charging available and is estimated to add about 4 miles (6.4 km) per hour of

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charging. Putting this into perspective, a Tesla Model S P90D owner would have to spend nearly three days to charge his/her vehicle from flat empty to full charge.

(ii) *Level 2 charging* (*alternating current*, *AC, charging*): This particular charging standard supplies 240 V to the EV. Such standards usually involve an EV user to invest in an "Electric Vehicle Service Equipment" (EVSE). EVSE is basically any device that supplies AC power, converts it into DC and subsequently fills a vehicle's battery. Such chargers are more efficient than Level 1 chargers and vary in the number of miles that are provided for every hour that an EV is plugged in. Usually, these chargers supply anywhere between 10 and 30 miles (between 16 and 48 km) per hour of charge and vary by the manufacturer type.

(iii) *Level 3 charging* (*Fast Charging*): "Level 3" charging, as mentioned in a few journals and articles, is actually a misnomer since these types of chargers are responsible for directly supplying DC power to the vehicle's battery (they bypass the vehicle's onboard charger and supply power to the battery via a special port). The speed at what these chargers supply an EV depends on how much residual charge is left in a battery (the same principle applies to other charging types as well). When the vehicle's battery is empty, the speed of charging is a lot faster since electricity can flow at a rapid pace. As the battery "fills" up, the charging rate tapers slowly due to the battery's charging characteristics. DC fast chargers currently come in three varieties: CHAdeMO chargers used by the Asian car manufacturers, SAE Combo (CCS) chargers used by the German and US manufacturers and lastly the Tesla supercharger.

However, with the quest for automated and connected vehicles heating up, wired chargers like the ones mentioned above do not provide that level of convenience or connectedness that most EV users desire. Recently, wireless chargers are seizing this market opportunity and almost all major EV manufacturers are testing some version of these wireless chargers. The following sections cover some fundamental principles of how these chargers work followed by how such chargers can play a role in a smart city context.

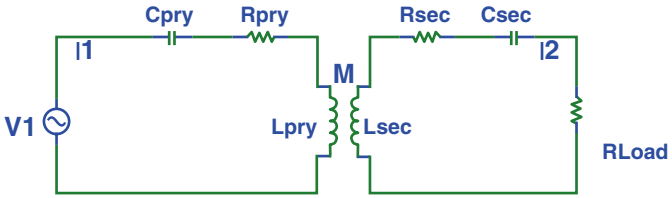
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Fundamentals of Wireless Charging Infrastructure for EVs

Essentially, when an AC powers a copper coil, it produces a short-range magnetic field. When a second coil is brought in the vicinity of this field, electrons are transferred to it thereby resulting in power being transferred wirelessly. More number of electrons tend to jump to the de-energized conductor if the frequency of electron transfer is higher, that is, if the frequency of the operating AC is high (not limited to the standard 50/60 Hz commercial supply). However, if the distance between the first and the second coil increases, the power being transferred decreases as well. In order to transfer power wirelessly over larger distances, it has been experimentally determined that the phenomenon of resonance should be employed (Chopra 2011). As a result, the energized coils should be tuned to the same frequency and to achieve this, the operating frequency of the AC signal is usually in the kHz range, achieved by using a high-frequency voltage source inverter. However, as frequency increases, the impedance seen by the source will become more inductive in nature and will correspondingly reduce the efficiency of the IPT system. To counteract this, a system of capacitors termed as compensation capacitors are added to the transmitter and receiver circuits, one to reduce the apparent power rating of the source, thereby reducing costs, and the other to cancel the receiver coil's reactance thereby improving the efficiency (Zhang and Mi 2016).

There are four topologies that exist for a compensation capacitor—namely Series–Series (SS), Series–Parallel (SP), Parallel–Series (PS) and Parallel–Parallel (PP). For EV applications, SS topology is the most preferential since it has the highest tolerance for misalignment between the transmitter and receiver coils (Chopra 2011). Figure 7.1 shows the SS compensated IPT system connected with a resistive load (power electronics are not displayed in Fig. 7.1). As shown in Fig. 7.1, I_1 and I_2 are the primary and secondary AC currents while V_1 and V_2 are its corresponding primary and secondary voltages. R_{pry} and R_{scc} are the internal resistances of the inductive couplers while L_{pry} and L_{scc} are its self-inductances. It is advantageous to have a higher value of mutual inductance (M) between the coils while operating at a specific high-frequency ω. C_{pry} and C_{scc} are the compensation capacitances of the SS system along the transmitter and receiver ends, respectively. On performing simple circuit analysis, the design parameters for the IPT system are derived as in Eqs. 7.1 and 7.2.

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V1- Source AC voltage (from high frequency inverter)
I1- Primary Current
C_{pry}- Primary Compensation Capacitance
R_{pry}- Winding resistance of primary coil
L_{pry}- Self-inductance of transmitting coil
M- Mutual Inductance of coupling
L_{sec}- Self-inductance of receiver coil
R_{sec}- Winding resistance of secondary coil
C_{sec}- Secondary compensation capacitance
I2- Secondary current
R_{Load} -Load Resistance

Fig. 7.1 Circuit diagram of SS compensated IPT system

$$I_2 = \frac{j\omega M}{\left(R_{sec} + R_{Load}\right) + j\left[\omega L_{sec} - \dfrac{1}{\omega C_{sec}}\right]} I_1 \tag{7.1}$$

$$V_1 = \left(j\omega L_{pry} + \frac{1}{j\omega C_{pry}} + R_{pry}\right) I_1 - \left(j\omega M\right) I_2 \tag{7.2}$$

The efficiency of the SS compensated system is given in Eq. 7.3.

$$\eta = \frac{P_{output}}{P_{input}} = \frac{R_{Load}}{\left[R_{sec} + R_{Load}\right]\left[1 + \dfrac{R_{pry}\left[R_{sec} + R_{Load}\right]}{\omega^2 M^2}\right]} \tag{7.3}$$

For any compensation topology, the secondary capacitance is chosen first in order to ensure that the receiver operates at the resonance frequency as shown in Eq. 7.4.

$$C_{sec} = \frac{1}{\omega^2 L_{sec}} \tag{7.4}$$

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Since SS-compensation topology is chosen for the proposed Wireless Power Transfer (WPT) system, the primary capacitance used to reduce the VA rating of the transmitting inverter is defined as in Eq. 7.5.

$$C_{\text{pry}} = \frac{1}{\omega^2 L_{\text{pry}}} \tag{7.5}$$

In a practical IPT system, the voltage drops across the capacitors will be quite profound. The primary capacitance will have a constant voltage drop while the drop across the secondary capacitance is dependent on the secondary power ratings. For AC pulse operations, a metallized polypropylene type capacitor is an ideal choice and a voltage rating of about 20% of the maximum voltage drop should be typically considered. A prototype charger was set up at Heriot-Watt University, Dubai to examine the practical functionality of this charger. The charger was set up to transfer 150 Watts of power and achieved a transfer efficiency of 96%. Figure 7.2 shows a practical setup of the IPT system followed by the prototype rover fitted with a supercapacitor bank as the storage medium.

Intelligent IPT Systems Proof-of-Concept for Connected Smart Cities

Although IPT solutions exist in today's market, widespread deployment of this technology is still in its early stages. Intelligent charging systems could be a useful addition that could provide a seamless experience for an EV user, while also monitoring the charging station's energy consumption. This section proposes a unique IPT charging station that can switchover between the grid and solar panels that are integrated into parking sheds/canopies.

Ideally, IPT stations should charge EVs when the local demand is low. However, the charging patterns of most EV users indicate that EVs are usually charged at night, increasing the demand from the local utility. In order to make the charging station more flexible and save utility companies from investing in expensive upgrades to the grid, renewable energy sources such as solar energy would be useful in providing charge to the EV. During daytime, when there is abundant sunlight, the panels would generate and store electricity by means of a charge controller and storage battery while also providing shade to EVs.

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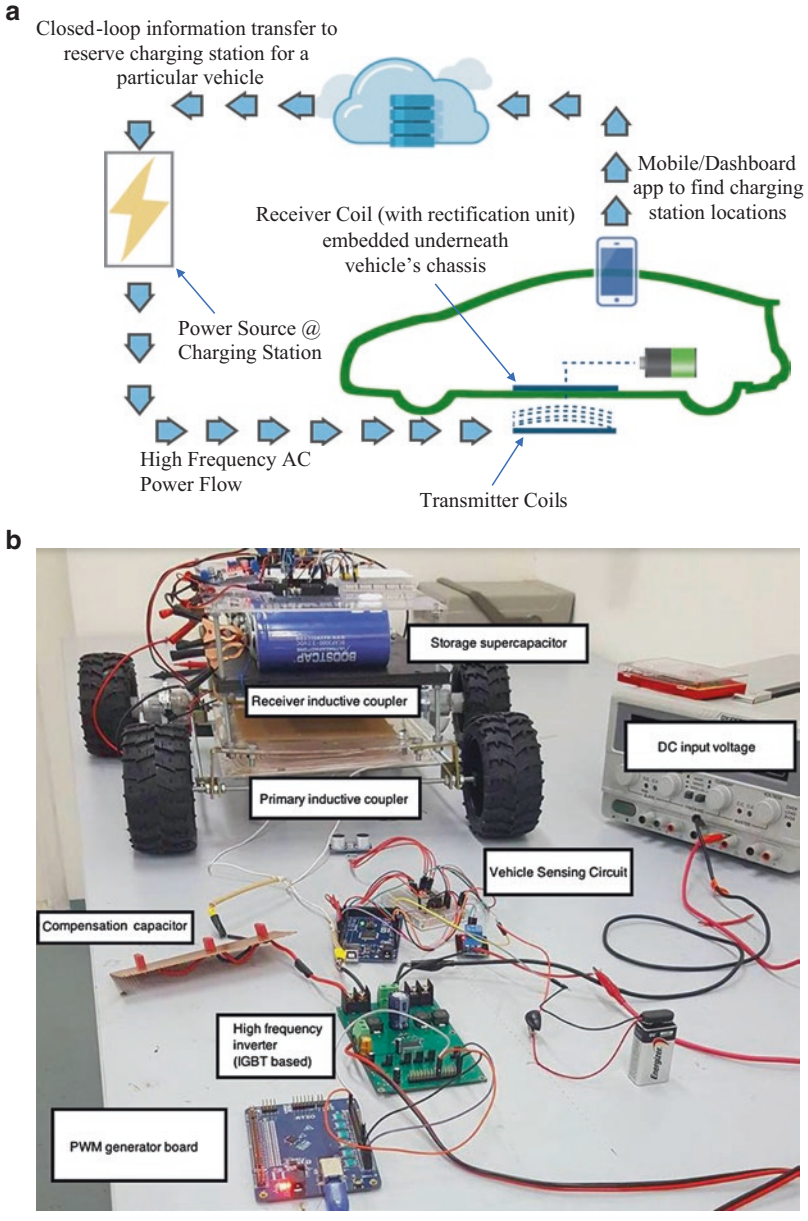


Fig. 7.2 (**a**) A typical IPT configuration for an EV; (**b**) Prototype of the IPT system

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In addition to energy storage, this system will utilize Internet of Things (IoT) technology that expands on the controlled charging model for EVs. The system will revolve around a central microcontroller unit (MCU) that communicates with a server through the Internet or the Cloud. These IPT stations will also be fitted with global positioning system (GPS) tracking capability, which would allow users to search for nearby stations through machine–machine communication link using mobile phones or the vehicle's instrumentation panel. Figure 7.3 displays the proposed IPT network. The following sequence of steps occurs in the proposed system:

- Once the EV reaches the charging station, a sensor (infrared) would detect the presence of a vehicle and request for authorization from the vehicle user through cell phone to pair with the transmitting station.
- Following this, pairing is accomplished by linking the vehicle with the charging station via a mobile app or the vehicle's onboard electronics (vehicle dashboard). This in turn will obtain vital information such as the vehicle's model number and battery capacity.
- After pairing is accomplished, the battery management system in the EV transmits its data to the transmitting station. So the MCU on the transmitter side pairs with the server and receives all the information about the battery such as the state of charge and the time needed to reach full charge.
- Once the estimated time of charging is calculated, the MCU on the transmitter side relays this information to the EV. On the EV, the user will visualize this information and will be able to choose the way he/she wants to charge (e.g., maximum charge, time-scheduled charge or charging up to a particular percentage).
- After a choice is made, the information is relayed to the MCU, which sends the corresponding signal to a changeover switch, initiating the wireless charging process. Once charging is completed, the user will be notified of its completion.
- Meanwhile, the server collects information about the real-time and predicted electricity demand metrics from the utility. Whenever the demand is high, the supply will be automatically switched to solar energy, if sufficient solar radiation is available.
- A separate charging meter installed onboard an EV or within the user's phone is more beneficial as it is possible for the user to be billed according to each charging session. This system would be suitable as users would be billed after each charging session and can be payable through their mobile phones.

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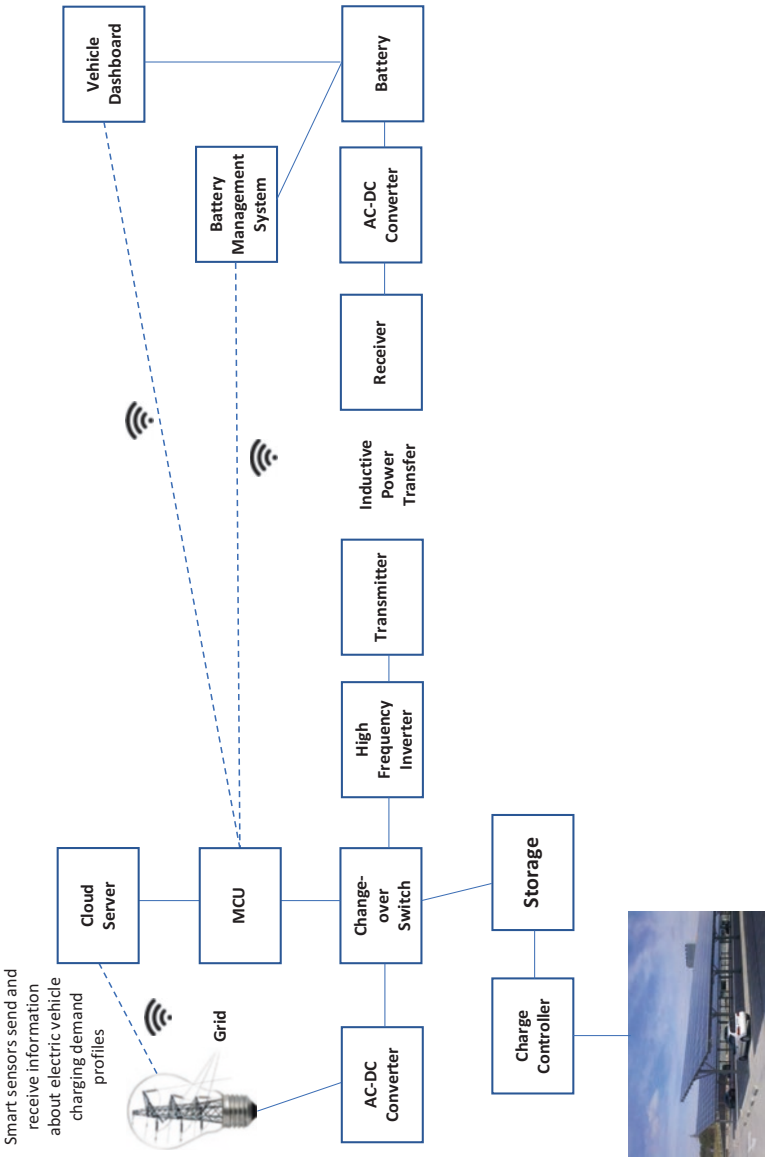


Fig. 7.3 Proposed IPT network

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Conclusion

This chapter starts off by making a case as to why smart transportation is needed for smart cities in GCC nations. Essentially, with increasing urbanization, more congestion and traffic roadblocks result in adversely affecting the local and global economy. Hence, disruptive technologies, such as adaptive signal lights or autonomous vehicles, can alleviate these problems by introducing a smart and connected way to efficiently contribute to a nation's growth. The chapter then presents a comprehensive review of IPT systems along with a detailed analysis of how circuit parameters can be calculated for powering an EV using the SS-compensation topology. An IPT system powered by solar canopies has been proposed and the charging strategy has been discussed for such a system. A 150 W prototype was constructed to validate the discussed principles and a supercapacitor was used as a storage medium for the transferred power. Ultimately, in order to reduce environmental impacts from the use phase of EVs, the UAE along with other GCC nations should invest in diversifying their energy portfolios in a quicker timescale. While many GCC nations such as Saudi Arabia, Qatar and the UAE have put forth strategic plans to diversify their energy resources by the 2030s, more steps can be certainly taken to quicken that timeline. For instance, GCC nations can encourage distributed energy programs like rooftop solar PV panels that can not only reduce the burden on the operating power plants but can also provide backup on hot days when generation capacity struggles to meet energy demands. Such programs can quicken the energy diversification process and will also reduce investments required by the federal government themselves. Starting with investments in transportation infrastructure and supporting further R&D programs can accelerate GCC's push for smart cities, opening up avenues for expansion of both local and global economies that will benefit all GCC nations greatly.

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CHAPTER 8

Intelligent Energy Management Within the Smart Cities: An EU-GCC Cooperation Opportunity

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Introduction

Smart Energy Cities (SECs) are expected to play a key role in the implementation of Europe 2020 Strategy and the European growth strategy for the current decade, along with its flagship initiatives. SEC is also expected to address a number of challenges toward the European Union (EU) 2030 Framework for Climate and Energy. In the Gulf Cooperation Council (GCC) region, there are strong governmental programs for extended smart energy deployment, while a number of smart cities projects exist already and numerous new smart energy city initiatives are planned for the near future. A general remark, regarding all GCC countries,

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_8

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is that intelligent energy management within these smart cities is not yet well established and respective systems are still in their early stages.

Information and Communication Technologies (ICTs) are mostly used by energy/facility managers, Energy Service Companies (ESCOs) and specialists, who take decisions based on the information they get. However, the buildings' occupants (energy end-users) are often excluded from this process. Although buildings' occupants seem to be gaining greater awareness of the value and need for sustainable energy practices, they do not necessarily behave in a more energy-conscious way. ICT-based systems that exploit Internet of Things (IoT) technologies can contribute significantly to energy saving, by motivating and supporting behavioral change of the buildings' occupants.

In this context, the main aim of this chapter is to present an "app-in-context" framework, extending sophisticated ICT-based energy management systems in order to empower occupants to engage in energy efficiency through behavioral change. Innovative user-friendly applications are proposed to convert data from smart meters into value for the buildings' occupants, through actionable personalized information, recommendations and incentives for behavioral energy efficiency. The personalized persuasive suggestions are coupled with an innovative reward incentive mechanism (using energy currency) in order to nudge end-users into more efficient usage of energy consuming devices and enhance participation and effectiveness of energy conservation actions. The proposed "app-in-context" framework can support energy companies from EU and GCC to acquire and retain energy consumers, as well as improve consumers' satisfaction through the innovative reward program.

Cities are often defined as the next frontier for the development of sustainable energy, where the efforts toward sustainable development and the respective initiatives are localized on a city level—namely the sustainable city. A sustainable city, or eco-city, is thus a city designed with consideration of the environmental impact, whose inhabitants prioritize resource management of energy, water and food inputs, limiting the corresponding waste output of heat, air and water pollution.

These operations are grounded on the utilization of ICTs toward sustainability, eventually leading to an enhanced quality of life via active engagement (KPMG 2015). According to IHS Technology (2014), the number of smart cities will be more than tripled over the next decade, at a worldwide level. The modern revolution of IoT and the roll-out of numerous smart devices and smart sensors have laid the foundations for developing innovative methodologies and tools for monitoring and

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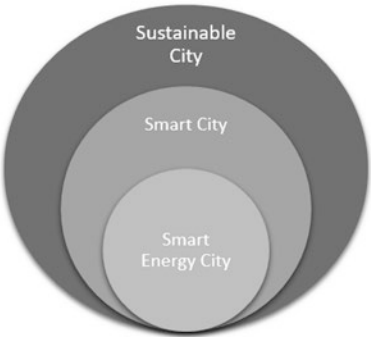


Fig. 8.1 Relationships between smart energy city, smart city and sustainable city

managing the energy use more efficiently. These tools can be applied by city authorities and energy managers to achieve financial, environmental and social targets.

SEC, as a core pillar of the smart cities, constitute an emerging urban development strategy, that incorporates these technologies and takes advantage of their numerous capabilities in the context of energy efficiency and sustainability (Fig. 8.1) (Glick et al. 2012; Van Landegem 2012). SEC are expected to play a key role in the implementation of Europe 2020 Strategy, the European growth strategy for the current decade, and its flagship initiatives, as well as to address a number of challenges toward the EU 2030 Framework for Climate and Energy (EC 2010). In the GCC region, there are strong governmental programs for extended smart energy deployment, while a number of smart cities projects exist already and numerous new smart energy city initiatives are planned for the near future. A general remark, regarding all GCC countries, is that intelligent energy management within these smart cities is not yet well established and respective systems are still in their infancy.

Indeed, optimizing the energy use in cities and buildings is a current research and business trend. Although numerous initiatives and ICT-based solutions exist, most of them focus on energy/facility managers, ESCOs and specialists, who take decisions based on the information they get. ICT-for-companies are very sophisticated systems (Building Energy Management Systems—BEMS, process analysis, etc.), which cannot be handled by the occupants (including households, employees and other buildings' occupants).

In order to achieve significant energy savings in the SEC context, appropriate energy efficiency measures have to be adopted by the big majority of the final energy end-users. ICT-based solutions that exploit

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IoT technologies can contribute significantly to energy saving, by motivating and supporting behavioral change of the buildings' occupants. However, the buildings' occupants are excluded from this process and although they seem to be gaining greater awareness of the value and need for sustainable energy practices, they do not necessarily behave in a more energy-conscious way.

ICTs that are aimed at facilitating the occupants' understanding of the building performance, and providing personalized motivation and support suited to their knowledge and experience, would help them to understand how a change in their behavior could contribute to reduced energy costs. Innovative user-friendly digital applications are therefore necessary to leverage data from smart meters into value for the buildings' occupants through actionable personalized information, recommendations and incentives for behavioral energy efficiency. These apps would simplify the complexity of the information gathered by those systems, and put it on the hands of energy end-users, in context (e.g. the end-user might want to know how to improve the building behavior when he/she is in the building, performing a specific action).

The main aim of this chapter is to present an "app-in-context" framework in order to bridge the gap between ICT-for-companies and occupants, making use of data captured from smart meters, sensors and appliances, as well as energy end-users' feedback. Innovative user-friendly applications are proposed to convert data from smart meters into value for the buildings' occupants, through actionable personalized information, recommendations and incentives for behavioral energy efficiency. More specifically, the personalized persuasive suggestions will be coupled with an innovative reward incentive mechanism (using energy currency), in order to nudge end-users into more efficient usage of energy consuming devices and enhance participation and effectiveness of energy conservation actions.

Apart from the introduction, the chapter is structured along four sections. Section "Smart Cities in the EU and GCC Context" provides the respective context of SEC initiatives in the EU and GCC. Section "Motivating Behavioral Energy Efficiency through Intelligent Energy Management" analyzes the options and solutions for using intelligent applications to engage the energy end-users. Section "Proposed Experimental Evaluation of Energy Currency" explores how ICT, local renewable energy generation and electronic local currency systems can provide a potentially powerful tool both for energy management and planning but also for local community empowerment and revitalization. An

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indicative example of energy currency concept in behavior energy efficiency is presented in the section "The Energy Currency Concept in Behavioral Energy Efficiency". Finally, the last section summarizes the key issues that have arisen in this chapter.

Smart Cities in the EU and GCC Context

The EU Perspective

During the last decades, the EU has set a clear strategy toward sustainable energy development via binding targets till 2020 and beyond. Specifically, the commitment includes a 20% reduction target of CO_2 by 2020, 40% by 2030 and an optimistic objective of further reduction of CO_2 up to 80–95% by 2050 (leading to carbon neutral cities). The 2012 Energy Efficiency Directive (2012/27/EU) establishes a set of binding measures to help the EU reach its energy efficiency targets. Under the Energy Efficiency Directive, EU countries must set up an energy efficiency obligation scheme. This scheme requires energy companies to achieve yearly energy savings of 1.5% of annual sales to final consumers (EC 2017a).

Moreover, the EU aims to replace at least 80% of its electricity meters with smart meters by 2020, wherever it is cost-effective to do so. This smart metering and smart grids roll-out can reduce emissions in the EU by up to 9% as well as annual household energy consumption by similar amounts. To measure cost-effectiveness, EU countries conducted cost–benefit analyses (CBA), based on guidelines provided by the European Commission. A similar assessment was carried out on smart meters for gas. Indeed, and based on the respective report for the findings from the CBA of a widespread roll-out of smart metering systems performed in various Member States (MS) (ICCS-NTUA and AF Mercados EMI 2015), the key driver of benefits in most cases is the energy efficiency and shifting benefits (e.g. electricity cost savings) available to customers.

In addition, significant debate on SEC and their benefits to both enterprises and final consumers, deriving from more dispersed energy systems and greater resource efficiency in the cities, has supported increased awareness (Griffiths 2016).

Moreover, the greatest EU Research and Innovation Programme, the Horizon 2020 Programme (EC 2017b), has as one of the main objectives the energy challenge through the implementation of smart European electricity grids, the reduction of energy consumption, and the utilization of energy and ICT innovation technologies on a city level.

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The Covenant of Mayors for Energy and Climate (Covenant of Mayors 2016), one of Europe's flagship initiatives and the "world's biggest urban climate and energy initiative" according to European Commissioner Miguel Arias Cañete, has received great attention during the previous years. It currently expands its geographical scope outside the European borders in order to transfer the valuable knowledge already gained to other regions (e.g. Sub-Saharan Africa). A number of Sustainable Energy and Climate Action Plans (SECAPs) have also been submitted in which the Covenant signatories outline how they intend to reach their long-term CO_2 reduction target (Covenant of Mayors 2016).

In addition to the above, there is a series of ongoing initiatives promoting the smart energy city concept. More specifically, a new European Innovation Partnership (EIP) on smart cities and communities (SCC) (EC 2012) was launched in July 2012 to promote the deployment of smart city solutions in Europe, focusing on the intersections of ICT, energy and transport. Cities themselves have also taken a pro-active role and launched the Green Digital Charter in 2009. The idea is that the cities signing up to the Charter commit to reduce the carbon footprint of their ICT and roll-out ICT solutions which lead to more energy efficiency in areas such as buildings, transport and energy. The Smart Cities Stakeholder Platform aims to support EU to achieve the target of 80% reduction of Greenhouse Gas (GHG) emissions by 2050 through promoting the development and market deployment of energy efficiency and low-carbon technology applications addressed to the urban environment.

The European Energy Research Alliance (EERA) Joint Programme on smart cities was launched in September 2010. The main scope of the program is to promote the development of tools and methods to enable a more sophisticated design, planning and operation of the energy system of a city in the near future.

The CitInES initiative (design of a decision support tool for sustainable, reliable and cost-effective energy strategies in cities and industrial complexes) aims to design innovative energy system modeling and optimization algorithms to allow end-users to optimize their energy strategy using data sources on local energy generation, storage, transport, distribution, and demand, including demand-side management and functionalities enabled by smart grid technologies. CitInES integrates information about local renewable energies, smart grid integration and demand-side management, as well as fuel price uncertainties (Page et al. 2013).

The framework of the ICT Roadmap for Energy Efficient Neighbourhoods (IREEN) initiative examines the ways that ICT for

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Fig. 8.2 EU and GCC perspectives

energy efficiency and performance can be extended beyond individual homes and buildings to the wider context of neighborhoods and communities (IREEN 2013).

Networking intelligent Cities for Energy Efficiency (NiCE) promotes the implementation of commitments to the Green Digital Charter, through the exploitation of future Internet technologies for the development of Smart Energy infrastructures, enabling new functionality while reducing costs (Fluhr and Williams 2011).

ENPROVE (Energy consumption prediction with building usage measurements for software-based decision support) provides an innovative service to model the energy consumption of structures supported by sensor-based data. The service makes use of novel ICT solutions to predict the performance of alternative energy-savings building scenarios in order to support relevant stakeholders in the procedure of identifying optimal investments for maximizing energy efficiency of an existing building (ENPROVE 2013).

Some of the most important EU and GCC initiates are illustrated in Fig. 8.2.

The GCC Perspective

In the GCC region, there are strong government programs for extended smart energy deployment, while a number of smart cities projects exist and numerous new smart energy city initiatives are planned for the near future. Moreover, researchers are strongly interested in these fields and respective

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assessments and comparisons between smart GCC cities are available in the literature (Tok et al. 2015).

Masdar City in Abu Dhabi constitutes an illustrative example of a smart energy city, as being a master-planned sustainable energy city developed as a greenfield project from scratch, thus representing a testing field for renewable energy innovations. The city is relying on solar, mainly, and other types of renewable energy sources in order to electrify the entire city. Some of the smart energy elements of Masdar City incorporate, among others, the reduction of buildings' energy consumption by 40% through intelligent design and the development of an electric vehicle ride-share program (Monitor Deloitte 2015).

The Silicon Park by the Dubai Silicon Oasis Authority, in Dubai, constitutes a complete smart city project that includes also smart energy elements and the King Abdullah Economic City, very close to Jeddah, is a brand-new city designed on social, economic and environmental sustainability pillars (Monitor Deloitte 2015).

The Smart Dubai is an initiative started in March 2014 with the main aim to transform Dubai into the smartest city in the world by 2017. A main pillar of this initiative is the efficiency and optimized use of city resources. Moreover, in the plans of the Dubai Electricity and Water Authority (Dewa) is to create a "smart electrical grid" that encourages citizens to use solar energy and sell the surplus to the government via the power network (Monitor Deloitte 2015). In addition, several campaigns have been organized by Dewa for consumer's awareness raising about the rational use of energy for cooling (Karlsson et al. 2015).

Moreover, Kuwait's State Minister for Housing Affairs, Yasser Abdul, stated that the adaptation of the "Smart Cities" plan within the new housing projects in the GCC region is aimed at the rationalization of energy usage at large (Arabnews 2016).

Motivating Behavioral Energy Efficiency Through Intelligent Energy Management

The Concept

It is argued that there is significant potential of a broad variety of energy-related and other data generated, when made available in a smart energy city, to perform various types of analyses to achieve a significant reduction of energy consumption in city premises (Androulaki et al. 2016). The successful combination of smart processes (e.g. real-time consumption management, smart automation, etc.) and smart technologies (e.g. smart meters,

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intelligent energy management devices, etc.) would enable energy efficiency and savings to be achieved (Marinakis et al. 2017). Moreover, the exploitation of intelligent systems, ICT tools and intelligent energy-related application can prove highly beneficial to citizens by empowering their energy consciousness and their overall understanding about their energy behavior and its impact (Doukas et al. 2016). The energy end-users' engagement in the context of SEC has the potential to produce significant impact on the reduction of energy consumption, energy cost and environmental footprint. This can be realized by taking advantage of a plethora of data generated through IoT technologies, smart homes, smart vehicles, wearables, smartphones and smart energy meters, along with data about the weather conditions, buildings' energy profiles, feedback provided by occupants, energy prices, energy production and other.

In this context, three user-centered applications are presented which can empower energy end-users to engage in achieving energy efficiency (Fig. 8.3). The personalized energy applications can be easily deployed and integrated with existing systems and infrastructure, in order to moti-

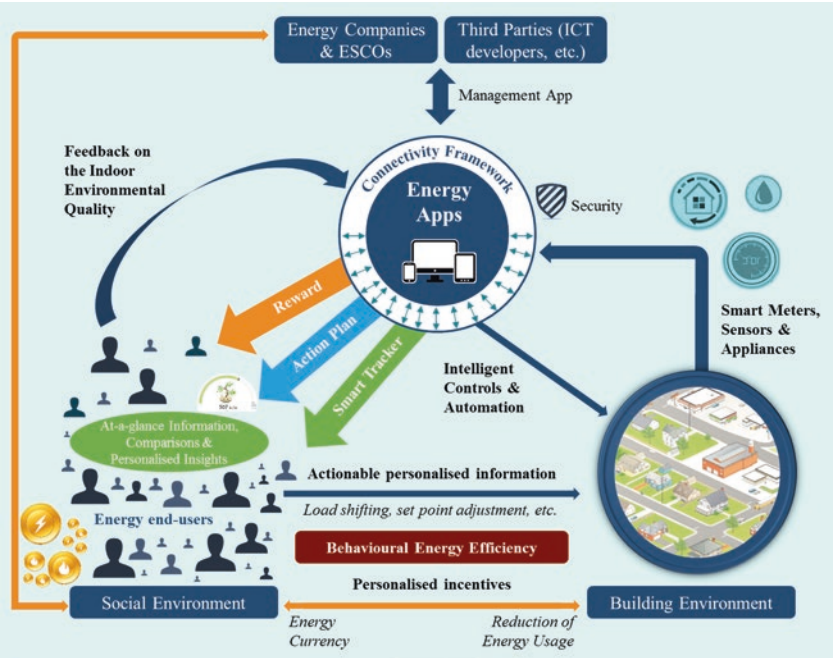


Fig. 8.3 User-centered applications

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vate and support behavioral energy efficiency. The overall concept is to leverage the available multidisciplinary data and turn that information into value for the end-user through actionable personalized recommendations and incentives for behavioral energy efficiency. The key functionalities of such intelligent applications that are characterized as essential for the energy users' engagement are identified and divided in three main axes, energy monitoring ("Smart Tracker" App), energy management ("Action Plan" App) and incentives for behavioral energy efficiency ("Reward" App).

The user-centered applications will allow EU and GCC energy companies and ESCOs to acquire and retain customers (energy end-users), improve customers' satisfaction through the abovementioned innovative reward program and provide new services. The Management App intends to be a useful tool for energy companies and ESCOs to facilitate the configuration of the user-centered applications in existing and new buildings, as well as for designated third parties (ICT developers and other companies offering energy products) to extend the functionalities of the apps or connect them to third-party products and software (designing new business models).

The Connectivity Framework will facilitate connectivity, integration and interoperability to the millions of devices deployed in the market today. This way, the user-centered applications will be able to interact and communicate with existing systems and data.

"App-in-Context" Framework for Behavioral Energy Efficiency

Technological Integration

The proposed "app-in-context" framework relies on a set of existing technological elements for visualization, predictions, action plans, thermal comfort sensation, and personalized behavioral change, developed mainly within the framework of OPTIMUS (2014) (Fig. 8.4).

The OPTIMUS technologies are appropriately integrated toward the development of the innovative user-friendly digital applications, as displayed in Table 8.1.

The three user-centered applications are described in the following sub-sections.

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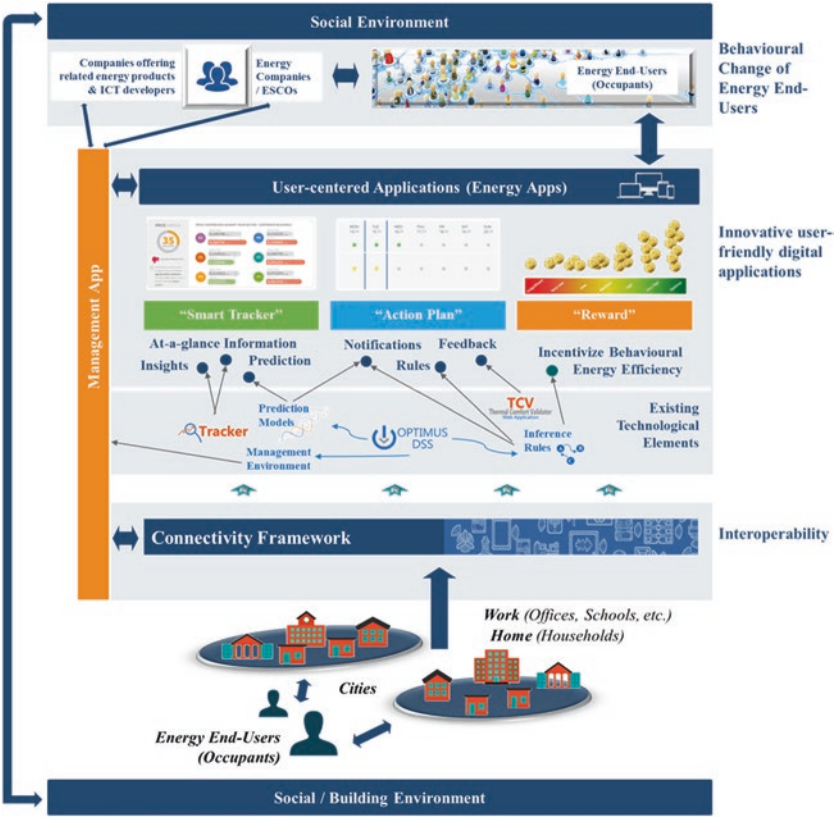


Fig. 8.4 "App-in-Context" framework for behavioral energy efficiency

Energy Monitoring ("Smart Tracker" App)
At-a-glance, real-time or near real-time personalized information is provided to the end-users through easy-to-comprehend visualizations, dashboards and appropriate filters, in terms of:

- Total energy consumption, cost and carbon footprint related to a building
- Appliance-level energy consumption data

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Table 8.1 Existing technological elements

Short description		*Integration*
OPTIMUS DSS	Based on real-time data monitored (weather conditions, buildings' energy profiles, occupants' feedback, energy prices and energy production) and predicted data produced by the prediction models, OPTIMUS DSS generates action plans based on a series of inference rules [21–22] **Prediction Models:** Data-driven models to forecast the energy behavior of a building according to some specific indicators (renewable energy production, energy consumption, indoor temperature and energy prices models) **Inference Rules:** The inference rules are expert knowledge-based algorithms aimed at giving suggestions for energy reduction. Each inference rule, or a combination of them, generates an Action Plan that is the suggestion for better managing the building with the purpose of decreasing its energy consumption. These include among others, the scheduling and management of occupancy, set-point temperature, on/off of the heating system, the operation of heating and electricity systems toward energy cost optimization, etc. Moreover, an inference rule for scheduling the energy usage considering different scenarios of energy market (green strategy, finance strategy and peak strategy) has been developed In order to set up the DSS, the following steps have to be carried out using the **Management Environment**: Creating a new building; Creating the building partitions according to the actual building; Adding the meters and sensors; Enabling the Action Plans to be used in the building	The prediction models are used for the "Prediction" widget of the "Smart Tracker" App and the "Notifications" widget of the "Action Plan" App The "Notifications" widget of the "Action Plan" App are based on the OPTIMUS inference rules The concept of the inference rule for scheduling the energy usage considering different scenarios of energy market is incorporated in the "Reward" App Management App is built on the functionalities of the Management Environment
TCV Thermal Comfort Validator Web Application	**Thermal Comfort Validator (TCV)** is a web application designed to detect the thermal comfort levels of the building's occupants. Accessible via computers or smartphones, TCV provides an online questionnaire, where building occupants are requested to answer a short series of questions, regarding their perception of temperature, wind and sunlight indoors. Their answers are analyzed and aggregated, in order to derive a general trend [23]	TCV is integrated into the "Action Plan" App, to collect users' feedback from the actual implementation of the action plans
Tracker	**TRACKER** constitutes a web tool that provides information on energy consumption overall figures, the energy sources breakdown per use, as well as data related to energy cost and CO_2 emissions	The "Smart Tracker" is on the functionalities of TRACKER

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- Information specific to individuals or behaviors
- Impact of weather conditions on the energy usage

The above allows the end-users to learn how much energy is being used by the different appliances, such as lights, consumer electronics or any other specific load and also link the energy consumption with specific individuals, behaviors and weather conditions. Their consciousness and understanding, therefore, about the way they consume energy and how that is interpreted in terms of energy cost and carbon footprint is raised.

Reliable predictions about energy usage, cost and CO_2 emissions on a daily, weekly, monthly, seasonal or yearly basis and comparisons between the actual and predicted values help citizens to identify how much energy has been used and what is the expected usage for the rest of the examined period. Having this information can result in better comprehension about energy consumption seasonality, better arrangement about future activities and early application of suitable actions to reduce the expected energy consumption and prevent exceeding targets or limitations.

Personalized energy insights are delivered through effective and realistic comparisons of the energy usage with the ones of other citizens in the same location, with similar buildings or others with similar characteristics. Such insights help understand the position of each citizen in terms of energy efficiency in comparison with others of the same energy profile and identify possible irregular behaviors or efficiency potentials and set feasible targets.

Energy Management ("Action Plan" App)

Having a detailed overview and knowledge about the way, the energy is consumed and what is the corresponding cost and carbon footprint is required to raise awareness, however, it is not sufficient by itself to lead to energy efficient behavior and significant energy savings. The ability for the energy end-users to get persuasive, personalized and realistic saving recommendations and tips, specific to target appliance and period is really important (e.g. when the heating period starts, the systems suggests ways to save energy and money on the heating system usage).

Intelligent data analytics processes based on experts' knowledge, inference rules and energy models are the key to generate short-term (daily/weekly) or long-term actionable personalized suggestions. These processes are performed on the various information captured from the building energy monitoring systems, the applied prediction models, the

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weather data capturing services and other possible data sources. The expected output is persuasive notifications when energy consumption exceeds a certain threshold, with details on which systems and appliances are driving the excessive usage, along with recommendations for how to reduce it. In addition, it can be based on the users' daily routines in order to reduce or eliminate the need for mechanical cooling and more. Examples of recommendations include supervising the load shifting, optimizing the boost time of the heating/cooling system taking into account the forecasting of the indoor air temperature and the occupancy levels of the building, scheduling the set-point temperature by taking into consideration thermal comfort as submitted by the occupants and the adaptive comfort concept, and scheduling of the amount of outdoor air to be used for cooling the indoor environment.

Highly important for the generation of energy efficiency recommendations is also the involvement of the end-user, so as to set his/her preferences, capabilities and constraints. The creation of custom scenarios and rules and their introduction in the analytical processes and the possible automated execution contributes to the feeling of well-being and security. In order to further ensure the user's well-being and comfort, his/her feedback about his/her perception of the existing conditions, such as thermal sensation, is also captured and incorporated, along with the potential context awareness of the surrounding environment by the intelligent systems.

Incentives for Behavioral Energy Efficiency ("Reward" App)

Even if the recommendations and guidelines for energy efficiency exist, they are not sufficient and the energy end-users' engagement must proceed one step further. The actual challenge is to provide tangible and meaningful incentives and motivation. This motivation has to really make the difference in terms of materiality for the end-users and go beyond just slightly reducing the energy cost or giving the feeling of environmental contribution, which typically exists as a form of motivation but is not that significant. A relatively new take on incentive mechanisms is the idea of reward programs using coins (Sgouridis 2012). A number of related approaches have been proposed for the reduction of CO_2 emissions, such as Ergo (Sgouridis and Kennedy 2010) and CarbonCoin, as well as for the in-feed of renewable energy, most notably SolarCoin. While these proposals address environmental issues, they overlook the energy efficiency sector. So, the connection between energy saving behavior and coins earning has to be studied and formalized.

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In this context, the reward app is introduced to incentivize behavioral energy efficiency, where energy end-users are able to earn coins by reducing or shifting their energy consumption. The coins earned are related with the actual compared to the predicted energy consumption ("Smart Tracker" App) and the daily amount of energy saved by the end-user (as a result of the implementation of the "Action Plan" App personalized information). The value of the coin varies among the end-users, based on their energy profile, the savings, the hour that these saving are achieved (increase value for the ones achieved in peak hour). It is also determined both by the absolute savings of the individual user and the achievements of the rest of the end-users of the specific energy company that applies this App. For every 1 kWh reduced, the end-user earns the respective coins, which can be used to decrease final energy cost by paying part of the bill or all of it to the energy company. The proposed approach enables dynamic billing and allows energy companies to incentivize end-users to follow the energy efficiency action plans.

Architecture

The overall architecture integrates the following modules (Fig. 8.5):

- *Connectivity Framework:* The Connectivity Framework extends connectivity, integration and interoperability. This module ensures that every sub-system is able to access the required data in a uniform way. Every data request can be passed through this module, which is capable of translating this request into the common format. A set of fully specified Application Program Interfaces (APIs) and Web Services was implemented and made available to internal or external components, which need to access data in order to enable a standard way for a high-level communication and interaction protocol between diverse tools, thus ensuring the necessary interoperability. This enables the desirable independence between the development of the various applications and services and the data access procedure. Consequently, third-party applications can connect directly to the middleware using one of the specified standards and at the same time, any possible change at the data access procedure will not require any adoption by the applications.
- *Engines:* The Engines are a set of multiple independent software components, each responsible for the implementation of a part of the proposed functionality. Each engine provides a fully specified

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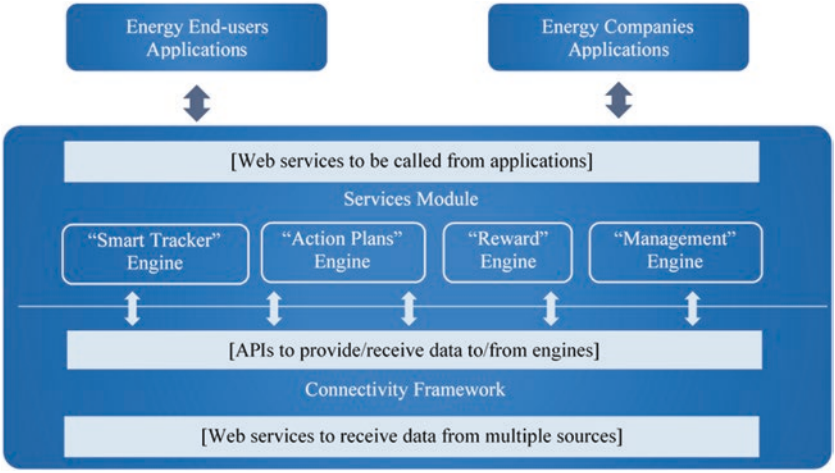


Fig. 8.5 Overall architecture

open Web Service to the applications, in order to handle their requests and provide the required results. The Engines are the following: "Smart Tracker" Engine, "Action Plans" Engine, "Reward" Engine and "Management" Engine.

- *Web and Mobile Behavioral Change Apps:* Web and mobile applications for iOS and Android can be developed with the use of cross-platform development frameworks. JavaScript-based technologies (frameworks like Meteor [2018]) are used, facilitating software development without loss of quality and allow reactive application development. All the applications communicate in a uniform way with the engines by using their offered Web Services, all aiming to support the users' behavioral change.

Proposed Experimental Evaluation of Energy Currency

Background

Energy and economic development are intimately linked—in fact, the contribution of energy availability to economic output is significantly underestimated when measured solely as the sector's output in monetary terms (Ayres and Warr 2005). At the same time, an energy transition

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toward a far greater contribution of variable renewable energy (VRE) sources is necessary and unavoidable (Sgouridis et al. 2016). Since widespread VRE requires storage through chemical or mechanical means with the inevitable round-trip losses, the more energetically desirable priority for the integration of VRE is to (1) be able to shift the load profile as close as possible to the output profile of these resources at a local level, (2) rely on energy imports from VRE far from the consumption center and (3) deploy local storage for dispatchable supply. Planning for the optimum deployment of such a system with multiple options is both difficult and ultimately undesirable in open, free-market economies. An alternative approach is to broadly set the targets and let the market system optimally reconfigure itself to fit the energy transition constraints.

The energy currency concept is proposed as a ground-breaking, yet suitable for gradual adoption, system for linking SEC with the three concepts of (1) the centrality of energy in the economic system, (2) the mandate for a transition to VRE and (3) the desirability of a guided free-market approach.

Aspects of the concept were explored earlier for the city (Sgouridis and Kennedy 2010) and country (Sgouridis 2014) scales. This section aims to specifically address how they could be implemented as part of an energy-smart city experimental development and evaluate the potential benefits and requirements for a comprehensive experimental evaluation. The objective of the experiment would be to monitor how the target community would evolve to embrace the alternative currency. The key metric for considering its success would come from a before and after comparison of the levels and profiles of energy uses but also of intra-community trade in services and local products.

Energy Currency Experimental Deployment Set-up

A sustainability-oriented community between 1000 and 10,000 residents that already has local VRE installed would be the ideal location for this experiment. The municipality should be engaged and interested in enhancing the sustainability goals but also in boosting the local economy. The residences should have smart meters already installed. The utility ideally should be small size and local or alternatively open to changing its traditional operational model.

Step 1. Development of the User-Level Energy Market Backbone

As envisioned in Sgouridis and Kennedy (2010) the first level for deploying a local energy currency system is to create a functional, reliable energy

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credit clearing mechanism. Energy credits can be perceived as the transaction units, named by the authors Ergos. Each Ergo corresponds to a nominal unit of energy. Perhaps the key aspect of a local energy currency system is to have this viable web-based interface for initiating and clearing every Ergo transaction from retirement in lieu of energy services to exchange for non-energy services, to participating in the asymmetric energy market. The ultimate output of this system is the setting of a dynamic energy value that is accessible in real time by all market participants.

Such a system can be seen as a hybrid variant of two existing systems. The first is the real-time pricing market currently available for wholesale electricity markets. The second is the development of phone credit systems that users in developing countries can use as a transfer and exchange mechanisms. These phone credit systems are also tied to energy systems to varying degrees in the likes of the M-Kopa and Inensus systems.

Step 2. Derivation of Locally Relevant Energy Pricing Algorithms

For the market to work as desired (i.e. in order to achieve energy constraint objectives), appropriate pricing mechanisms should be developed in order to offer sufficient incentives for user response. The algorithms should be flexible enough and changing over time to reflect how users adapt (e.g. some users may decide to opt for residential VRE and battery storage systems as a way to enhance their participation in the market or potentially to shield themselves from the market).

The Ergo market could provide time of use signals either through tying to a variable monetary pricing exchange or it could be isolated from the monetary system and use time of use multipliers (e.g. one Ergo could provide 1 kWh on average but only 0.5 kWh when the system becomes supply constrained and 3 kWh if there is oversupply).

Step 3. Provision of Meaningful Ergo Exchange Incentives for Non-Energy Uses

A key finding from multiple local currency projects is that in order to precipitate their circulation and use, the local authorities should ultimately accept it as part of their service charges/local taxes. While the problem of exchange is much smaller for a currency that has a physical redeeming value (the energy unit), it may still be helpful to give the currency an initial boost of credibility among the users.

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Step 4. Participant Engagement and Habituation Period
Given that participating in a real-time electricity retail market may be viewed as inconvenient and restrictive, efforts should be made to showcase the opportunities that such a system would provide to participators—both in income generation if they decide to become active issuers with their own storage and supply systems but also as a way to support local exchanges. To ease the burden of initial adoption, the designed application should have several profiles pre-programmed that the user could choose from to run in the background with only limited number of notifications issued to receive the user's authorization in extreme events. Also, the design of non-intrusive, ambient data devices (such as colored spheres indicating the relative energy availability/Ergo price in the exchange) would be interesting avenues to pursue.

These deployment steps provide some critical suggestions of how such a different demand-side management system could be brought closer to reality through a targeted experiment in an urban development either in the GCC or in the EU.

The Energy Currency Concept in Behavioral Energy Efficiency

In order to create strong and meaningful incentives for energy efficient behavior of the energy end-users, a methodological approach that incorporates the energy currency concept is presented. It involves both the energy provider and the end-user, aiming to produce mutual benefits from the achievement of energy efficiency targets and the creation of monetary incentives and awards.

To better demonstrate the process, suppose that n users participate in the case. The profile of each user is defined, seasonally adjusted and a personal energy saving target is set for the next day. Suppose that n_1 users manage to achieve their target, while n_2 users consume more energy than the threshold. The energy savers get 1 virtual coin per kWh saved (ES), which daily currency rate C_i is equal to $\frac{B}{ES}$ €/coin. Here, B denotes the bonus of the user in real money, which amount is calculated by sharing the total target to the users which have achieved their proportionally target. After k days of participating in the virtual market, each user j has collected m_j coins, which has monetary values determined as follows:

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$$\text{Value of coins}_j = \frac{C_{\text{Day1}} \times ES_{\text{Day1}} + C_{\text{Day2}} \times ES_{\text{Day2}} + \ldots + C_{\text{Day}\,k} \times ES_{\text{Day}\,k}}{m_j} \tag{8.1}$$

where C_i is the daily currency of virtual coins at day i and ES_i the energy saved in that day in kWh, which is the same to the amount of coins earned.

Given the real present value of the virtual coins, the mean currency of each user is determined and coins can be used to lower the cost of the bill at the end of each billing period. For instance, for a consumption of X kWh with a price of p_1 €/kWh, the original energy cost of the user would be $p_1 \times X$. Given that the user has m coins of currency p_2, the user can trade his coins and pay $p_2 \times m + p_1 \times (X - m)$, thus saving $m \times (p_2 - p_1)$. If $p_2 < p_1$, the user is actually saving money, while otherwise the user must become more environmental friendly to improve his/her currency and trade when it is profitable. The lower the value of p_2, the higher the energy cost reduction.

The above approach is presented below using an indicative example. Suppose that an energy provider has ten clients. Their targeted and actual energy consumption and the corresponding coins earned for three successive days are shown in Table 8.2.

In order to calculate the daily currency rate of the earned coins, assume that for each day the available bonus budgets from the energy provider is 2.5937, 1.8627 and 0.4967, respectively. Table 8.3 presents the daily currency rate of the earned coins.

Now, for the calculation of the value of each coin for each different end-user, the aforementioned formula is used and the results are the following (Table 8.4).

The benefits for the energy savers are derived from the use of their earned virtual coins to pay a part of their total energy consumption. In the context of the example, user 10, has to pay 43.5 euros for the 500 kWh he consumed. Having earned 300`ros. The rest 200 kWh are paid with the rate of 0.087 euros per kWh. The final payment for the 500 kWh is 17.90 euros. Therefore, the energy savings he achieved resulted in a decreased energy spending of 25.60 euros.

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Table 8.2 Energy consumption and coins

Users	*Target (kWh)*	*Actual (kWh)*	*Coins (ESi)*	*Target (kWh)*	*Actual (kWh)*	*Coins (ESi)*	*Target (kWh)*	*Actual (kWh)*	*Coins (ESi)*
	Day 1			*Day 2*			*Day 3*		
User 1	110	118	0	110	125	0	110	111	0
User 2	120	125	0	120	123	0	120	122	0
User 3	250	248	2	250	258	0	250	252	0
User 4	1852	1800	52	1852	1865	0	1852	2216	0
User 5	136	130	6	136	135	1	136	137	0
User 6	190	200	0	190	188	2	190	195	0
User 7	120	100	20	120	125	0	120	124	0
User 8	250	285	0	250	245	5	250	252	0
User 9	1852	1860	0	1852	1862	0	1852	1852	0
User 10	1800	1900	0	1800	1840	0	1800	1500	300
Total	6680	6766	80	6680	6766	8	6680	6761	300

Table 8.3 Daily currency rate of the earned coins

Days	*Total budget*	*Total coins (ESi)*	*Daily currency rate (Ci)*
Day 1	2.5937	80	0.0324
Day 2	1.8627	8	0.2328
Day 3	0.4967	300	0.0017

Table 8.4 Value of coins

Users	*Coins (ESi)*	*Daily currency rate (Ci)*	*Coins (ESi)*	*Daily currency rate (Ci)*	*Coins (ESi)*	*Daily currency rate (Ci)*	*Total value of coins (€)*	*Individual value of coin (€/coin)*
	Day 1		*Day 2*		*Day 3*			
User 1	0	0.0324	0	0.2328	0	0.0017	0.0000	0.0000
User 2	0	0.0324	0	0.2328	0	0.0017	0.0000	0.0000
User 3	2	0.0324	0	0.2328	0	0.0017	0.0648	0.0176
User 4	52	0.0324	0	0.2328	0	0.0017	1.6859	0.0322
User 5	6	0.0324	1	0.2328	0	0.0017	0.4274	0.0572
User 6	0	0.0324	2	0.2328	0	0.0017	0.4657	0.1758
User 7	20	0.0324	0	0.2328	0	0.0017	0.6484	0.0306
User 8	0	0.0324	5	0.2328	0	0.0017	1.1642	0.2328
User 9	0	0.0324	0	0.2328	0	0.0017	0.0000	0.0000
User 10	0	0.0324	0	0.2328	300	0.0017	0.4967	0.0017

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Conclusion

In the process of building future SEC, ICT infrastructure will be a key enabler. ICT are mostly used by energy/facility managers, ESCOs and specialists, who take decisions based on the information they get. However, the buildings' occupants are excluded from this process. The key questions regarding the engagement of energy end-users in the context of an SEC and the role that advanced technologies could play in improving quality of life for its citizens include the following:

- How can smart technologies support urban energy transformation and thus increase the citizens' quality of life?
- How can the energy end-users get a deeper understanding about their energy behavior and its impact?
- What is the role of social innovation and citizen engagement toward energy efficient societies?

The multidisciplinary nature of the available data creates the need to develop commonly accepted schemas/structures and enhance connectivity and interoperability between the different data sources, in order to enable their efficient integration. In addition, the ICT solutions should incorporate concepts and technologies from energy behavioral modeling and behavioral change techniques, smart cities, energy optimization and also take into consideration different groups of variables, such as energy-related behavior, building characteristics, sociodemographic and personality variables and more.

In this context, the role of the proposed digital applications is to bridge the gap between ICT-for-companies and occupants, simplify the complexity of the information gathered by those systems and put it on the hands of energy end-users. The personalized behavioral change applications facilitate energy end-users to:

- Know how much energy is consumed in total and the contribution of the specific end-user and other peers to that
- Get personalized recommendations of action plans for energy conservation and load shifting, along with an estimation of their impact on energy use and user comfort
- Be motivated to adapt behavioral change toward energy conservation

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More specifically, an innovative reward incentive mechanism is proposed (using energy currency), in order to nudge end-users into more efficient energy usage and enhance participation and effectiveness of energy conservation actions. A significant reduction of final energy consumption of 15–25% in the buildings and houses where it will be used is expected. The proposed "app-in-context" framework can support energy companies from the EU and GCC to acquire and retain energy consumers, as well as improve consumers' satisfaction through the innovative reward program. It constitutes an area of common interest, fostering effective EU-GCC clean energy cooperation, by using an innovative approach for behavioral energy efficiency.

Acknowledgments This chapter was elaborated within the framework of the project "EU-GCC Clean Energy Technology Network", European Commission—FPI service contract number PI/2015/370817 (http://www.eugcc-cleanergy.net). The content of the chapter is the sole responsibility of its authors and does not necessarily reflect the views of the EC.

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PART IV

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CHAPTER 9

The Influence of Big Data and IoT on Smart Cities

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Introduction

Smart city initiatives produce a large amount of data and information, collected through various sources. With the introduction of new technologies such as the Internet of Things (IoT) and Big Data, collected data can be accumulated, analyzed, and elaborated on to ultimately obtain valuable insight. The combination of Big Data and IoT is a research area that presents interesting challenges for the future of smart cities. These new challenges are related to the integration of business and technical streams into the smart city ecosystem. In this chapter, we present an overview of the Big Data and IoT technologies and show how they interact while converging. Several smart cities applications are analyzed within the context of the IoT and Big Data. Moreover, a future integration framework is proposed and research challenges are identified. This study can serve as a guideline for industries or stakeholders who engage in the development of smart cities initiatives in the context of Big Data and IoT. Many real estate companies have developed innovative smart city visions based on a portfolio of products and services for

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_9

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the real estate market. Such visions were derived after several years of innovation and on-the-field experience both in mature and developing economies. Integrated facility management platforms, real estate infrastructure convergence to IP, machine to machine (M2M) technologies, IoT, real-time business, and e-health are only a few building blocks of a solution that delivers enormous benefits to the real estate industry.

The new concept of connected devices over the existing ICT network has been developed with the appearance of smart devices. The past few years have seen a tremendous growth of devices connected to the network, and thus expanding the boundaries of conventional networks. This new configuration of connectivity has introduced the IoT technology. IoT is a technology which appeared first in 1999, as Ashton (2009) described it as an Internet evolution at MIT's AutoID lab. More specifically, IoT can be regarded as a concept under which a plethora of things/objects can be connected via wireless and wired connections over the internet. The IoT concept has become fairly matured with the attention of multiple research groups providing productive applications like smart home, smart city, smart transportation, and so forth. In the smart city context, the aim is to provide smart services to improve the quality of life through connected adaptive devices. Smart devices produced a large amount of data on a real-time basis for collection and elaboration from the aggregation devices. Due to the high volume of collected data, it is very difficult with the existing mechanisms to satisfy the real-time processing demand. Hence, the engagement and collaboration with the Big Data analytics become mandatory as a first step for a smarter city.

In this chapter, IoT and Big Data analytics are integrated with the smart city architecture for the deployment of smart cities. The proposed architecture is capable of handling different types of data formats structured, unstructured, and real-time decision-making. However, the data orchestration layer is the most influential component of the total framework for the realization of a smart city. In this study a hub approach and Hadoop are chosen as the storage and processing medium for the heterogeneous data.

Related Work

The concept of the rapid development of a smart city has attracted many researchers and architects toward studies on efficient framework and standard design. Standardizing the smart city models can provide various benefits from researchers in different standalone frameworks. Many

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research projects have covered different approaches ranging from abstract concepts to a complete set of services.

Nowadays, many researchers are working to present various solutions based on IoT technologies for smart cities. Similarly, various test bed simulations have been proposed to overcome the challenges. A full set of smart city services on various modules has been proposed by Sanchez et al. (2014), where the authors developed a large-scale of IoT infrastructure in a Santander city. Based on the city requirements, a user-friendly interface has been designed, and each citizen can test the IoT platform under different scenarios. These scenarios include security, ICT and non-ICT services, smart services, and unified control center. However, the data collected from different IoT sources is not tested for future urban design and planning. Also, the user demands are dynamically changed and the IoT-based smart environmental is not matured for supporting smart services such as smart buildings, and smart homes for the following two reasons: (1) compatibility of new technologies and optimization techniques (e.g., an IoT component such as wireless sensor network (WSN) has high packet loss in a heterogeneous wireless environment) and (2) limitation of current IoT-based solutions to specific application domains. In addition, different smart services such as smart transportation, smart waste management, and noise pollution are not reflecting a standard solution (Li et al. 2009; Maisonneuve et al. 2009; Nuortio et al. 2006).

IoT technology is not enough for the efficient design of a smart city. The elaboration of the data from different sources, which is obtained with the introduction of the Big Data technology, is required. Big Data supports off-line processing and can therefore help for designing and planning smart city and smart services. However, Big Data does not support real-time decisions. Various techniques based on Hadoop framework are implemented to analyze the data for better designing and planning smart city services. For example, a platform called City Data Analytics Platform (CiDAP) has been proposed (Cheng et al. 2015), where a layered platform of data processing between the data sources and applications has been developed. The entire platform consists of different components such as IoT agent, IoT collection unit (IoT broker), a communication city server, and a Big Data processing module. The data are collected from different sources and passed on to the IoT broker. The IoT broker separates the data based on different sensors IDs and then assigns an index number. Finally, the IoT broker sends data to IoT agent for further processing.

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Similarly, several projects are developed based on Big Data analytics such as FIWARE (2018) and SCOPE (2018). The projects provide different mechanisms for the big data in real-time environment; though they are not open, they are available for use in different environments. From the literature, we can found example of Big Data analytics for the designing and planning smart city services (Li et al. 2009).

However, real-time elaboration and processing of large amount of data is still an interesting research challenge. In general, a smart city can be built based on real-time big data analytics and ICT/non-ICT communication models. The above literature identifies some important open issues that need to be addressed, for example, ICT/non-ICT communication models, real-time big data analytics, and acquisition and collection of data from different sensors installed into the smart city. In this chapter, we identify the need for an efficient model for smart cities based on Big Data architecture.

Proposed Scheme of the Big Data and Smart City

In this section, the development of a layer architecture that supports and integrates different data from IoT devices or City services is presented. City services produce a huge amount of data such that it is very difficult with traditional IT systems to collect and extract meaningful insights from. To address this problem, big data processing technologies have provided platforms for data distribution, processing, and interactive visualization (Kang et al. 2016). The proposed scheme is composed of different layers that enable the integration of smart city services with big data technologies. The proposed scheme consists of four levels: (1) infrastructure layer, (2) data orchestration layer, (3) services enablement layer, and (4) application layer. A brief overview of the proposed smart city architecture is provided in the next subsections followed by a description of the four levels of the proposed scheme (Fig. 9.1).

Infrastructure Layer

The infrastructure layer is the set of connected devices and the data generated and acquired from different sources. A smart city includes a complex and comprehensive applications domain to support the amount of data collected. The implementation of the smart city relies on all kinds of data

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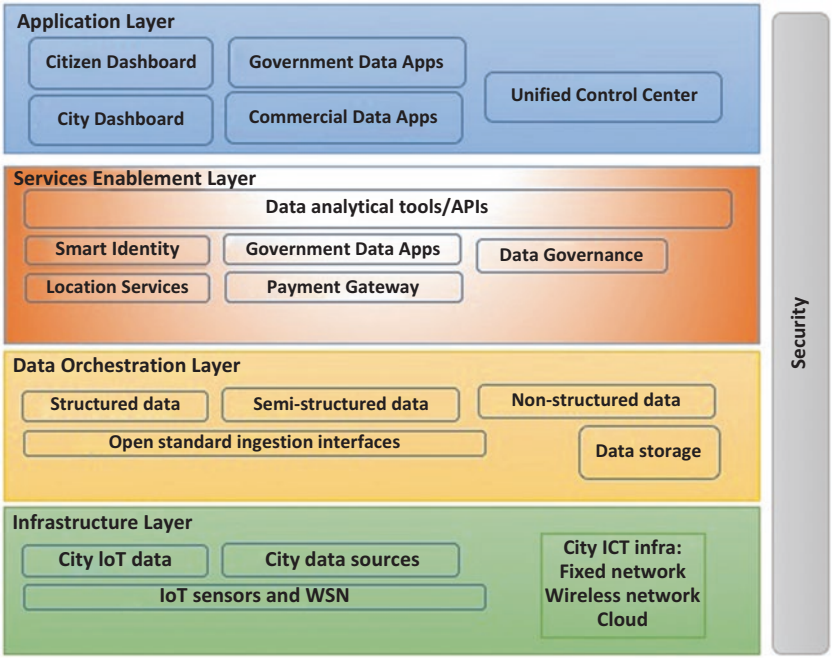


Fig. 9.1 Proposed scheme for Smart City, IoT, and Big Data (Source: Authors)

and computations due to their indispensability (Rong et al. 2014). The smart city aims to provide better life and services to the tenants, to optimize residential resources, to reduce traffic congestion, improve e-government and healthcare services, and to manage waste, among others. To achieve all the preceding aims, data acquisition on a daily operation basis is required. However, the data acquisition has become challenging due to the huge amount of data created by connected devices and people. For the further processing and the conversion into digital data, big data mechanisms are necessary to be implemented.

The installation of low-cost sensors is required for the acquisition of heterogeneous data from the city IoT. The city becomes smarter with the increased number of installed and connected sensors (Rong et al. 2014). In addition, there are other sources of data coming from government systems, commercial systems, as well as archived data that need to be revisited.

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Another component of the infrastructure layer is the connectivity using multiple communication technologies, such as 5G, Wi-Fi, Bluetooth, and ZigBee, to transmit data from IoT devices to the data orchestration layer.

Data Orchestration Layer

The data orchestration layer acts as the mediation between the data acquisition, service, and application layers. Since all the processes such as data aggregation, manipulation, ingestion, transformation, and storing are performed in this layer, data orchestration is considered as the brain of the proposed architecture.

This layer collects all the unstructured data from the IoT and city sources, which are then stored in a shared data storage located either in a data center inside the smart city or in a cloud storage such as Amazon EWS, Openstack, S3, Google cloud services, or Microsoft Azure platforms. In order to perform the tasks, multiple hardware and software components are utilized in this layer. Stored data are processed using batch-based programming tool such as MapReduce (Dean and Ghemawat 2008) or other processing engines for big data platforms.

Additional platforms and technologies for data storing and manipulation are Hadoop distribution file system (HDFS), HBASE, and HIVE. In stream processing, data is processed and utilized quickly in order to properly support any changes in a smart city in real time. There are many technologies that can be used for real-time streaming processing of unstructured data such as Spark, Storm, and S4 (Neumeyer et al. 2010).

Services Enablement Layer

The service enablement layer provides the city services to the tenants in the smart city. The layer consists of multiple components such as smart identity, payment gateway, and smart home automation services. Smart identity services are introduced for better control, management, and visibility of activities. The prime focus of introducing smart identity is to maintain a single customer identity using various technology platforms, which all converge to the same subscriber of services. The following technologies will be considered: smart cards, magnetic cards, RFID tags, NFC enabled devices, and mobile applications in order to support smart identity. The smart identity becomes the key identity for all permanent or tempo-

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rary subscriber/user of the smart services including access control, entry/exit to authorized buildings, virtual wallets, loyalty program management, and location-based services.

For these services, visitors received a temporary smart identity card while entering the complex and their information (name and national ID) are attached to it. There is an option online to load a balance for making some payments for city services from this smart card. While exit from the complex the card ID will be detached from the visitor information.

Another value-added service from this concept is to register all tenants and visitors in a loyalty program where users can redeem and consume points according to a present pointing scheme based on purchases from stores, restaurants inside the smart city. In addition, smart identity concept is the enabler to many location-based services that could be introduced such as push notifications to customers on their cell phones while roaming in the smart city campus.

With the home automation service residents are able to control or monitor signals from different appliances or basic services using IoT sensors. A smartphone or web browser can be used to control or monitor the home automation system. The home automation components provide security, air condition control, digital signage, smart lighting, and audio/video control.

Application Layer

The application layer is responsible for the data presentation. The main components are the unified control center, city dashboard, big data, open data, and government and commercial applications. The unified control center collects all the data from different smart services into the same platform. It integrates and interchanges between the other components all the required information. Such data can be used by the big data analytics model in order to predict behavior in the business and management performance contexts. The outcome of the analysis can be presented in a form of report. Dashboards are often used for easy interaction with the models. The ideal architecture requires a security model throughout the processes and examines security issues from a systems perspective to provide business value into the smart city organization.

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Big Data Collection Process Overview

Smart city applications producing continuous large data from heterogeneous sources and the existing traditional warehouse approach is inadequate to handle such large amounts of data given the limited processing speed and the high storage cost. To address this problem, a smart hub approach is used for this chapter. The main concept of a data hub is to make different types of data readable after some processing and then available through multi-option interfaces.

Traditional Data Warehouse Approach

The traditional data warehouse approach collects all data into a centralized place as shown in Fig. 9.2. Afterward, extraction, transformation, and loading (ETL) tools allow processing of the data with the aim to identify relationships and build data model. Finally, data marts for each business unit can be identified and loaded. The main disadvantage of this approach is that it requires a considerable investment in the first place and even more to add new data sources or change the model. This approach is not efficient in real-time (read/write) operations on stored data.

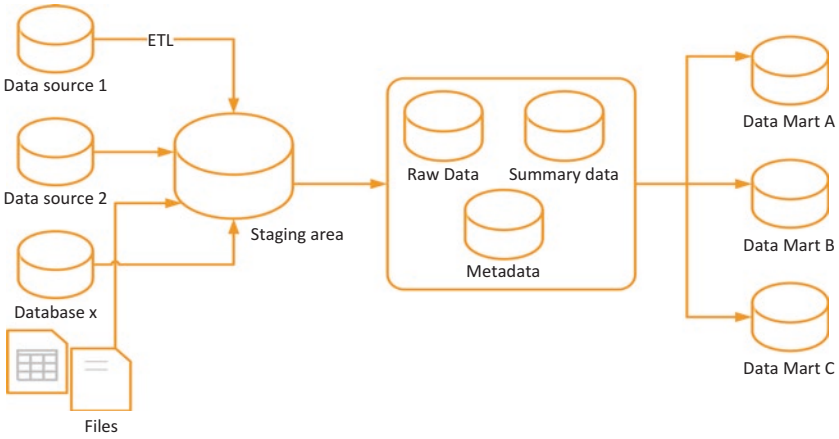


Fig. 9.2 Traditional data warehouse approach

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Data Virtualization Approach

The main idea behind this approach is to have a data processing pipe that maps the data on the fly to data models represented into a controlled access data as shown in Fig. 9.3. This is similar to the processing virtualization concept. End users see what seems to be a data mart but that only carries a cached version of the data while the rest is pushed on the fly (data streaming).

The main advantage of this approach is that data maintaining functionality will not be replicated as each system maintains its own data while the user still can see specific selections of such data. This also reduces the level of investment and speeds up the time to market.

The main disadvantage here is that the performance of the system, as well as data availability, depends heavily on the level of integration of all the sources. This means that all systems should be ready all the time for data extraction. Based on the above discussion, a hybrid approach can be optimized. First, data virtualization is applied so as to monitor the types of data with a high request frequency for storing in the storage area. This storage is evolving with the size of data stored which gives the chance to minimize the initial investment and optimize the ongoing one to match the data demand.

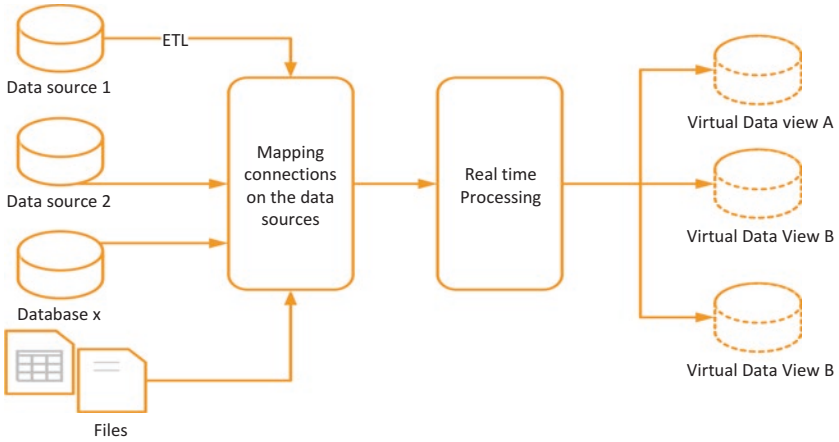


Fig. 9.3 Data virtualization approach

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Applications of IoT and Big Data in the Smart City

Throughout the world, real estate is going through a major transformation. New cities are being created where the network and services running through them are integral to the design and day-to-day use. Technology will improve life for the office worker and resident alike, enhance building performance and conserve energy. The vision of the smart city is an environment designed to attract knowledge and talent from around the world and to spur innovation and creativity. The goal of the smart city is to promote education, art, science, medicine, industry, environment conservation, transportation, social communications, and public administration to enhance urban life.

In smart cities, people will move around, learn, consume, and interact through the use of advanced technologies that have a social dimension, are location-aware, mobile, and reactive. Smart cities are emerging partly because the oil wells that are funding the buzzing Middle East industry are not bottomless: governments in the Gulf are looking for new wealth generated from commerce and tourism to pay back their investment in the new smart built environment. It has become clear to developers and investors that technology can be a key differentiator to put clear blue water between them and their competitors. The truly smart city is not just a dream: the technology already exists. The challenge is to pull it all together into a unified, easily managed environment.

A great view or a prime site helps, but in a building boom that has brought unprecedented competition for landlords and property developers, there is one other essential for attracting new business: access to open data and broadband services, on every floor of every building, in homes and offices, shopping malls, and civic centers. Now real estate investors have a new option. In addition to selling units and facilities within the real estate campus, they can also deliver the converged broadband telecommunications services as the fourth utility (after electricity, gas, and water) and gain revenue from the services occupiers want and they can enjoy a higher return on their investment and achieve higher sale prices for their properties.

In a smart city, built-in broadband infrastructure is as important as the roads, supporting entertainment, information, and business communications. A smart city requires a high capacity backbone network to support future demand: and fiber terminated on each floor of every building so that whenever and wherever services are needed they can be simply and

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quickly activated. Using IP technology, a fiber network will carry information systems to facilitate the automation, centralization, and remote monitoring of essential building services, making these cities easier to live in, cheaper to operate and more energy efficient. Additional services can then be accessed without digging up roads or rewiring.

Fiber is just the foundation for a range of advanced services that can be layered on top. Customers of all types, including residents, facilities managers, retailers, corporates, small and medium businesses, and hoteliers can share the same single converged IP infrastructure supporting video, voice, and data services for different terminals over mobile and fixed line access technologies across an entire development. In the smart cities, there is a big ecosystem consisting of different types of buildings such as smart homes, smart buildings, and smart communities.

Smart Homes

In a smart city, residents are able to connect to the network instantly, accessing millions of games, films, music tracks, and countless other services. They can turn on the air conditioning from their mobile phone or check the family is safe by remotely accessing a home set-top camera. Assistive technology can give greater independence to the elderly or disabled. A home hub could wirelessly link multiple personal computers (PCs) and personal digital assistants (PDAs) to high-definition television, video, and radio, with multimedia services like online gaming and music downloading available on demand. The smart city extends all of the home automation capabilities to the outside of the home and your profile can follow you to any terminal within the smart city.

Smart Businesses

In a smart city, multisite businesses can network voice, video and business-critical enterprise applications. With the help of an international carrier, these can run seamlessly across corporate wide-area networks on different continents. Example applications are intranets and secure collaboration, email and voice mail, conference calls and instant messaging. Unified communications make it easy for employees to hot desk or work remotely. Managed firewalls, antivirus, storage area networking, remote access, messaging, and web hosting can all be added. Branches of multinational

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businesses will have all of the powerful communication tools that offices in London, New York, or Tokyo have.

Smart Hotels

Hotels in a smart city can offer guests video-on-demand and IPTV as well as office services like video-conferencing, which can be billed on a per-use or monthly basis. In the public spaces, plasma/LCD televisions, wireless access, digital signage, and virtual reception can be provided. Add to these, point-of-sale terminals in bars and restaurants, a front office booking suite, automated check-in and smart-card room locks. Room comfort settings can be delivered over IP phones and smart bathrooms let management know when supplies run short.

Smart Shopping Malls

Malls and souks can use multiple VoIP phones and business applications on corporate intranets to check stock availability. Applications can stream video feeds onto in-store display screens and security cameras as well as connect to chip-and-pin machines and electronic payment terminals.

Smart Buildings

Office buildings already contain a number of networks: fire alarms, security alarms, door access controls, utilities monitoring, lighting systems, lifts, heating, ventilation, and air conditioning. This is a complex environment with high installation costs and limited automation. The aforementioned services can all be run over the same network, delivering better performance for less cost. Accurate information gives owners the ability to save energy by offsetting peak loads. Intelligent buildings know when to turn off lights or turn down the cooling system and even before they are completed, developers are able to adjust internal temperatures for the comfort of building workers.

Smart Government and Public Services

The need for physical human resources and dedicated resources for management of offices can all be reduced by providing online access to voting, birth certificate applications, tax payments, and so on. On-campus

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hospitals can be created with telemedicine in mind—outpatients can have their heart rates, blood pressure, and insulin levels monitored and recorded remotely with the vital statistics fed into telemedicine control systems.

Schools and universities in a smart city can support distance learning and rich media. Lectures delivered by professors around the world can be conducted via telepresence. In a smart city, smart government and public services mean the public are healthier, better educated, and disasters can be more easily prevented or mitigated. Even the crime rate can be ultimately reduced.

Smart Communities

Smart communities are cities and corporate facilities that leverage technologies to better engage with citizens. Smart technology helps public- and private-sector planners develop viable platforms made up of IoT and M2M technologies. Smart technologies help unify systems and use resources more efficiently and address community challenges like high-energy costs, traffic congestion, and public safety.

With smart communities and cities, one can collect critical data and gain near real-time visibility into vital operations. This helps in streamlining the decision-making process and facilitating faster response. For example, if a water pipe breaks, sensors will be able to detect the sudden pressure change and notify public works officials, who could then dispatch the closest field crew to repair the damage. In the event of area flooding, residents could receive alerts, traffic lights could be adjusted to steer drivers toward safety and digital signage could be used for information sharing. This is one of the many ways in which smart cities' technology can help communities become more resilient.

When a city is able to collect data from IoT and connected machine technologies, communities can benefit from revenue generation opportunities, make the use of efficient limited resources, and attract businesses, residents, and workers.

Big Data Tools and Systems

Big data tools and systems are required to implement the functionality and services for the smart city. The approached list of vendors that allow us to achieve the required design with their various constraints are presented below.

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Hortonworks Framework

The Hortonworks framework is the main platform for the Hadoop infrastructure and Big Data analytical stack as shown in Fig. 9.4. The Hortonworks framework is divided into three main layers:

(a) The ingestion layer: We will use Sqoop to ingest data from structured query language (SQL) and structured data sources. Then, we use Apache Flume to ingest real-time and change-based triggering data. Finally, we use Kafka to ingest big non-structured data, volumes up to terabytes.
(b) The data management layer: We use Apache Hadoop file system with YARN for data operation management and jobs handing. YARN is the architectual center of Hadoop that allows multiple data processing engines such as real-time streaming, interactive SQL and batch processing to handle data stored in a single platform. We utilize HDFS V2.2 which is a scalable, fault-tolerant, distributed storage system that works closely with a wide variety of concurrent data access applications and is coordinated by

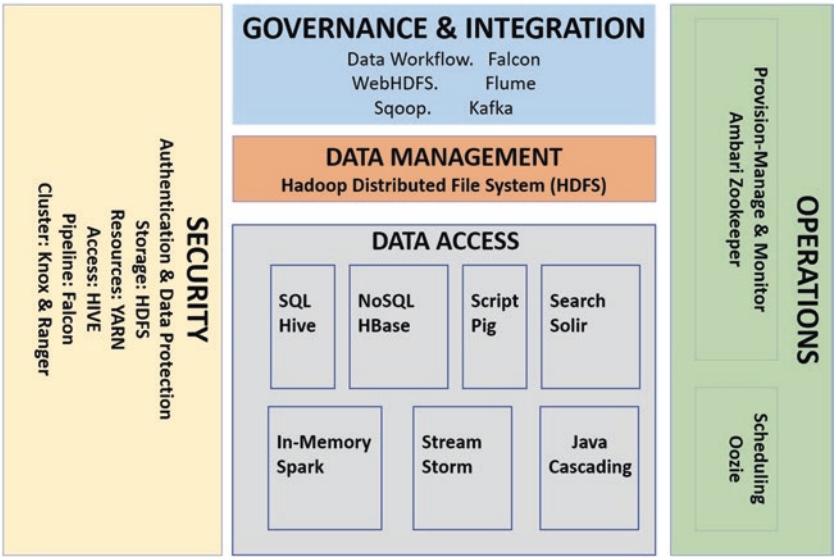


Fig. 9.4 Hortonworks proposed framework

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YARN. HDFS will "just work" under a variety of physical and systemic circumstances. By distributing storage and computation across many servers, the combined storage resource can grow linearly with demand while remaining economical at every amount of storage.

(c) The analytical and data access: In this layer, tools that allow multiple techniques for data access are used, like: Data flow Scripting language (Pig Latin) & Java scripts data access using Cascading. Interactive SQL access (will use Hive for large & distributed SQL-based data access while using HAWQ "which became open source as well now" for low latency interactive SQL like data access like interactive dashboards in our case). HBase for value store high volume noSQL data access and Accumulo for secured noSQL data access. Storm & Spark: Storm for Data streaming & Spark for in memory data access.

The Hortonworks frame utilizes many other tools for data management that we intend to use, such as:

Falcon for data life cycle management as Falcon simplifies the development and management of data processing pipelines with a higher layer of abstraction, taking the complex coding out of data processing applications by providing out-of-the-box data management services. This simplifies the configuration and orchestration of data motion, disaster recovery, and data retention workflows.

Apache Ranger for data access security on HDFS level as it offers a centralized security framework to manage fine-grained access control over Hadoop data access components like Apache Hive and Apache HBase. Using the Apache Ranger console, security administrators can easily manage policies for access to files, folders, databases, tables, or column. These policies can be set for individual users or groups and then enforced within Hadoop.

Knox as the data access application programming interfaces (APIs) gateway as it provides perimeter security so that the enterprise can confidently extend Hadoop access to more of those new users while also maintaining compliance with enterprise security policies.

Ambari for the cluster management as Ambari enables system administrators to provision, manage, and monitor a Hadoop cluster, and also to

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integrate Hadoop with the existing enterprise infrastructure. Some of its main features are provisioning, managing, monitoring a Hadoop cluster, and integrating Hadoop with the Enterprise.

Apache ZooKeeper that provides operational services for a Hadoop cluster. ZooKeeper provides a distributed configuration service, a synchronization service, and a naming registry for distributed systems. Distributed applications use Zookeeper to store and mediate updates to important configuration information.

Apache Oozie as it is a Java Web application used to schedule Apache Hadoop jobs. Oozie combines multiple jobs sequentially into one logical unit of work. It is integrated with the Hadoop stack, with YARN as its architectural center, and supports Hadoop jobs for Apache MapReduce, Apache Pig, Apache Hive, and Apache Sqoop. Oozie can also schedule jobs specific to a system, like Java programs or shell scripts.

IoT Intelligent Application Enabler Platform (IAE)

The Intelligent Apps enabler is a flexible platform that facilitates and rationalizes the exchange of data within any IoT solution, fulfilling the customer needs for device, communication, and message management. It eliminates the usual complexity of developing and integrating IoT applications. It is a generic platform allowing us to create and manage end-to-end IoT services. With this platform we can deliver a purpose-built end-to-end service beyond connectivity, encompassing terminal device, and network and back-end applications.

One of the main goals of this platform is to enable as much as possible the utmost replication from one project to another and then optimize the costs. Focus is on building reusable blocks to provide end-to-end solutions to multiple customers. This platform will fulfill the IoT needs of device management, communication and message management, business data management, and assets repository management.

IoT Gateways

The IoT gateway offers a key building block to enable the connectivity of legacy industrial devices and next-generation intelligent infrastructure to the IoT. It integrates technologies and protocols for networking, embed-

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ded control, enterprise-grade security, and easy manageability on which application specific software can run. IoT Gateways enable:

- Connectivity up to the cloud and enterprises.
- Connectivity down to sensors and existing controllers embedded in the system.
- Pre-process filtering of selected data for delivery.
- Local decision-making, enabling easy connectivity to legacy systems.
- A hardware root of trust, data encryption, and software lockdown for security.
- Local computing for in-device analytics.

Cloud Infrastructure

The enterprise-class UCS C240 server extends the capabilities of the UCS portfolio in a 2RU form factor. Based on the Intel® Xeon® processor E5-2600 v3 series, it delivers good combination of performance, flexibility, and efficiency. In addition, it comes with good levels of internal memory and storage expandability with exceptional performance.

OpenStack Cloud Platform

OpenStack is the leading open cloud platform. Ubuntu is the reference operating system for the OpenStack project, which is why deploying OpenStack with Ubuntu is the best way to ensure a straightforward implementation. Ubuntu Openstack contains all the current integrated OpenStack projects and some additional technologies beneficial to helping run an OpenStack cloud. The following is a high-level overview of our reference implementation for production use:

Compute—Nova: Nova, an OpenStack component enables the provision and management of large networks of virtual machines, creating a redundant and scalable cloud-computing platform. It gives the needed to run instances, manage networks, and control access through users and projects. Like the rest of the Ubuntu operating system, it supports most standard hardware configurations and well-known hypervisors.

Storage—Swift or Ceph: Swift, OpenStack Object Storage creates redundant, scalable object storage using clusters of standardized storage

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servers. Rather than a file system or real-time data storage system, it provides a long-term storage system for more permanent, static data. Examples include virtual machine images, photo storage, email storage, and backup archiving. Ceph is used for block storage as part of OpenStack Cinder. Ceph provides a feature-rich experience and is also able to provide Object Storage via a gateway giving an option to standardize on a single storage technology based on storage requirements.

Image service—Glance: The OpenStack Image Service provides discovery, registration, and delivery services for virtual disk images. It includes a standard REST interface for identifying them in back-end stores such as OpenStack Object Storage, with new virtual disk images being registered via the Image Service. Administrators can also access information on publicly available disk images and use the client library for streaming virtual disk images.

Authentication—Keystone: Keystone, the OpenStack Authentication service provides identity, token, catalogue, and policy services for use by OpenStack components. It provides a pluggable back-end that has been designed to support various protocols (e.g. Basic Auth, OAuth, OpenID, PKI) for authentication and authorization, allowing clients to obtain security tokens to access different cloud services.

Management—Horizon: The OpenStack management service or dashboard provides OpenStack users with a web-based user interface with which to control OpenStack's component services (Nova, Swift, Keystone, and Glance) and a single API with which to access them.

Networking—Neutron: Neutron, the networking service provides an API that can define network connectivity and addressing in the OpenStack cloud. Neutron enables operators to leverage different networking technologies supported by Ubuntu OpenStack such as Juniper's Contrail, Nuage Networks, MidoNet, VMware NSX, PlumGrid, CPlane Networks, and Calico from Metaswitch. Standalone, Neutron provides an API to configure and manage a variety of network services ranging from L3 forwarding and NAT to load balancing, edge firewalls, and IPsec VPN.

Metrics—Telemetry: Previously known as Ceilometer, the Telemetry module collects measurements about the OpenStack system and stores it in the form of samples in order to provide data about anything that can be billed. In addition to system measurements, Telemetry also captures event notifications triggered when various actions are executed in

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the OpenStack system. This data is captured as Events and stored alongside metering data.

Juju and MAAS: Juju and MAAS are the fastest and most integrated way to deploy OpenStack on Ubuntu. Using libraries of "charms" developed from experiences at customer sites makes it simple to deploy, configure, and scale out cloud services with only a few simple commands. MAAS is the bare-metal provisioning tool that turns hardware environment into a cloud in minutes. It takes the pain out of detection and configuration and gets the servers ready for Juju.

Virtualization: Ubuntu Server includes open-source hypervisors LXD/LXC alongside its default option, KVM. All are supported as virtualization options for Ubuntu OpenStack deployments.

jBilling and PayOne Payment Gateways

jBilling is a web-based enterprise billing and rating system. It manages subscribers with automatic invoicing (email and PDF) and payment processing (credit cards, checks, and direct deposit). It is robust, well documented, and easy to use, while PayOne is an unrivaled transaction processing solution that authorizes multiple payment methods (credit and debit cards) through different payment channels such as e-commerce, mobile, MOTO, and IVR. With a wide range of features, it provides both web and mobile experience to cardholders to conduct their payment transactions. Through advanced Fraud Detection and Prevention, PayOne gateway helps in minimizing the hidden costs associated with fraud and chargebacks.

QlikView Interactive BI

QlikView Interactive BI is a business discovery platform that delivers self-service BI that empowers business users by driving innovative decision-making with many features such as:

- Consolidating relevant data from multiple sources into a single application.
- Exploring the associations in the data.
- Enabling social decision-making through secure, real-time collaboration.
- Visualizing data with engaging, state-of-the-art graphics.

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- Searching across all data—directly and indirectly.
- Interacting with dynamic apps, dashboards, and analytics.
- Accessing, analyzing, and capturing data from mobile devices.

Identity and Access Management

Manage the end-to-end lifecycle of user identities across all enterprise resources, both within and beyond the firewall and into the cloud. The Identity Management platform delivers scalable solutions for identity governance, access management, and directory services. This modern platform helps organizations strengthen security, simplify compliance, and capture business opportunities around mobile and social access.

API Gateway

API gateway allows integrating cloud services, on-premise services proxy and manages interactions with cloud services. In addition, it can secure and manage APIs and SSO for Web Services Extend Enterprise Security to mobile and cloud applications. API gateway extends authentication, authorization, and risk policies to mobile, cloud, and enterprise applications. It enforces Data Security Policies through scanning messages and data payloads against security and privacy policies and block, redact, remove, or encrypt data.

Research Challenges

The big data context in the smart city has opened a number of opportunities for a new value proposition (Lohr 2012). In this section, some business and technology challenges are presented.

Business Challenges

Many smart city business models have been presented from commercial companies for a business market growth using new technologies such as IoT and Big Data. During the master planning development, the real estate developers faced difficulties for the application of Big Data into to the existing planning. Another challenge is the sustainability of cities using IoT and Big data technologies to improve their services. It is also in general challenging to clearly recognize the benefits of the IoT and Big data usage. The integration cost for the smart city is

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another challenge worth mentioning. Different hardware and software platforms are typically required for integration in order to effectively provide smart services using Big Data tools and systems. A key to reducing the cost is the usage of robust open standard technologies and frameworks.

Technology Challenges

The rapid growth of the smart services in the smart city and the huge amount of data requires a well-defined controlling and monitoring technology mechanisms. Privacy is an important challenge since private information of citizens may be exposed to analysis, sharing and use by third parties. Moreover, smart cities technologies raise a number of cybersecurity concerns that require attention especially when IoT technology is used.

Effective data analytics and data integration is another technology challenge worth mentioning. Despite advancements in integration efforts and applications, data quality remains a barrier to any data integration mechanism. This is particularly the case when data are incorrect, missing, use the wrong format and/or are incomplete (Gouveia et al. 2016).

Artificial intelligence and machine learning algorithms can be efficient in addressing many of the data-related challenges identified above, (Jin et al. 2014). However, their ease of applicability for extremely large data sets, such as in the case of smart cities, needs to be further evaluated (Tsai et al. 2014).

Conclusion

In this chapter, a comprehensive view of the role of IoT and Big data in a smart city is presented. In this context, different technologies and open-source software required for building the Big Data stack are discussed. Moreover, a scheme for the integration of Big Data, IoT and smart services under the smart city area is proposed. Finally, several business and technical challenges are identified for future research.

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CHAPTER 10

Opportunities and Challenges in Internet-of-Things (IoT) Deployment for Smart Cities

Ali Raza

Introduction and Background

The Gulf Cooperation Council (GCC) possesses a unique opportunity to realize secure internet-of-things (IoT) applications for government and public safety services. The security of IoT is considered to be of the same level of importance as public safety networks. This can be brought about with an approach for a unified network that allows interworking across the various public safety agencies in the GCC and delivers the economies of scale that are not possible in the niche targeted market of public safety. The number of public safety users globally is estimated to be between 10 and 20 million, which compared to the regular commercial market of over 3 billion is regarded as a niche. The challenge for device manufacturers and the ecosystem of infrastructure suppliers to provide security implementations tailored to the requirements of a single nation is a substantial one. Every nation bears the burden of securing communications in a way that can protect the public infrastructure and services from cybersecurity threats that are ever evolving. However, to tailor and individualize an entire network can be hampered by budgetary constraints even at a national level. Hence, a significant opportunity exists when a large group

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_10

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of users is formed through some level of harmonization across government agencies that are able to cooperate in terms of security implementation. The existence of such an opportunity for smart city IoT deployment in the GCC is discussed in this chapter with a special focus on long-term evolution (LTE).

LTE as a standard and technology can deliver the IoT technology which smart cities should consider when moving in the direction of scalability, reliability, and growth of public services and smart applications. The recent standardization of Narrowband IoT (NB-IoT) by the third-generation partnership project (3GPP)—an industry standardization body, brings reliability to the forefront with licensed wireless spectrum that is protected, unlike other IoT wireless technology. For governments, to deploy IoT-based applications becomes more practical as the issues related to interference faced in unlicensed wireless spectrum can be managed. However, focusing on spectrum is not enough. Reliability in terms of security requires a lot more attention in the case of IoT as devices are not in possession of a user and are more vulnerable to attack. Even if physical security were to be addressed, the security threats brought about by sniffer technologies can result in severe exploits. To overcome some of the vulnerabilities, more robust security implementations are required.

It could be argued that the commercial market segment of LTE can wait for security enhancements to evolve while steps to mitigate vulnerabilities are taken in the interim. However, this is a luxury the public safety world can least afford where the loss of a life in an emergency is a key performance indicator. This chapter discusses the security vulnerabilities of such a promising technology and presents the approach to mitigate them today through a vision of unification and cooperation of public safety agencies in the GCC. Methods of security implementation, based on the fundamentals of intelligence sharing are provided and discussed. The position presented in this chapter establishes the economies of scale that can be leveraged by the GCC member states to secure IoT for smart cities.

Smart cities are widely perceived as urban dwellings in which smart services are delivered to improve the quality of life for people. A network of smart devices, sensors, and computers are distributed around the city and connected in a web by technologies that securely transfer data to platforms, which in turn perform analytics to yield information of value. This value is then passed on to the city's population in terms of improved

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transportation, safety, security, healthcare, buildings, waste management, and utilities, to name a few.

There are a variety of sensors used to generate the data, which is collected in a centralized location. Some of these include temperature, humidity, pressure, position, acoustic, electric, and proximity among others. The ability to map out activities and events around the city with an increased level of accuracy and precision is brought about by advanced analytics and machine learning algorithms used to process this data coming in at high volumes and velocities.

This system of inter-related computing devices, or things, with their ability to connect to the Internet, is collectively referred to as the IoT. IoT is a key contributor to the concept of smart city which is gaining a significant amount of interest in the GCC. The development of IoT devices really took off with investments from venture capitalist firms into IoT startup companies. The aim initially was developing proof-of-concept systems with a marginal focus on security assessments. The direction taken after demonstrating the proof-of-concept is usually toward marketing and sales to get the product out to the market and maximize market share. This is often done without a revisit to the design drawing boards to truly assess the vulnerabilities of the platforms, operating systems, code, and protocols. The approach taken in this case by such companies is to fix issues through software and firmware upgrades in the next development iteration, with a few iterations planned each year. This in turn does not allow enough time for testing the new firmware upgrades in terms of security assessment.

In an IoT ecosystem, gateway devices have the role of interconnecting a number of protocols to support different air interface technologies such as Bluetooth, LoRA, SigFox, and Wi-Fi. Developers have focused on the security of the gateway devices to ensure that attackers are unable to access and compromise downstream devices. For example, a smartwatch with multiple sensors could connect to a smartphone over Bluetooth. The smartphone then plays the role of mediator and gateway hub to connect upstream and securely deliver the data to cloud applications for processing and analytics. Compromising the smartphone could potentially lead to a compromise of the data on the smartwatch and reveal personal location information.

IoT deployments in smart city applications would also use a topology where a heterogeneous mix of IoT devices are interconnected through a central gateway device that is able to translate multiple different protocols

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and transport (or backhaul) the traffic to the central platforms for data analytics. The security of the gateway devices has typically been the focus of security hardening measures. The purpose of security hardening is to close all known vulnerability gaps and potentially detect new unknown threats. There is little focus on the security and hardening of the end-point sensor devices primarily due to their limited memory and computing capabilities, complemented with a need for longevity, and hence energy conservation. Running security protocols on systems that are limited (or constrained) due to these criteria is quite challenging. This is one of the reasons why the focus of security has been on the gateway devices. However, to ensure that the correct end-point devices are connected to the gateway and sending data upstream, authentication of the devices to the gateway is considered a bare minimum security requirement.

Public safety services are an important security and safety contribution to the smart city ecosystem. However, security vulnerabilities of IoT devices limit the deployment of applications in the domain of public safety. Public safety networks are considered mission critical and are planned for high levels of resiliency and survivability. Managing security enhancements across multiple IoT technologies is not a practical approach. At the same time, to opt for a single IoT technology can be restrictive.

In recent years, the 4G (LTE)–a cellular technology standardized by the 3GPP—has been deployed for public safety networks, also known as public safety LTE (PS-LTE). A special 3GPP group called the SA6 working group (3GPP SA6 WG) provided the focus on mission-critical features and applications. These features were made available in the twelfth release of the 3GPP standards (R12) published in 2015. Additional features and enhancements were made available in the next subsequent release R13 which was published in 2016. Future work on R14 and R15 will include contributions from the SA6 working group. 3GPP supports machine type communications (MTC), which allow devices with LTE capable modems to upstream data via the LTE infrastructure. These modems could be hosted on end-point devices that host the sensors, in which case the traffic is routed directly to the cloud from the device hosting the sensor. These modems could also be on aggregate gateway devices. The LTE modem on the gateway is used to upstream traffic to the cloud in the northbound direction. In the southbound direction, the gateway supports a number of IoT protocols.

MTC was not originally designed for resource-constrained devices where power, memory, and CPU were limited. MTC devices were

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designed for applications not requiring human interaction or a graphical user interface. Mission critical-MTC applications are considered for very low and predictable latency use cases, which include traffic safety, control of critical infrastructure, and wireless connectivity for industrial processes. In such use cases, a low device cost and very low device energy consumption is not required. However, in the case of smart city deployments where a large volume of such devices are going to be geographically spread, the use of constrained devices will be important.

In Release 13, NB-IoT was published by the 3GPP SA6 WG. Similar to MTC, NB-IoT devices leverage the standardized air interface of LTE, however, modified to account for the constrained environment they are expected to operate in. An important modification is the narrow channel bandwidth applied to NB-IoT.

Indeed, MTC and NB-IoT devices are vulnerable to the same exploits identified for LTE, which have been meticulously treated in Clancy (2011). Release 12 and Release 13 standards do not address the impact of air interface shortcomings, which are detailed in later sections. The use of NB-IoT for PS-LTE to support smart city services will require enhancements to security. Overcoming the air interface shortcomings is not a trivial task but certainly achievable through partnership with the manufacturers of the devices and the enhanced NodeB (eNodeB) base stations, which the devices connect to. For device manufacturers to implement non-standardized (or proprietary) solutions, the cost for a single operator or city is prohibitive and uneconomic. Equipment vendors are able to provide products and solutions at lower cost leveraging the economies of scale.

For a single city, the economies of scale are not achievable by vendors. Hence, when multiple cities are able to jointly drive the requirement for a solution to the security shortcomings, there is an opportunity. However, every city and public safety entity would require an implementation of security mitigation that is relevant and suitable to their use cases and scenarios. Hence a coordinated effort is required among the cybersecurity teams responsible to provide the needed protection.

Such an opportunity exists among the six countries which are members of the GCC. These include the Kingdom of Saudi Arabia, the Kingdom of Bahrain, the United Arab Emirates (UAE), Kuwait, Qatar, and the Sultanate of Oman. A number of the GCC member countries are driving forward in the adoption of public safety LTE technology. The protection

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of the services provided over PS-LTE is paramount and needs to be addressed as a matter of urgency.

In the section "LTE Technology for Smart City Applications," LTE technology is covered broadly but with a focus on the security vulnerabilities and exploits. In the section "The Internet-of-Things: IoT," the IoT technologies are presented along with their applications and shortcomings. The section "Narrow-Band IoT (NB-IoT)" details the NB-IoT technology advancements published in the 3GPP Release 13 standards. The section "Security Challenges in LTE for a Smart City Framework" discusses the security coordination which can be achieved among the GCC member countries. Finally, the section "GCC Opportunities and Challenges for Smart City Solutions" presents the opportunities and challenges for the GCC region.

LTE Technology for Smart City Applications

In 2004, 3GPP initiated the LTE program for an evolved packet system (EPS) which was focused on providing radio access (eUTRAN) targeting high peak data rates, higher throughput, higher spectral efficiency, and lower latency. In addition, and as shown in Fig. 10.1, the integration of the radio access technology with an all IP packet core (evolved packet core (EPC)) was important to make networks more scalable and less complex.

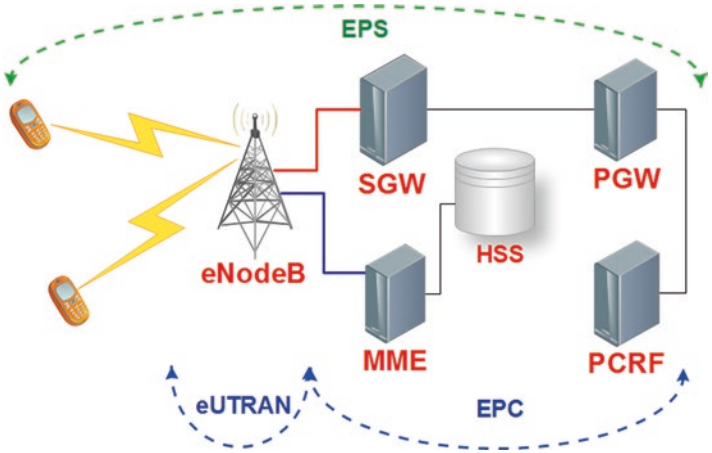


Fig. 10.1 LTE technology architecture

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The core network was intended to be backward compatible in the sense that integration to legacy networks such as GSM (2G) and WCDMA (3G) was part of the requirements for LTE (4G). In 2008, the 3GPP Release 8 (R8) was published with the detailed specifications and commercial deployments of LTE. Since then, there have been subsequent releases of the 3GPP standards with the most recent release R13, finalized in late 2015 and ratified in March of 2016.

In R12 and R13, 3GPP prioritized the use of LTE technology for mission-critical applications and use cases which target public safety, emergency response, and security services. In R12 relevant contributions toward PS-LTE were the inclusion of Proximity Services (ProSe) and enhanced multimedia broadcast and multicast services (eMBMS). ProSe allows for user equipment (UE) devices near each other to communicate directly without the relaying traffic through the cellular network. Termed as device to device (D2D) communications, this feature replicates the direct mode operation, which is possible in other public safety technologies such as terrestrial trunked radio (TETRA), where devices are able to communicate in the absence of radio coverage when they are in proximity to each other. Furthermore, the ability for devices to communicate in groups, as in TETRA, was brought about through the introduction of group communication system enablers (GCSE) and eMBMS. ProSe, GCSE, and eMBMS introduced in R12 support the uses cases for PS-LTE that require applications such as mission-critical push to talk (MCPTT) specified in R13 and MC-Data and MC-Video being specified in future R14 and R15 revisions.

LTE: Technology Overview

LTE: Authentication and Security Architecture

LTE UE devices obtain an IP address during the initialization process which enables communication in the EPC core network (Rossler 2009). The UE proceeds to register to the LTE network using the EPS-AKA authentication mechanism. This requires the network to request the UE's International Mobile Subscriber Identity (IMSI) for authentication.

The IMSI is sent in clear text to the Mobility Management Entity (MME) which forwards the access request (network attach) to the Authentication Centre (AuC) function in the Home Subscribers Service (HSS) (See Fig. 10.2). Both the Universal Integrated Circuit Card

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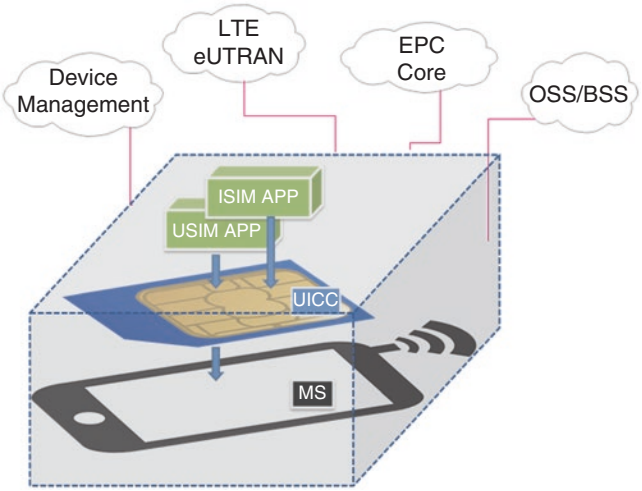


Fig. 10.2 UE ecosystem

(UICC) in the UE and the AuC in the HSS have a secret key Ki (pre-shared by the service provider and stored on the UICC and also in a database in the HSS after UICC activation).

The USIM in the device and the HSS in the network authenticate each other mutually before a user communicates any useful information. A summary of this process is shown in Fig. 10.3.

As shown in Fig. 10.4, the IMSI is sent from the mobile device to the HSS in the network. This information is transferred via the NAS protocol highlights that the packet is not protected. Efforts to capture the IMSI have been made easier due to the IP nature of 4G LTE networks. A simple Wireshark capture can display this vital information to a malicious user without spending much in purchasing an IMSI catcher Xu et al. (2005, 2006) in text. The flow of such a capture sequence is shown in Fig. 10.4.

The vulnerabilities with the authentication procedure include:

1. The authentication procedure lacks privacy protection.
2. The authentication procedure is susceptible to denial-of-service (DoS) attacks.

A DoS attack can be launched on either the MME or the HSS by an attacker disguising to be a legitimate user, constantly sending fake IMSI's

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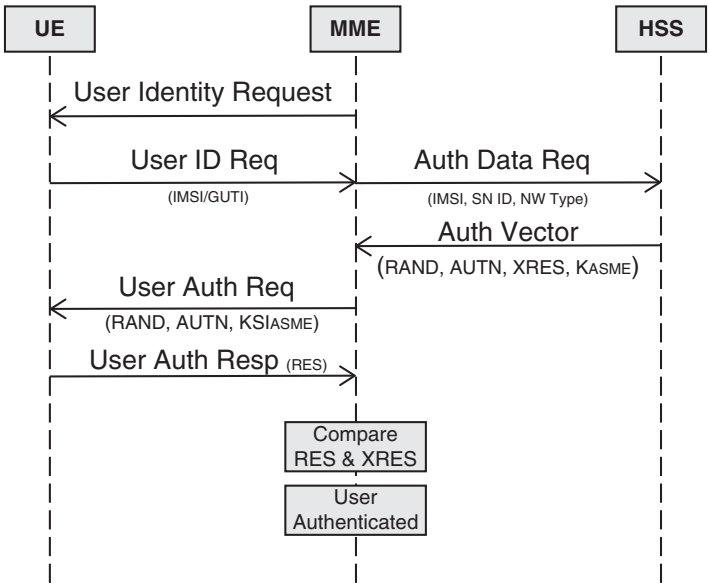


Fig. 10.3 LTE authentication process

to overwhelm the HSS. With multiple UE IMSIs being captured, a distributed DoS (DDoS) attack can be possible on the LTE network.

With the increasing sophistication of programming tools, the wider availability of SDR (software defined radio) transceivers and the growth in hacking skills among rogue agents, the steps illustrated in Fig. 10.4 can be achieved at low cost, although it is non-trivial. As the device attempts to connect to an eNodeB in the first step, several messages are exchanged between the UE and the eNodeB. Plaintext is used as per the 3GPP standards which allows for any device to attempt connecting to an available network.

With this approach comes the possibility for an exploit as the plaintext exchange of messages becomes a vulnerability. The rogue agent would attempt to listen to the exchange of messages between the UE and the eNodeB, which are in plaintext using an SDR transceiver that is tuned to the frequency used by the LTE network operator. As the 3GPP LTE standards are openly published and widely available, the rogue agent would select the Frequency Division Duplex or Time Division Duplex mode of operation, program the channel bandwidth

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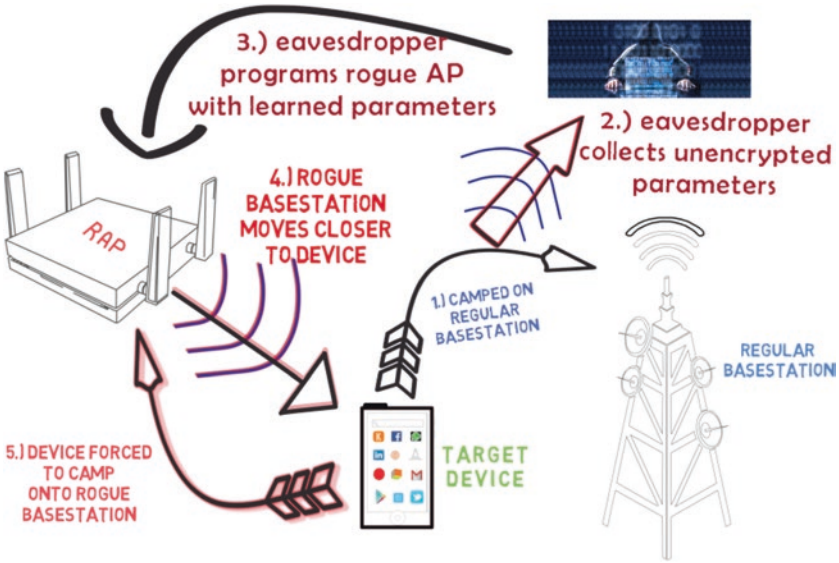


Fig. 10.4 Steps toward a compromise of an LTE base station by an intruder using a rogue access point

assignments pre-defined in the standards and begin to listen for activity on various frequencies. This is a process known as scanning.

Once the desired parameters are learned through the SIB and MIB message exchange, the rogue agent can configure these parameters in a rogue access point (RAP) which is also built using an SDR transceiver. With the RAP ready for the attack, the rogue agent can move the RAP to a location which is within proximity of devices that would attempt to connect to an eNodeB. Such locations could be at the exits of underground or subway stations in urban metropolitan areas. The UE would detect the signal from the RAP to be at a higher power than a nearby legitimate eNodeB. It would select the RAP to continue the process of service enablement. However, as the RAP is only a rogue device without the network functionality required to complete the service enablement process, the RAP will simply reject the request from the UE to attach to the network. The UE can be blocked from trying to attach to a network through a legitimate eNodeB for a substantial period of time. In most cases, rebooting the device can overcome this substantial time period. However, a typical

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user would not be aware that the reason for a lack of service is a RAP and would possibly wait for the device to attach eventually. The intentional blocking of a user from access the legitimate service provided by the network is regarded as a "denial-of-service" attack. The attacks possible in LTE can be mitigated with changes to the standards that do not allow the IMSI or other messages to be transmitted in plain text in the early stages.

The Internet-of-Things: IoT

The roots of IoT originate from the Massachusetts Institute of Technology (MIT), from work at the Auto-ID Center. This group worked in 1999 in the field of networked radio frequency identification (RFID) and emerging sensing technologies. With seven research universities located across four continents, these institutions, worked in collaboration with the Auto-ID Center on the design on an architecture for IoT (Ilic et al. 2016).

IoT is simply the point in time when more "things or objects" were connected to the Internet than people. In 2003, there were approximately 6.3 billion people living on the planet and 500 million devices connected to the Internet. By dividing the number of connected devices by the world population, we find that there was less than one (0.08) device for every person. IoT did not yet exist in 2003 because the number of connected things was relatively small given that ubiquitous devices, such as smartphones, were just being introduced.

Explosive growth of smartphones (following the unveiling of the iPhone in 2007) and tablet PCs brought the number of devices connected to the Internet to 12.5 billion in 2010, while the world's human population increased to 6.8 billion, making the number of connected devices per person more than 1 (1.84 to be exact) for the first time in history.

Today, IoT is made up of a loose collection of disparate, purpose-built networks. Cars, for example, have multiple networks to control engine function, safety features, communications systems, and so on. As IoT evolves, these networks, and many others, will be connected with added security, analytics, and management capabilities. This will allow IoT to become even more powerful in what it can help people achieve.

IoT today is defined by a heterogeneous mix of technologies which include Bluetooth, ZigBee, SigFox, and LoRA, to mention a few. These individual technologies are based on independent standards which are considered quite diverse in their implementation and the market segment they are or were originally intended for.

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Interconnecting these devices is a challenge for developers. A common and robust security model does not exist across these technologies. Distributing a mix of these devices for a certain type of application (such as we expect in smart cities) requires the implementation of a smart gateway. Gateway devices can be implemented to combine a number of these technologies on a single platform with the support of diverse protocols and technologies. Gateways connect devices in a way to provide a translation service among devices that use different protocols or technologies together. A simple example of a gateway is an Android device that can serve as an intermediator between a Bluetooth smartwatch, which can monitor our heart rate for instance, and a cloud application platform as shown in Fig. 10.5, where analytical processing of the data collected can be carried out to provide valuable information. The Android device acts as a gateway accepting data inputs from the Bluetooth smartwatch and forwarding it over a Wi-Fi-based home gateway router to the cloud service or even via cellular UMTS or LTE networks.

These gateways will be required to overcome the security challenges across the separate technologies. This complexity makes the gateway products risky to support due to the vulnerabilities of data loss and brand damage. The importance of securing the gateway is imperative as it can prevent hackers accessing the downstream devices in addition to protecting against interconnectivity attacks. Securing gateways, and the devices that hang off them, requires identifying and authenticating each device. Public key cryptography between devices and the gateway for authentication and for verifying the integrity of firmware updates is a common approach used for

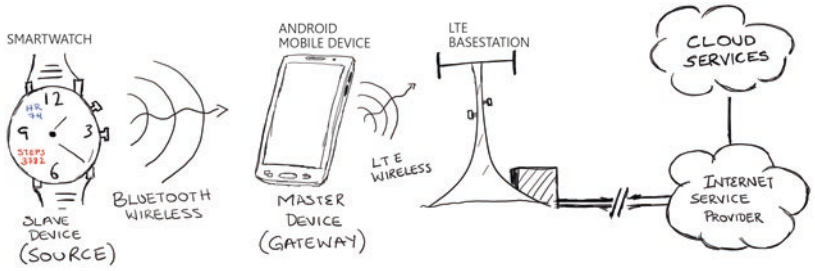


Fig. 10.5 IoT web connectivity to cloud-based services over 4G cellular network provided by an Internet service provider

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this purpose. Software frameworks available such as Eclipse Kura can offer the security of devices and the gateway.

IoT developers must stringently test devices and gateways based on their inherent vulnerabilities. This is especially important in products such as connected cars and drones that can be used as weapons if they are compromised. Testing criteria, documentation, and methods must be jointly developed to thoroughly test the solutions threat surfaces against appropriate attack vectors.

Narrow-Band IoT (NB-IoT)

NB-IoT Applications

Mobile broadband telephony for bandwidth-hungry media content is fundamentally centered around information delivery to and from end-users. MTC, in which end-point devices are unmanned are increasingly being applied for different applications. The 3GPP termed these use cases under the general header of MTC. However, it should be noted that MTC and IoT are often used interchangeably.

MTC applications are generally categorized broadly as massive-MTC (M-MTC) and mission-critical MTC (MC-MTC). M-MTC is used when applications use a dense deployment of wireless sensors forming an ad-hoc network with a number of gateway anchor points. The wireless sensors are different types of sensors, actuators, and similar devices. M-MTC devices typically have to be of very low cost and have very low average energy consumption enabling very long battery life. At the same time, the amount of data generated by each device is typically small and the data-rate and latency requirements are often relatively relaxed.

MC-MTC applications depend on the concepts of reliability, resilience, and survivability. MC-MTC is required to support such applications, which may include public safety, control of critical infrastructure, and wireless connectivity for industrial processes. Many of these applications also have requirements on very low and predictable latency. At the same time, very low device cost and energy consumption are typically less important for these kinds of applications.

In both cases for M-MTC and MC-MTC, it is important to be able to provide connectivity in non-conventional locations such as deep within the basement of buildings and in very rural or even deserted areas with very sparse network deployments. A radio access technology supporting

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such massive-MTC applications must therefore be able to operate properly with very high path loss between base stations and devices.

NB-IoT Opportunities

A common challenge across the heterogeneous mix of IoT technologies is the use of the unlicensed ISM band frequencies. Being unlicensed, any user can transmit on the frequencies defined in the ISM band. In such cases, applications depending on IoT devices deployed in the ISM are susceptible to degraded services. Degradation is brought about by the interference caused by unwanted transmitters. In some cases, the power level of an interfering signal could be high enough to drown out the desired signal for the IoT application.

An analogy commonly used to understand this phenomenon is of two people having a conversation near an airfield. While there are no aircraft in the vicinity, the conversation is not impeded. However, when an aircraft passes overhead, the noise is loud enough to drown out the conversation, forcing the conversing parties to temporarily stop communication.

An ongoing parallel 3GPP activity referred to as NB-IoT was started as a 3GPP technology track separated from the evolution of LTE. Recently, the NB-IoT technology has been aligned with LTE and it can now be seen as part of the overall LTE evolution. The focus in this chapter on NB-IoT is to specifically highlight its key contributions to the world of smart city technology.

Security Challenges in LTE for a Smart City Framework

Advancements offered in the 3GPP standards coupled with the dedicated non-ISM bands raises an opportunity for the case of secure smart city technology. LTE technology, like all other wireless systems, is vulnerable to radio jamming. Radio jamming is a simple and well-known attack that is considered the simplest way to launch a localized DoS attack against a cellular network (Perez and Pico 2011). To successfully jam a desired service with an interferer, the user has to be in proximity of the user for whom the intended DoS attack is being perpetrated. All end-user devices in proximity of the jamming interferer will be impacted. Recently, as discovered and reported in Lichtman et al. (2013) and Talbot (2012),

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advanced attacks with a significant level of sophistication are possible and provide a more effective way to jam LTE networks. These attacks exploit the vulnerabilities inherent in the cleartext transmissions used in LTE. As an example, the physical resource blocks assigned to uplink control channels are transmitted in broadcast messages from and eNodeB. These messages are network configuration messages and are unencrypted. For an attacker, being able to intercept and exploit such messages, the opportunity to execute a DoS attack across an entire LTE cell served by an eNodeB or a particular sector widens the threat landscape. In addition to this, the unencrypted configuration messages sent with such broadcasts also lead to DoS attacks in which the attacker mimics an eNodeB (rogue base station).

When a mobile terminal (MT) or UE powers on, it will try to acquire the LTE network parameters and eventually connect to the network. This involves a number of acquisition procedures to be executed. For devices to acquire this information, the 3GPP standards dictate the use of information known a priori to the UE. Although such information is essential in simplifying the initial access procedure for the UEs, it could be potentially leveraged by an attacker to model an advanced jamming attack, optimize the configuration of a rogue base station or model other types of sophisticated attacks.

GCC Opportunities and Challenges for Smart City Solutions

To prevent the types of sophisticated attacks highlighted in the previous section, a number of viable technical solutions can be proposed. Enhancing the security of LTE such that the values offered by NB-IoT as an alternative to the ISM based wireless sensor technologies can be leveraged is an important consideration for smart city evolution.

However, implementing these security enhancements can be quite challenging as discussed next. In order to protect the broadcasted system information messages that can be used by an attacker, some method of encryption will be required. As with other information known by the UE a priori, the information needed to successfully decrypt these messages will also need to be known in advance by the UE. Although exploring the depths of these technicalities is not the real intention of this chapter, it is useful to highlight one approach to set the context. The UE and the net-

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work are provisioned with a pre-defined key which is used for encryption and decryption. Any such provisioning is done securely and guarded through advanced key derivation algorithms. The UE and the network are able to signal the use a particular key association for a given session.

In the current 3GPP standards, such implementations do not exist. One of the challenges encountered in implementing this approach in the standards is the backward compatibility with other UEs that are using the same network. For an eNodeB to begin transmitting encrypted MIB and SIB messages, all the UEs would require provisioning of the keys as well as the algorithms and supporting hardware and software combinations.

Vendor Selective Chipset Implementation

Vendors chipsets typically implement the medium access control (MAC) and physical (or PHY) layers of the open system interconnect (OSI) stack (3GPP 2010). This implementation will conform with the 3GPP specifications, which are published and widely available. This applies to both the base station manufacturer and the handset manufacturer, enabling their equipment to interoperate. Changes to the implementation at the base station or the chipset will not be welcome by either manufacturer. When a change is made at the base station, there has to be a corresponding change made at the UE. This approach deviates from the standards adoption by both manufacturer types.

The support for such security enhancements is pursued more in the mission-critical space such as in the world of public safety and smart city technology. The number of users that require these solutions is limited and does not deliver on the economies of scale required to keep the supply chain profitable. In addition to this, the manufacturers are required to maintain separate programs of conformance, compliance, and interoperability for each combination of base station and UE based on the chipsets used.

To demonstrate the gravity of how non-trivial this can be, Operator 1 intends to use UE devices from chipset manufacturers A, B, and C. At the same time, to prevent any kind of vendor lock-in, Operator 1 also decides to deploy base stations from manufacturers X and Z. This would mean that there are six separate and independent programs of interoperability testing which are not aligned to any standards. In the event that manufacturer X implements an approach which conforms with the chipset from manufacturer B only, then the interoperability of manufacturers A

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and C already successfully in place with base station manufacturer Z are risk of being broken.

Furthermore, UE chipset manufacturer C might be required to support base station manufacturer Y for a new Operator 2. In the commercial space, this approach begins to suffer from scalability and complexity issues very soon. In the non-commercial operator space (e.g., in the case of public safety networks), this issue is amplified by the lack of volume orders to justify even the case of any Operator 1, deciding to use UE chipset manufacturer A, while at the same time agreeing to be locked-in with base station manufacturer Z.

In terms of base station sites, a city requiring blanket coverage may need approximately 280 sites using a high-frequency band (e.g., 2.6 GHz). In comparison, a lower frequency band (e.g., 700 MHz) would be able to support the same coverage requirements with approximately 95 sites. This is a difference of 180 sites. Furthermore, a commercial network will need to add to the original 280 sites required for blanket coverage when capacity holes need to be filled in as the subscriber base grows. Such explosive growth in subscriber base is hardly an issue in the world of private non-commercial operator scenarios (e.g., when LTE is deployed solely for the use of government and public safety services). The number of subscribers here is merely a fraction of the numbers encountered in the commercial operator space.

For a base station manufacturer, the consideration to support non-standardized features and functionality over the lifetime of a network will only be appealing in the commercial scenario with a large number of base stations. Similarly, for a UE manufacturer, to partner with a base station manufacturer for such deviations from standards, the demand needs to be justified. Table 10.1 considers a tri-sector base station with the number of UEs per sector for both scenarios. These figures are based on the actual dimensioning done for a 4188 km² city. The commercial LTE network

Table 10.1 City-wide dimensioning scenario

	Sectors	*UEs per sector*	*UEs per site*	*Number of sites*	*Total number of UEs*
Commercial LTE	3	60	180	280	50,400
Public safety LTE	3	15	45	95	4275

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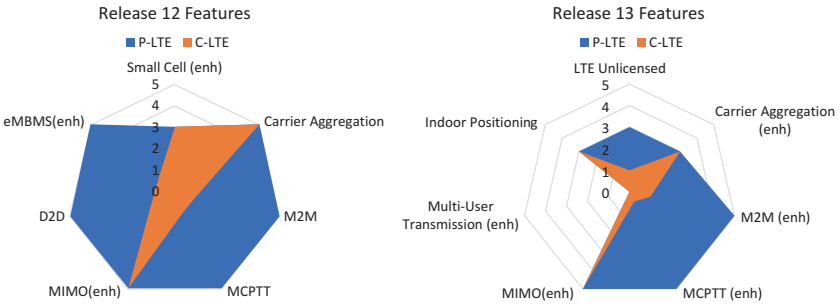


Fig. 10.6 PS-LTE versus C-LTE: levels of interest in 3GPP release features

uses an 1800 MHz deployment while the PS-LTE network uses a 700 MHz deployment. The total number of UEs in the case of PS-LTE is significantly lower than the case for commercial LTE (Fig. 10.6).

Opportunities

Within the GCC, the number of private PS-LTE operators is increasing. The number of users in this community is expected to grow as more countries are integrating the requirements of public safety, government enterprise, and smart city technology, to be served by a private secure LTE network.

The proposal put forward in this chapter combines the security interests across the GCC nations to secure the private LTE networks against the exploits which are also presented and described in this chapter. A budgetary dimensioning done across the GCC countries is shown in Table 10.2.

The ideal scenario assumes the operators for each country are using the same base station manufacturer and the same UE manufacturer. In this case, the base station and UE quantities justify the investment for a security-enhanced solution that diverges from the mainstream standards. The security issues described in this chapter will impact other countries implementing LTE technology as part of the smart city infrastructure to benefit from the emerging NB-IoT capabilities. A further ideal scenario is the deployment of the base station and UE quantities from a single vendor that manufactures both systems. In addition, the home country of the manufacturer can also benefit, adding to the overall economies of scale.

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Table 10.2 GCC-wide dimensioning example—based on data collected from regional operators

Country	*Sectors per eNodeB*	*UE per sector*	*UEs per site*	*Number of sites*	*Total number of UEs*
KSA	3	20	60	3500	210,000
Bahrain	3	20	60	200	12,000
Qatar	3	20	60	1800	108,000
Oman	3	20	60	2500	150,000
UAE	3	20	60	1500	90,000
Kuwait	3	20	60	1200	72,000
				10,700	642,000

Conclusion

Smart cities will benefit from the technologies offered by the 3GPP standards for wireless sensor technology. The inherent security flaws in the LTE technology highlighted in this chapter are a major gap which needs to be filled. Ideally, the standards need to address these gaps in future releases to address the security vulnerabilities of such a promising technology. While it could be argued that the commercial market segment of LTE can wait for such security enhancements, the potential risk on public safety is significant and requires immediate action. However, as discussed in this chapter, the opportunity to drive independent enhancements, even at a national level, is not possible due to the lack of economies of scale. This chapter presents an opportunity to combine the interests across the GCC countries through a vision of unification and cooperation of public safety agencies in the GCC. This is expected to establish the economies of scale that can be leveraged by the GCC member states to secure IoT applications for smarter Gulf cities.

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PART V

Social Perspective

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CHAPTER 11

Dubai Happiness Agenda: Engineering the Happiest City on Earth

Ali Al-Azzawi

Introduction

Dubai's government opted for a strategy to focus efforts on transformation toward a world-class smart city, where smart technologies are seen as enablers toward the goal of happiness. Such a strategy needs to be grounded in clear definitions, frameworks, and activities where excelling in their practice would eventually lead to the realization of the vision outlined above. There are various definitions of smart cities that include information and communication technologies (ICT), quality of life, efficiency, and competitiveness, while maintaining a balance with respect to economic, social, environmental, and cultural aspects. Within such a broad range of issues are dominant dimensions such as the ones suggested by the European Union project aimed at ranking the smart cities, which include economy, living, mobility, governance, environment, and people.

A primary step in this endeavor is to deal with the definition of happiness. Though at first this may seem challenging—trying to unpack various philosophical and psychological theories, some dating back to ancient

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_11

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philosophers—this may be overcome by focusing on the well-established 'well-being' literature and turning toward fulfilling the needs of city residents in such ways as to raise happiness.

A simple ABCDE model is presented here that starts with subjective well-being (SWB), which is equated to the sum of affective (A) and cognitive (C) needs, though this equation ignores basic needs (B) that address the prosaic aspects of life in the city, as well as the deeper and more profound eudaimonic needs (D), which are more about higher meaning and purpose. The model also includes enabling needs (E)—both internal (personal) and external (environmental). The internal enablers are the personal skills and attitudes a person has, while the external enablers are the aspects of the social environment around them. This view forms the basis of Smart Dubai Office's (SDO) ABCDE model of needs. SDO therefore aims to increase happiness by satisfying and facilitating these needs, thus creating a more complete and holistic positive experience of the city.

The mechanism for fulfilling these needs is the Happiness Agenda, which aims to systematically address the needs of customers and increase happiness in a structured and methodical way. This agenda has been designed to be fully aligned with the City Transformation Agenda, with its three impact axes of customer, financial, and resources. The Happiness Agenda is composed of four portfolios: Discover, Change, Educate, and Measure. Each portfolio, in turn, is composed of programs that are focused on achieving the strategic objectives of the portfolio, with each program having a variety of specific projects to be executed. The projects within these portfolios are designed to find and measure needs, create changes and interventions, create awareness so that other stakeholders may contribute to fixing issues proactively, and innovate toward happiness by satisfying these needs. This chapter describes how psychological techniques and measures, combined with smart technologies, are used as tools within the Happiness Agenda.

The happiest city on Earth—this is the vision for Dubai, as outlined by His Highness (HH) Sheikh Mohammed Bin Rashid Al Maktoum, vice president and prime minister of the UAE and ruler of Dubai. Smart Dubai's mission is to facilitate happiness by 'embracing technology innovation—making Dubai the most efficient, seamless, safe and impactful experience for residents and visitors'. For such a mission to be achieved, the SDO prioritizes happiness as a 'measurable strategic initiative' rather than a marketable campaign.

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However, not surprisingly, whenever happiness is mentioned, it does not take long before someone asks, 'What do you mean by happiness?' and, in the case of Dubai, 'How will the level of happiness be raised?' These and other questions will be addressed in this chapter, in order to understand the technical approach taken by SDO, the organization charged with fulfilling this vision as well as transforming Dubai into a world-class smart city.

Nonetheless, before continuing, it is useful to briefly touch upon what a city is. William Shakespeare reminded us, 'What is the City but the People?' (Coriolanus, Act 3, Scene 1). In more modern times, in his seminal city planning book, Jan Gehl emphasizing *Cities for People* (Gehl 2013), and in his book, *Triumph of the City*, Edward Glaeser points out, 'Cities aren't structures; cities are people', and goes on to conclude, 'Ultimately the job of urban government isn't to fund buildings and rail lines…but to care for the city's citizens' (Glaeser 2011). The question about the role of government regarding the care and happiness of the people has been the subject of debate not only in the social and political arenas but also in academia (Layard 2011), including discussions around the links between well-being and public policy (Diener 2009). This role was already unambiguously stated at the dawn of the UAE through HH Sheikh Zayed's first newspaper headline in the first edition of the UAE's national paper *Ittihaad*, where he promised his people that 'Public services will be provided in all places towards citizen happiness'.

Such understanding of what a city is and what the role of government is in facilitating happiness for its people resonates well with the idea of a smart city, which is an evolution of the *Technopolis* concept (Gibson et al. 1992). A smart city is one that aims—among other goals such as sustainability—to enhance the quality of life. The International Telecommunication Union (ITU) defines a Smart Sustainable City as 'an innovative city that uses information and communication technologies (ICTs) 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, environmental as well as cultural aspects' (UNECE 2015). This definition highlights the importance, especially for highly technical organizations such as the ITU, of keeping an eye on the main purpose of the city as a place for people to live.

Such emphasis is reflected in the objectives outlined in the *Smart Dubai 2021* strategy for transforming Dubai into a world-class smart city by

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2021. The strategic objectives are anchored in the six EU-based research documents highlighting the main areas of focus for smart cities (CRS 2007), and are as follows:

- *Smart living*: Smart livable and resilient city.
- *Smart economy*: Globally competitive economy powered by disruptive technologies.
- *Smart people*: Interconnected society with easily accessible social services.
- *Smart mobility*: Smooth transport driven by autonomous and shared mobility solutions.
- *Smart environment*: Clean environment enabled by cutting-edge ICT innovations.
- *Smart governance*: Digital, connected, and lean government.

As can be seen from the above strategic objectives, there is a significant focus in SDO's strategy on enhancing the quality of life, directly and indirectly. However, in order to specifically ensure that the focus on happiness is embedded into the whole organization—and the city—SDO has launched the Happiness Agenda, which cuts across these six objectives, ensuring that attention to happiness is holistic.

This vision of the happiest city on Earth is undoubtedly noble, with many technical, social, and psychological challenges. In the next section, this chapter outlines the strategic objectives of the Happiness Agenda and the mechanisms employed to reach this vision—followed by an overview of the technological and psychological tools used to ensure success—describing some actions taken to overcome such challenges, and data showing progress toward this vision.

Kick-Starting the Happiness Agenda

Why is happiness important? Many ethical arguments suggest that happiness is a good thing, and should therefore be increased in communities. Also, there has been evidence to show objective benefits of subjective well-being—and these have been well documented—such as health and longevity, income, productivity and organizational behavior, and individual and social behavior (De Neve et al. 2013). Further, the benefits of frequent positive affect have a positive influence on healthy and prosocial behavior (Lyubomirsky et al. 2005a, b). There has also been evidence that

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'happiness, pleasant moods, and closely related constructs precede indicators of physical well-being and adaptive coping' (Lyubomirsky et al. 2005a, b) and that 'pleasant moods boost people's abilities at resolving conflict' (Lyubomirsky et al. 2005a, b) and 'promote original thinking' (Lyubomirsky et al. 2005a, b). Interestingly, there is also some support for a 'causal relation between positive moods and immune function' (Lyubomirsky et al. 2005a, b). Of course, the causes and consequences of happiness and well-being have been the subject of much research (Huppert 2009).

The definition of happiness, in its various flavors, has been debated in ancient times, by the likes of Aristotle and others before him. In modern times, there has been a growth in rich literature on happiness (also known as well-being in academic literature), and many publications over the past decades have addressed happiness as a whole topic or science—by Ed Diener, Daniel Kahneman, and other notable contributors to the field. Layard, for example, laid out a comprehensive review of the science of happiness, including aspects of policy-making toward a happier society overall, rather than just economic development (Layard 2011). His review also included the work of Martin Seligman, the inventor of *Positive Psychology*, which focuses on *Flourishing* (Seligman 2011), and illustrates a framework called PERMA that aims at increasing happiness at the level of individuals and society as a whole: PERMA refers to Positive emotion, Engagement, positive Relationships, Meaning, and Accomplishments/Achievements.

Therefore, in order to get on with the task of fulfilling Dubai's vision, a primary step is to deal with the definition of happiness. Although at first this may seem challenging—with various philosophical and psychological theories—the challenge may be overcome by focusing on the well-being literature and turning toward fulfilling the needs of city residents and denizens in such ways as to facilitate happiness. The focus on needs implies the requirement for action toward fulfilling these needs rather than merely providing a passive definition of happiness. The Happiness Agenda therefore aims to address the needs of people in the city, which are essential to enhancing happiness for both the short and the long terms.

The ABCDE Model of Happiness

Starting with the commonly used definition for happiness as SWB, it is equated to the sum of affective (A) and cognitive (C) needs (OECD

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2013), although this equation ignores basic needs (B), which address the prosaic aspects of life in the city, as well as the deeper and more profound eudaimonic needs (D), which are more about higher meaning and purpose. Interestingly, the World Happiness Report defines SWB to include A, C, and D (Helliwell et al. 2017). The model also includes enabling needs (E): internal (personal) and external (environmental). The internal enablers are the personal skills and attitudes a person has such as optimism and mindfulness, as well as their personality traits such as openness and extraversion. The external enablers are the social environment around them, including aspects such as fairness, inclusivity and trust. This view forms the basis of SDO's ABCDE model of needs (Fig. 11.1). SDO therefore aims to increase happiness by satisfying and facilitating these needs toward a more complete and holistic positive experience in the city.

Affective and Emotional Needs

'Affect' is used here to mean emotional response to inputs—such as sensory inputs—that may include such responses as fun or other hedonistic pleasures, or displeasure (Blyth et al. 2003). However, according to Norman, 'affect is an evaluative system' (Norman 2003), which will lead to an approach-avoidance response. Such evaluation may also occur as a result of other pleasures, not just physical. It has been shown that regular positive affect has many distinct benefits, including longer life and greater success in life (Lyubomirsky et al. 2005a, b). Diener and others have

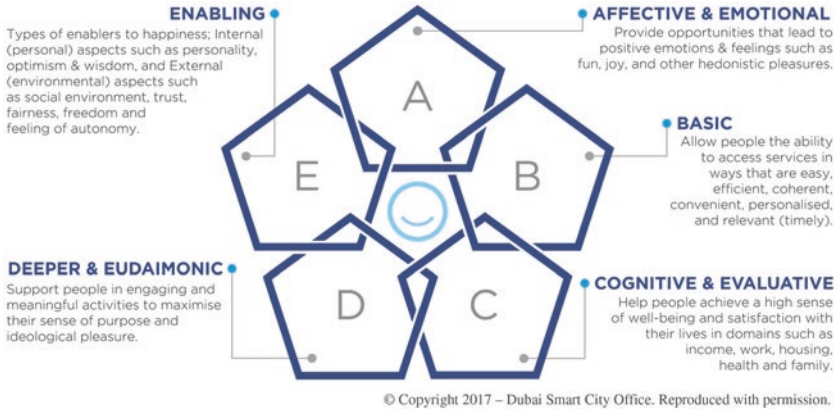


Fig. 11.1 The ABCDE model for the needs of happiness

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reported that, 'Subjective Well-Being is typically defined as the sum of affective and cognitive components' (OECD 2013; Miao et al. 2014; Diener 1984). Some models of pleasure also include psychological, ideological, and sociological pleasures (Tiger 1992). Further, people may experience emotional responses even spontaneously, without immediate external inputs, for example on remembering a positive or negative experience. In this regard, this is the *affective well-being* a person may experience.

Therefore, the Happiness Agenda aims to *provide opportunities that lead to positive emotions and feelings such as fun, joy, delight, playfulness, amusement, and other hedonistic pleasures.* However, it is interesting to note that there is an optimal ratio of positive to negative emotions, referred to as the Losada ratio (Fredrickson and Losada 2005). Research has shown that having this ratio at 3:1 (three positive, and one negative) results in the best chances for good general well-being, or happiness. Of course, the levels and types of positive affect in general are also subject to differences based on the variety of cultures around the world (Fors and Kulin 2016).

Basic Needs

As highlighted by Maslow, people have basic needs, which must be fulfilled in order for them to feel satisfied (Maslow 1954). With regard to living in a city, people also have basic needs related to services. Drawing on well-established research-based insights from domains such as service and interaction design, there are well-known aspects to service provision—including technology interfaces—that enhance the quality of people's experience with services including the user interface (Al-Azzawi 2013; Stickdorn et al. 2011). There are also well-known design and usability heuristics that help in ensuring minimal disruption to the use of technology or a service in general (Nielsen and Molich 1990).

The Happiness Agenda therefore aims to *allow people the ability to access services in an easy, efficient, coherent, convenient, personalized, relevant (timely), and seamless way.* For example, people need to be aware of the service before they can actually access it. However, this may be extended to their need that a service be efficient and convenient from their point of view: for example having minimal steps, automation, personalization or even transparency (in the sense that it gets done without their specific intervention). Further positive value may be derived by a reduction of cost in terms of time and money.

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Cognitive and Evaluative Needs

Cognition is a process related to assessment (thinking and evaluating). According to Norman (2003), 'Cognition is a system for interpretation and understanding', which will eventually lead to an approach-avoidance response. With respect to well-being, this can be related, for example, to a person's assessment of their 'satisfaction with Life' (Diener et al. 1985). This general assessment is essentially the person's 'overall' subjective averaging for their satisfaction of important domains in their lives (Kahneman et al. 1999; Diener 1984), such as work, income, housing, and the physical environment in which a person is living. Regarding the physical environment, the literature is full of evidence for the positive value that well-designed spaces, both individual and urban, can have on people's well-being—in particular spaces with a feel of nature (Kaplan and Kaplan 1989), where people can gain much from the restorative benefits of nature (Al-Azzawi 2012; Kaplan 1995). Some research has shown that simply adding small pockets of greenery, or even painting urban spaces green, can make people feel better (Montgomery 2013).

However, what is important to one person may not be to another, for the purpose of the Happiness Agenda, which is looking at communities and city populations, but it is possible to use pre-existing lists based on domains that tend to be listed as important by most people around the world (Biswas-Diener 2010; Frisch 2005). Therefore, the Happiness Agenda aims to *help people achieve a high sense of well-being and satisfaction with their lives in various domains such as income, health, commute, housing, recreation, work, food, community, education, marriage/partnership, family, and friendships.*

Deeper and Eudaimonic Needs

If only affective, basic, and cognitive needs are addressed, however, then many lay people and even academics may argue that something is missing. The value of having a sense of purpose and deeper meaning in life is a profoundly human trait (Zhang et al. 2018; Seligman 2011). People look for meaning not only in relationships or actions but also in stories and things (Csikszentmihalyi and Halton 1981). In fact, this sense has been highlighted and discussed by ancient philosophers like Aristotle—for whom this was true happiness—which they referred to as eudaimonia (Huta 2014): living a life of true virtue, where people are able to actualize their 'daimon' (true self) (Vittersø 2003). Thus, aside from the functional

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needs, people also have deeper needs associated with deeper meaning, eudaimonia, and purpose.

Such deeper senses can also be achieved in one's work and general activities and have been referred to as the state of engagement and flow (Csikszentmihalyi 1990). In this state, the person is so engaged in the activity that time slows down for them: they are so fully focused on what they are doing that they lose themselves in the activity and stop noticing the world around them. Therefore, the Happiness Agenda aims to *support people in engaging and meaningful activities that maximize their deeper sense of purpose and their level of engagement. For example, the sense of flow in work and other activities, or being occupied with things bigger than 'self', like spirituality, care for the environment or nation, charity, benevolence, community involvement, craftsmanship, and achievement.*

Enabling Needs

The needs outlined so far are ones that a person could obtain or somehow be able to arrange for themselves. There are, however, other factors that a person needs in other ways, in order to elevate their level of happiness, although these are more akin to enablers. In this regard, their presence will act like a general substrate in their lives that are more or less likely to help them—or make it easier—on their journey to happiness. There are two types of enabling needs: internal and external.

Internal (personal) enablers are factors that influence happiness, although they tend to be about the person themselves or the way they react to their environment. Personality is no doubt a big influencer, and the person's genetic pre-disposition is a significant factor (De Neve et al. 2012). Significant amount of research has been conducted on this topic (Anglim and Grant 2016; Morris et al. 2015; McCann 2011), with some research suggesting that 50% of a person's happiness level may be attributed to their natural 'set point' (Lyubomirsky et al. 2005a, b). In terms of the Big Five personality traits (McCrae and Costa 1987)—*openness* (to new experiences), *conscientiousness*, *extraversion*, *agreeableness*, and *neuroticism*—the traits most correlated with happy people are openness and extraversion, while the negatively correlated one is neuroticism (Gutierrez et al. 2005; Weiss et al. 2008). However, other personal factors also support and enable happiness, such as optimism (Seligman 2006) and resilience (Seligman 2011), which are skills that can be learned (Lyubomirsky 2007). Also, a major enabler of happiness is positive mental health (Dickerson 1993). As has been shown in many publications and research

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projects, poor mental health accounts for significant misery (unhappiness), and addressing such conditions has a substantial and positive effect on the happiness of individuals and society at large (Layard and Clark 2014).

Other psychological dimensions have also been linked to well-being such as personal growth and self-acceptance (Ryff and Keyes 1995), including mindfulness, where an individual is able to live in the moment without judgment (Chang et al. 2015). Research has also highlighted the contribution of personal skills toward increased happiness (Layard 2011).

Therefore, the Happiness Agenda aims to *provide opportunities that help individuals understand themselves (personality), their pre-dispositions, personal skills, such as optimism, resilience, and mindfulness, and how these influence their happiness, and ways to improve them. The agenda also intends to find ways of raising awareness of mental health issues and finding ways to help people overcome such challenges.*

External (environmental) enablers are also important to happiness in terms of providing the right mix of environment. Aside from the benefits of the actual physical environment (including the natural environment), which may be considered part of the cognitive and evaluative needs, social environmental variables can also enable happiness. These may include trust, governance, transparency, freedom, inclusivity, and fairness as well as the general outlook of a culture, where some show general positivity and happiness. Other psychological dimensions relevant to the social environment have also been linked to well-being, including autonomy and environmental mastery (Ryff and Keyes 1995).

It is not surprising to find a lot of evidence regarding the power of freedom to raise happiness (Layard 2011), and this is reflected in the notion of being able to choose according to one's preferences, or at least to have some degree of influence on one's surroundings, where 'institutional conditions in the form of the extent and form of democracy have systematic and sizeable effects on individual well-being' (Frey and Stutzer 2000). In this case 'democracy' is not necessarily the idea of having a full system for political influence, but is a matter of provision of some system of voicing personal preferences and being able to somehow influence decisions.

Trust has been shown to be another important social variable (Hamilton et al. 2016). The World Happiness Report also highlights the importance of trust with regards to happiness, noting that 'it has already been established that even beyond social trust and absence of corruption there are

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several different aspects of life where trust is important for well-being—in the workplace, on the streets, in neighborhoods, in business dealings, and in several aspects of government' (Helliwell et al. 2017). The report goes on to describe the complex relationship that trust has with various social variables, such as income and equality. However, other publications report that people are actually looking for fairness rather than equality per se, and more specifically that 'people aspire to equal opportunity' (Starmans et al. 2017).

Culture is also relevant. Recent literature on cultural values around the world, exploring various empirical evidence and general data sources such as the World Values Survey, has proposed that there are effectively three types of cultures: with emphasis on honor (African, Islamic, and Christian orthodox countries), achievement (Asian, Confucian, and western countries), and joy (Latin American and Caribbean countries) (Basáñez 2016).

The Happiness Agenda therefore aims to *provide and highlight opportunities that help improve external and environmental influencers that would raise happiness.*

Strategic Objectives and Portfolios

The mechanism for fulfilling and facilitating these needs in Dubai is the Happiness Agenda, which aims to systematically address the needs of customers and city residents, and to facilitate happiness in a structured and methodical way. However, before the Happiness Agenda can take shape, there must first be an assessment of the current state of happiness in Dubai, and clear objectives made for the agenda itself. First, it was noticed that there was very much an informal knowledge base around happiness, and activities and their impact were based on assumptions. A better approach would be to have formal definitions, with shared understandings, that guide strategic activities in Dubai. In this case a strategic objective for the Happiness Agenda is to *discover* people's needs, formalize definitions, and establish a baseline with regards the current levels of happiness for various domains, segments, and sub-cultures in Dubai.

Second, although there were several efforts around the city to increase the quality of experience, there was no specific consideration for impacting happiness from city planners and other private sector groups. A more impactful approach would be to have unified and coordinated city leadership planning, using happiness impact forecasting. Therefore, another

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strategic objective would be to create *change* by developing and influencing policies and approaches to focus the city and people on happiness.

A third aspect of the city that was assessed was the quality and level of understanding of factors associated with personal and organizational happiness. Such levels were found to be low, and a better position would be to have deep organizational and personal understanding of factors associated with happiness across the city. This finding leads to the third strategic objective, which is to *educate* and build awareness around the topics associated with happiness at various levels including academic, practitioner, and practical.

Finally, an assessment was made concerning the measures and insights made at the scope of government and private sector leadership regarding the daily satisfaction and happiness levels. These measures were found to be limited and would benefit from being enhanced to contain deeper, live, and targeted measures of satisfaction and happiness across the city. Ultimately, what is not measured cannot be deliberately improved. Therefore, the fourth strategic objective of the Happiness Agenda is to *measure* happiness by conducting research, and to formulate and implement predictive happiness impact scores as well as a citywide happiness index.

Taking the above strategic objectives as the drivers of the Happiness Agenda, the agenda itself was organized into four portfolios: Discover, Change, Educate, and Measure. Each of these portfolios is composed of programs that are focused on achieving the strategic objectives of the portfolio, with each program having a variety of specific projects to be executed. The projects within these portfolios are designed to find needs and measure them, create changes and interventions, create awareness so that other stakeholders may contribute to fixing issues proactively, and innovate toward happiness by satisfying these needs. In this way, psychological techniques and measures combined with smart technologies are used as tools within the Happiness Agenda. The Discover portfolio centers on finding out essential and baseline aspects of happiness in Dubai. The Change portfolio focuses on interventions that directly facilitate increase in happiness. The Educate portfolio aims to build awareness and understanding of happiness and the needs underpinning it, as well as the methods that drive and facilitate it. The Measure portfolio is used to close the feedback loop, and it relies on the position that 'if you can't measure it, you can't improve it'.

A critical aspect of the Happiness Agenda is the development of a network of individuals—Happiness Champions—who were focused on

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happiness within their organization as well as having high-level access within the organization's structure. This network serves two primary purposes: to develop a sense of collaboration among primary city stakeholders (public and private sector) and to ensure alignment and coherence of happiness related projects across the city, where the champions are able to share existing and future projects as well as learn from each other's successes. This network is a key aspect of ensuring efficiency in a smart city.

Finding Opportunities

Having set the scientific basis and the principles underpinning the framework of the Happiness Agenda, the task then moved toward the phase of finding opportunities to take action within each of the portfolios: Discover, Change, Educate, and Measure. Keeping in mind that SDO is about using technology to transform the city into the happiest city on Earth, each of the tools, measures, and interventions is focused on using existing technologies, or developing new, innovative, and smart technologies to drive this goal.

Discover: Snapshot

As part of the preliminary baseline assessment of the state of happiness in Dubai, SDO conducted an initial study, utilizing standard academic surveys aimed at measuring different aspects of happiness. These included the Cantril Ladder (Cantril 1965), used in the World Happiness Report: emotions (Diener 2009), psychological instruments aimed at measuring people's values (Schwartz 2003a, b) as well as their satisfaction with life in general (Diener et al. 1985) and domains such as health, housing, and education (Biswas-Diener 2010; Frisch 2005). The first snapshot study sampled more than 2000 Dubai residents, while the second snapshot sampled 10,000 residents, representing the overall mix of the local population in terms of demographics. The results were used to gain an understanding of the motivations, values, and domain satisfactions in Dubai and to find correlations for specific segments, and thus providing more accurate guidance for further interventions. For example, the data showed that for Emiratis, housing has a high correlation with happiness, and upon further investigation, SDO went on to work with Mohammed bin Rashid Housing Establishment in order to improve satisfaction with their services, thereby enhancing happiness.

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Discover: Sector Review

In order to establish a baseline understanding of the primary sectors in Dubai in terms of people's general needs and specifically digital needs, a comprehensive review was conducted for the following sectors: tourism and travel, trade and logistics, health, education, and finance. For each of these sectors, key stakeholders were interviewed to find out the state of the main customer journeys in terms of the positive and pain points. To this end, each review produced detailed customer journey maps and stakeholder maps, highlighting typical touchpoints and communication channels along with a detailed analysis of the experience at these touchpoints, for both customer and supplier, as well as key information and trends within the sector. The analysis concluded with a detailed list of improvement areas and recommendations. Each recommendation followed a simple template to ease the assessment: why the recommendation, who is it for, what to do, and how to do it?

With such a simple approach and initial assessment, these reviews were used to conduct further detailed studies to follow the areas of improvement and validate the recommendations, by conducting further engagement with stakeholders including customer segments within the sectors. The aim of these steps is to derive a clear set of actions that will spawn specific projects to improve happiness within these sectors. Such sector reviews are critical for cities with specialist segments, such as Hajj pilgrims in Mecca, where there are specific needs, and much to learn through the analysis of behavioral data, which can then be used for personalizing people's experience in the city during a highly emotionally charged spiritual event where deeper needs take a priority.

Change: Happiness Hack Dubai

As a result of the review of the travel and tourism sector, a 'Happiness Hack' was undertaken with the aim of making distinct improvements in travelers' happiness. The hackathon focused on various aspects of traveler experience. The activity benefited from further sector review at a wider field, scanning current innovations and future technology horizons.

The hackathon involved over 40 experts from around the world—from various fields such as artificial intelligence, data science, industrial design, electronics, and robotics—all focusing their attention on four main themes: presenting Dubai as a great destination where the future is created,

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welcoming the arriving visitors with comfort and ease, creating a seamless guest experience in their hotel that is close to the comfort of a home visit, and enhancing the general city experience with a high degree of personalizing the visit to their emotional needs.

The event concluded with a demonstration of four unique product ideas as working prototypes ready to be taken into the next phase of a pilot product development or to be used to conduct user research, and then toward a production product. However, the overall output of the event was also a practical demonstration of collaborative innovation by city organizations and the private and public sectors as well as the on-hand practical knowledge gained by the Happiness Champions, who were critical at the hack week, where the ideas were generated and clarified.

Change: Behavioral Economics

A key element of the Happiness Agenda is to use evidence-based interventions, using scientific methods to drive intervention design. Such interventions may be pre-existing ones based on published scientific works, or ones created specifically for the context found in Dubai. Such methods can also use a combination of different disciplines in order to derive value for the city as well as its inhabitants. For example, in an effort to increase happiness in Dubai, and to drive further public engagement, SDO is collaborating with Dubai Police and Oxford University, by using state-of-the-art behavioral economics and nudge techniques that have already shown tangible results elsewhere in the world (Abdukadirov 2016; Thaler and Sunstein 1999). One such effort is concerned with reducing aversion and delay in fine payments while at the same time increasing compliance and the degree of public engagement, which would give an overall rise to happiness among residents of Dubai. The success of such projects has the potential to transform a normally mundane or negative experience into a dynamic and potentially positive experience.

Change: UCD for Basic Needs

There are clear strategic and tactical benefits to establishing and using User-Centered Design (UCD) methodologies within organizations that aim to serve people with products or services including digital and smart services. Such benefits include reduced Total Cost of Ownership, increased adoption and use, increased task-completion rate, and improved efficiency

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and productivity (Al-Azzawi 2014). For these reasons, SDO employs such methods and principles in the design and production of products like *DubaiNow*, an omni-channel platform (aiming to serve the general individual resident of Dubai with a common platform for city services, especially public sector); *Dubai Pulse*, the smart city platform that is intended to provide city data, data visualization, and development platform services to entrepreneurs and organizations; and the *Happiness Meter*, to provide instantaneous measures of various aspects of happiness in the city. Although these products may not directly fall within the scope of the Happiness Agenda, ensuring the quality of their user experience certainly does. In particular, these platforms are intended to provide their services while ensuring that the basic needs are met in terms of, for example, usability, coherence, efficiency, and convenience. To this end, these platforms are systematically monitored to ensure a high-quality user experience, with audits that result in trackable usage issues or 'customer experience bugs'.

Creating Tools

Part of the endeavor to create systematic change toward the happiest city on Earth is to develop and install robust systems within organizations, which work toward monitoring levels of happiness and changing the practices in a positive direction.

Change: Corporate Happiness Framework

To this end, SDO has collaborated with Dubai Silicone Oasis Authority and Oxford Strategic Consulting, to produce a Corporate Happiness Framework (CHF) that aims to help organizations increase happiness within. The framework is based on the Happiness Agenda's scientific model of ABCDE of happiness needs, where focus is also maintained on the causes of happiness. In this framework, happiness is not seen as the 'contented happiness' but rather as 'active committed enthusiasm' (ACE) (Jawad and Scott-Jackson 2016). The CHF includes core criteria to increase happiness as well as specific criteria that can be customized to the context of any organization. Further, the CHF includes tools, questionnaires, and a star-rating points system that allows organizations to be ranked in terms of the efforts being employed internally. The framework recognizes the importance of happiness at work, as it accounts for significant aspect of people's lives in the city. In the corporate context especially,

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the objective is that employees, customers, and other stakeholders should not just achieve contentment but enjoy ACE.

Measure: Happiness Maturity Model

In concert with the CHF, SDO also developed the Happiness Maturity Model (HMM), which was further enhanced in collaboration with Oxford Strategic Consulting, to ensure further academic rigor. Similar to other maturity models based on the original from Carnegie Mellon University, the HMM helps organizations establish an understanding of the degree of maturity with regards to implementation of the Happiness Agenda in order to deliver its targeted outcomes. There are five levels in the HMM, numbered 1–5, with increasing levels of maturity: *ad hoc*, *developing*, *standardized*, *tactical*, and *embedded*. The HMM includes a full description of these levels as well as a framework project plan for any organization intending to maximize happiness within their organization. This project plan is provided by SDO as a template as well as an explanation of how to use HMM to understand the level of happiness maturity within the organization. Aside from an example project plan, the release also provides descriptions of initiatives to undertake and people and infrastructure to put in place in order to proceed to the next stage of the maturity model. There are also standard measurement instruments, showing causal factors and internationally accepted indices of happiness, ensuring that the measures explain and drive actions toward ACE and not just passive contentment. Importantly, the templates also have clear explanations of how the HMM relates to the CHF process.

Measure: Happiness Algorithm

Measuring and improving happiness at a corporate level is only part of the challenge of the Happiness Agenda. The main target is the city at large. SDO therefore developed and implemented a citywide Happiness Meter, of which the first variant measured satisfaction at the point of interaction with services (digital and non-digital). Building on this successful variant, SDO looked for opportunities to create completely new ways of measuring happiness in the city while utilizing existing data within the city.

SDO established a collaborative project with an international company specializing in machine learning and data science, in order to develop sophisticated algorithms that aim to predict happiness based on the data

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existing within the city infrastructure, which reveals people's behavior and demographics. The algorithms allow SDO to create models that facilitate prediction of happiness based on these data and any simulated input to the model. This valuable asset also has distinct advantages over traditional methods of measuring happiness because it allows instantaneous measures of happiness when compared with the expensive and slow methods that rely on collecting new data at long intervals, which can also be invasive to people. These algorithms are the first in the world to attempt such a measurement, and SDO is now working on implementing this system throughout Dubai, along with exploring opportunities from artificial intelligence technologies. A simple application of these algorithms is to connect them to human resources data within an organization, enabling instantaneous measure of happiness in the organization.

Measure: Decision Tools

Early prototypes of such integration with human resources systems were produced to show the viability of creating tools that aim to help decision makers improve their decision-making process by including models that take advantage of the Happiness Algorithms. However, these were not limited to human resources systems and were also tested with other scopes, such as people's satisfaction with life domains (e.g. housing, income, leisure, and health). In this way, executives can simulate the influence their decision may have on the happiness of residents, based on project types. For example, they are able to assess the rise in happiness created by a local park project as compared to a school project within a community, which are competing for the same space or funds. Therefore, their decisions will be informed by the extent to which each of these projects will raise happiness in that community.

Measure: Smart Happiness Project Evaluation

As mentioned above, the SDO, established by HH Sheikh Mohammed to oversee the smart city transformation of Dubai, follows the Smart Dubai 2021 strategy that ensures a holistic and all-encompassing smart city, using six dimensions to drive and assess initiatives throughout the city for both the public and private sectors: smart living, smart economy, smart mobility, smart governance, smart environment, and smart people. However, when taking happiness as the ultimate goal, a clear

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and evidence-based view must be taken regarding the influence of these dimensions on the happiness of the people in Dubai. Therefore, as a step toward systematically assessing the various effects that each of these dimensions have on happiness, SDO collaborated with expert academics at the University of Oxford and the Gallup Organization. The project was set up to find out the extent to which these dimensions influence happiness. In this way, SDO can make data-based recommendations on how best to use resources and direct forthcoming projects in a way to have maximal impact on happiness in the city. Further, the project forms the foundational work for the Smart Happiness Project Evaluation. This compound index gives a data-based link between happiness, these six dimensions and the strategic objectives of Smart Dubai 2021. The initial ground work is complete, and the team has now taken further steps to create a tool that will help assess projects, policies, and initiatives in terms of happiness and the value they have toward the transformation of Dubai into a world-class smart city—and the 'Happiest City on Earth'.

This critical tool allows Dubai to achieve its vision by enabling various entities and organizations to assess each of their initiatives using methods that give them data-driven insights regarding the way these initiatives will contribute to the vision of happiness in a smart city, and thereby to enhance their initiatives to make them more effective toward this vision. Further, the tool will take into account the challenges of social comparison (where people's happiness is dependent on who they compare themselves with) and adaptation (where people get used to improvements), by including these aspects into the outcome calculations of the tool. This tool will be part of the decision-making process, and it will further enhance leadership guidance by enabling initiative adjustments for maximum longevity, avoiding a focus on short-term gains in happiness, and, instead, aiming for sustainable long-term happiness in a smart Dubai.

Institutionalizing Happiness

It is, however, not enough to just develop and use the abovementioned methods and technologies within the Happiness Agenda. It is also important to create awareness of happiness topics among Dubai's population in general, as well as to encourage and develop formal education with a view to further the world knowledge, and contribute to global thought leadership. In this regard, SDO sought to raise awareness of world-class service

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provision among the Happiness Champions by sending nearly 40 Champions on a week-long intensive training at the Disney Institute, where they learned from the Disney masters the details of how to create a magical experience.

Educate: Happiness Diploma

A simple way to improve education around the topic of happiness is to collaborate with existing educational institutions in Dubai to provide specialized courses. SDO has therefore collaborated with RIT-Dubai University (a branch of Rochester Institute of Technology in the USA) and Gallup in order to bring a comprehensive professional diploma focused on corporate happiness.

The happiness diploma comprises both practical and theoretical knowledge around the topic of happiness, and specifically corporate happiness. The diploma also covers a deep dive into the details of the Happiness Agenda with such topics as the Happiness Agenda framework, SDO's model of the ABCDE of happiness needs, the Happiness Meter, and the HMM. The diploma also helps students learn methods to evaluate and assess happiness in organizations, leadership strategies and methods that enhance happiness, and ways in which these can be applied—including plans and strategies for implementation—in the corporate context.

Educate: PhD Program

While projects such as the happiness diploma essentially use pre-existing academic and practitioner material, SDO has also developed relationships with world-renowned universities to offers PhD students unique research opportunities related to smart cities. For example, SDO has partnered with the University of Surrey, a highly ranked university in the UK, to provide PhD students with an opportunity to research on cutting-edge topics that can be applied to happiness in a smart city context, such as urban design, co-creation, and digital storytelling. Given the complexity of designing smart cities of the future, urban design revolves around reconsidering conventional approaches to UCD, while the digital storytelling project revolves around tourist experiences. The way in which tourists capture and share records of their trips has changed in recent years due to the ubiquity of digital photography and social media. PhD students

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learn to use a combination of design ethnography, prototyping, and field trials and have the opportunity to use such methods applied to real challenges in Dubai, facilitated by SDO as the industrial supervisor.

Of course, such research programs, as well as in-house SDO research projects, open up prospects to contribute to the literature on happiness and well-being. SDO will therefore continue to find opportunities to showcase the Happiness Agenda and its research and practice in peer-reviewed academic literature, in an effort to share the lessons learned from experience, and in applying these projects in a real city.

The above strategic objectives and associated activities will ultimately embed and institutionalize happiness culture not only in the daily lives of the residents of Dubai but also in its public, corporate, and academic institutions.

Opportunities and Challenges

Though the Happiness Agenda has a clearly defined scientific basis on how happiness may be facilitated—as well as systematic approach rendered in its strategic objectives and organizing portfolios—creating lasting change toward a happier society, especially on the scale of a city, is not without its challenges. There are many opportunities and challenges toward this goal, and some of these are highlighted below.

Cultural Diversity

There is no doubt that values vary across cultures (Schwartz 2003a, b), and as mentioned above, some have suggested that there are three main cultural super-groups in terms of value emphasis, including those that emphasize honor, achievement, and joy. Further, there are many studies showing that SWB varies across cultures and nations for various reasons (Minkov 2009; Rice and Steele 2004; Diener and Suh 2000). So even if there are limited number of value sets in these different cultures, the question that still remains is that in a vastly multi-cultural society, such as the one found in Dubai, what is the best way to design happiness interventions or policies that improve the happiness for all the people in such heterogeneous societies?

Therefore, to address such challenges, the Happiness Agenda continues to rely on the rich source of research methods specifically designed to take

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a multi-cultural context into account (Van de Vijver and Leung 1997). Also, referring back to the mission of SDO—to use technology toward achieving its vision—there are opportunities to personalize interventions and services using data insights and such technologies as artificial intelligence and machine learning.

Social Comparisons

Having what you want may not be enough to be happy. It depends on what other people, in your perceived 'group' have. This social comparison was first theorized to account for how people evaluate their opinions. However, more recent research has focused specifically on happiness and well-being (Clark et al. 2018). The challenge here is that although individuals in a society may strive toward their goals and then achieve them, they are also comparing themselves (upward and downward) to other people, and so if, for example, everyone improves their living conditions and a person still thinks they are in the bottom of their group, even though the whole group's conditions have been raised, they may still feel unsatisfied.

The notion of intrinsic and extrinsic motivations toward goals plays a role here. Such motivations are inherently developed at cultural and personal levels, and there are many studies looking at ways of measuring (Gibbons and Buunk 1999) and overcoming such challenges across society. Though social comparison may have a 'dark side' (White et al. 2006), some have made the suggestion that, done right, social comparison itself is the solution (Diener and Fujita 1997).

Adaptation

Even though there are many ways to positively influence the level of happiness in an individual or society, there still is the question of the permanence of such improvements and the rate of regression back to the original levels. In a famous paper, Easterlin explores the link between income and happiness and concludes that 'as economic conditions advance, so too does the social norm, since this is formed by the changing economic socialization experience of people' (Easterlin 1974). This is known as the Easterlin Paradox, highlighting people's adaptation of happiness to rising income levels. In psychological terms, this is related to habituation, a phenomenon seen in various aspects of life, and it has

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been investigated by various studies, for both positive and negative events (e.g. lottery winners, marriage, unemployment, and disability) (Clark et al. 2018).

This is also related to the notion of hedonic adaptation (or the *hedonic treadmill*) (Oswald and Powdthavee 2008; Frederick and Loewenstein 1999). There have been various studies to find ways to overcome such adaptation with regards to happiness (Lyubomirsky et al. 2005a, b), and more recently, the Hedonic Adaptation Prevention (HAP) model that looks at 'variety' as a way to overcome such effects (Sheldon et al. 2012).

Conclusion

This chapter has attempted to show how the seemingly 'soft' goal of creating the happiest city on Earth may be considered in a systematic way, more akin to an engineering approach to a problem. First, happiness itself was framed and organized in terms of the types of needs that people have (ABCDE model) and the variety of ways in which these needs may be fulfilled or facilitated. Next, how the organization of projects may be approached in a systematic way to ensure that right actions are done in the right way to the right people, using technology where possible to ensure the most efficient way of undertaking these measures, and actions or interventions. In fact, these methods are being applied in Dubai as a whole and smart districts within, such as Dubai Silicone Oasis and Dubai Design District, the home of SDO. There are plenty of ways in which these methods may be applied directly to other smart cities in the Gulf Cooperation Council (GCC) region and beyond, like the very modern King Abdullah Economic City and Neom (in Kingdom of Saudi Arabia), and even in the more traditional cities such as the holy city of Mecca.

Acknowledgments I would like to thank the Happiness Champions and many other colleagues in the Government of Dubai, who have helped in the continuing successes we have had within the Happiness Agenda, for their passionate support with their new ideas and unending energy. Special thanks go to my colleague and boss, H.E. Dr. Aisha bin Bishr, the Director General of SDO, for her unwavering support and leadership that developed the Happiness Agenda into what it is now, and her vitality and vision to continuously push us toward the (im)possible. Most importantly, I feel a deep sense of gratitude to HH Sheikh Mohammed bin Rashid Al Maktoum, for the precious opportunity to contribute to the wonderful city of Dubai.

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CHAPTER 12

Smart Cities and Place Making: The "Sense of Place" in the Implementation of Smart Cities in the Arabian Gulf

Giovanna Potesta

Introduction

The Arabian region is currently one of the most fervent incubators of smart cities. The phenomenon has been triggered by several causes, sometimes not strictly dependent among themselves. The availability of wealth enables the investment of considerable amounts of money in the creation of new cities. Technological advancement has matched well with the novelty of city planning. New cities, in fact, can theoretically adapt thoroughly to the contemporary needs of its inhabitants without the constraints of historical preservation. In addition, rapid growth in the Gulf countries has been supported by the foresight of illuminated rulers, whose administrative strength has enabled the reaching of viable results in a short period of time. Along with these two conditions, the awareness that the present wealth—mostly generated by fossil fuels—necessitates alternative opportunities for economic growth also plays an important role.

The cities of the Gulf over the last 50 years have transformed dramatically. The modernist model suppressed the urban environment of the

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_12

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traditional Arab city. The transformation of the physical model has had consequences for the cultural references and social behaviors of the citizens of the Gulf countries. Whereas the modernist cities of the Arabian Peninsula still had a connection with the past in the form of modernist regionalism, smart cities belong to the era of globalization. Like many of the products of postmodernism, the smart cities in the Gulf aim for the status of global cities and currently seek the re-proposition of a magnified and generalized Arab identity.

Smart city concepts can represent an opportunity: smart governance, planning flexibility, and new relationships between society and technology. The goals of Arabian smart cities are ambitious and involve an impressive amount of human and economic capital. The two partially developed cities, Lusail and Masdar, offer to visitors and workers an idea of what a newly founded smart city might resemble in reality. The projects for smart cities emphasize technological operations, respect for the natural environment, a reduced carbon footprint, economic growth, and international entrepreneurship. Not often do the vision and goals accentuate the human conditions. New technologies and sustainable performance do not necessarily suffice for the creation of a sense of belonging for the residents. This chapter addresses the importance of increasing the conditions for the existence of a "sense of place". The sense of place is an emotional condition, historically originating—or rather rising spontaneously—from a blend of building techniques and societal values. It formed through a lengthy process not replicable in the conscious act of founding a contemporary city.

Thinking Sustainably: Smart Cities and Smart Growth

The United Nations Population Fund in 2008 anticipated that 80 % of the world population in 2020 would be living in urban areas (UNFPA 2009). At the same time, the UN stated that cities are responsible for the consumption and emissions of CO_2 in a proportion that, at that time, ranged between 60 % and 80 % (UNDP 2015). According to the UN-Habitat World Cities Report of 2016, the population living in urban areas in 2015 reached four billion, and the worldwide migration of populations toward urban areas was measured at a pace of 77 million per year (UNHSP 2016). Contemporary metropolises are expected to grow beyond 10,000 million inhabitants, while a multitude of cities already have populations of between

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five and ten million inhabitants. Urban life does not necessarily indicate wealth. In fact, in 2001, 31.6 % of the urban population lived in slums (UNHSP 2003). Along with massive urbanization, the planet has registered demographic growth that represents a challenge to survival. Protection of natural resources and the connection of people to services therefore constitute the primary goals toward a sustainable future.

Smart cities and smart growth define manners of examining city growth in a sustainable fashion. Although both strategies attempt to solve the challenge posed by the increasing world population in terms of sustainability, their goals do not always coincide. Generally, what most authors intend for smart cities are cities where every form of urban action—material or immaterial—is detected, measured, and managed by information and communication technologies (ICT) (Albino et al. 2015). Smart growth, in contrast, is an agenda generated within a new urbanist vision. Hence, its inherent principle is the densification of the urban environment as the main tool for sustainable accretion (Downs 2005). Not infrequently, smart city implies smart growth and vice versa. Smart growth is envisioned through the application of new technologies. The principles of smart growth inform municipality codes and strategies of urbanization promoted by private agencies. Most recurrent principles in initiatives supporting smart growth have concerned the following aspects: containment of the sprawl of the city, densification of urban areas, mixed use of buildings and mixed-use zoning, maximum use of pedestrian links, and optimization of public transportation. Smart growth also promotes the idea that part of the costs sustained by the public for the implementation of a new development should be paid by the developer (Downs 2005; Duany and Speck 2010). Urban sprawl is the principal enemy of smart growth. Building sparsely increases the availability of green lands and natural resources but demands high infrastructural costs. Nonetheless, not every author agrees that smart growth responds properly to the needs of a sustainable environment. Particularly in cultures where the dispersed city is an acquired model, as in the USA and to some extent in the UK, the call for "building dense" has encountered resistance (Marcial et al. 2012).

Interpretations of Smart Cities

In addition to the confusion between smart cities and smart growth, an element of ambiguity is represented by what "smart" means. Albino et al. (2015) identified 23 definitions of smart cities. From these definitions,

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two patterns of interpretation emerge: “smart” referring to the smartness of the systems providing the services in a city, or “smart” referring to the ability of the city to react to the challenge of the impoverishment of the planet. Almost every author has recognized the importance of establishing a better quality of life that encompasses the largest possible number of people. Strategies for realization of this goal have differed. Some scholars have confided in technological investments as a means to attract a “creative class” capable of enhancing the economic growth of the city and therefore the well-being of its inhabitants (Nam and Pardo 2014). The consequence, according to this position, is that economic growth and human well-being are strongly connected. In reality, studies directed toward assessing “happiness” of people relative to per capita wealth have shown that beyond a certain limit, the equation “more money = more happiness” no longer works (Montgomery 2013).

Recurrent components associated with smart cities are: smart economies, smart people, smart governance, smart mobility, smart environments, and smart living. The smartness of the system implies efficiency in the following aspects: industry, education, e-democracy, logistics and infrastructure, efficiency and sustainability, security, and quality (Albino et al. 2015).

Albino et al. extended the analysis, isolating the meaning of the most common indicators of smart cities available in the literature. The analysis used four indicators: networks (physical and informational), economy (promotion of urban growth), social (inclusiveness of citizens in the processes of smart cities), and natural environment protection (Albino et al. 2015). The indicators aim to establish an absolute leadership, assessing the degree to which a city is smart. The level of smartness therefore depends on subjective metrics generated from the standards of the agencies that produce them. In addition, whereas developed countries face the problem of retrofitting the existing cities in a smart way, many developing countries aim to combine the smartness of the services with the physical action of planning a city that did not exist before.

It is not easy to quantify the number of smart city projects worldwide. Whereas environmental concerns and citizen accessibility to services are nonetheless the primary reasons for the implementation of smart cities, the interests of multinational companies work as fuel. Cisco and IBM, to name two major companies, have elaborated platforms that are able to combine needs and solutions for worldwide cities aimed at smartness (Cisco 2017; IBM 2017; Panasonic 2017). The digitalization of data

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provides a virtual model that overlaps with the physical reality of the traditional city, merging the limits between the two (Yigitcanlar 2015). Some authors have pushed the duality further in command of the virtual city. The virtual city becomes a tool that is able to shape the physical city, inverting the cause-effect process. In the futuristic vision "prediction" of Dan Hill, in a view somewhat nostalgic for the Citta' Nuova of Sant'Elia (Gravagnuolo 1989), urban reality is transfigured into an obsessive engine of control:

> *Every breath of air, every footstep, every shift in temperature as the sun creeps across the stone is generating data for the city's intelligence, helping refine the current set of 'predictions'.* (Hill 2015)

Human activity is painted by Hill's prediction with the same constraining precision of his fictional "average man", who is caught in the act of picking "slivers", small intelligent films, available to everybody in the street:

> *A sharp-dressed man wearing glasses picks one up and it flares into life. It pulls down his ID via fingerprint and rapidly unfurls a series of updates, largely image based, with the occasional blare of audio coned for his ears only. His predictions rattle up the screen with a slight flick of the wrist. He mutters something under his breath to the sliver. The sliver, using its creaking 5G connectivity, borrows a few processor cycles from the lighting pole he is passing before switching its attention to a park bench as it, too, is passed by the increasingly broad strides of the man. Finally, the sliver hops onto a meatier access point baked into responsive kerbside.* (Hill 2015)

Hill attempts a reconciliation of virtual reality and physical reality that loses strength and credibility in its tension toward the integration of the two. If the imagery of Hill looks forward to the future, the rhetoric of the narration looks at the past. Hill defines reality as something magic. In this sense, the effort to portray a unique, positive view is a typical product of a modernist interpretation of reality. In other words, he pushes backward the conceptual identity of smart cities, which in fact are conceptually a peculiar product of postmodernism. The connotation resides in the multifaceted aspects in which it can be caught and in its ephemeral expression of a reality that is changeable and fragmented. Smart cities and physical cities represent two different models of space. The duality is not by itself a problem, but we should be aware that a twin system of spaces demands a

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twin system of efforts to guarantee accessibility to all citizens (Frenzel and Vilijasaar 2016).

Goals and Contradictions of Smart Cities

The implementation of smart cities in different contexts requires the use of diversified indicators. In Europe, smart cities are mostly intended as projects aimed at retrofitting historical cities. Sensors are placed in the existing urban environment with the purpose of collecting data to be used by citizens. Data can provide access to better information and better management of resources and services. Municipalities and local governments are the depositaries of data. Sensors placed in many European cities already measure levels of carbon dioxide emissions, energy consumption per capita, and usage of services. Smart cities in Europe are usually marketed with an emphasis on the viability of the services offered. It is not the city itself, therefore, that is smart but the monitoring system, which is able to produce "smart citizens" (Scott 2014). A smart citizen is a citizen whose life is improved by the possibility of sharing data collected by a public authority.

Smart cities in the Western world are tailored to existing historical cities and subsequent enlargements. Europeans, unlike Americans, have never experienced a strong break from urban life. Actually, after years of urban dispersion, the population of the USA, especially the younger generations, is re-discovering the pleasure and the need to live in dense urban areas (Gallagher 2014; Glaeser 2011; Kneebone 2009). Cities stand again as centers of production, although the cities of the contemporary economy have ceded their roles in industrial production for the role of centers of innovation industry. Industrial innovation attracts work forces and the creative class necessary for the existence of smart cities. Following this line of thinking, smart cities attract and produce smart citizens, triggering a mechanism of economic growth in line with the ideals of the neoliberal economy. Smart city principles encourage economic growth and advocate for soft environmental impacts (Caragliu et al. 2011). This double goal carries with it a contradiction in principle. In fact, in traditional optics, economic growth implies more production and, inevitably in the industrial economy, greater consumption of resources. Still adhering to this logic, the sustainability of economic growth and the diminishing impact of human action on the environment open contrasting perspectives. The discrepancy between cause and effect is not the only ambiguity pervading the

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postulation of smart city sustainability. A different reason for concern is insistence on the technological manipulation of data. High monitoring activity triggers the existence of a virtual reality that could be an advantageous service but could also be a threat to individual freedom and equality. The ubiquity of sensors, cameras, and monitoring devices works as a controlling tool. As the capability of tracking the performative aspects of contextual reality increases, independence of personal actions becomes part of the public domain. Data can be shared by citizens but inevitably conveyed into platforms managed by private companies. Because data constitute instrumental knowledge for public authorities and private organizations, they do not always build up value for the private citizen. A system operating for data collection exerts substantial costs that likely must be paid by increased taxes. In addition to these concerns, another reason for perplexity is unwise use of smart cities. This perplexity refers to the type of relationship that people are going to have with the space in which they live. People live in a space that is increasingly virtual, experiencing alienation from the physical space. The virtualization of space creates boundaries of disaffection from geographical space. People who share virtual space lose familiarity with physical space (Yigitcanlar 2015). This aspect represents the focus of this analysis, and we will elaborate on it further in the next part of the chapter. For the moment, we will illustrate the first principle of concern, which is the antinomy between sustainability and economic growth.

As mentioned before, smart cities, in most interpretations, imply two principles: sustainability and economic growth (Albino et al. 2015; Monfaredzadeh and Berardi 2017). These two concepts are in a sense antitheses. In most of the metrics defining sustainability, energy efficiency represents a foundational pillar. It is therefore expected that smart cities, logically, claim energy efficiency. In contrast, as we have already said, smart cities base their existence on continuous economic growth. "However, as much as economic growth increases the city's ability to attract capital, business, talent, and visitors, it often does this using more resources" (Monfaredzadeh and Berardi 2017). "ICT already consumes almost 10 % of the global electricity supply: that is, 50 % more energy than the entire air transport industry" (Picon 2015). Continuous economic growth, whether centered on traditional cities converted into smart cities or whether acting as the constituent principle of new planned cities, inevitably reaches a collision point. Economic growth leads to competing economic plans. "Under the neoliberal 'growth-first' ideology, the

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outcomes of competitiveness are usually measured through the economic performance within the city" (Monfaredzadeh and Berardi 2017).

Smart cities facilitate connections, mostly between services and to services. The existence of a reliable service network attracts investors. Smart cities grow and become hubs that attract further investments. Networked systems of smart cities can operate to produce offers that anticipate demand, lining up with an operational management common to neoliberal economies. Therefore, the commercialization of the system and its marketability not only create economic growth but also set the conditions for further growth. Economic growth is, in this vision, linked to what has been called a creative class. Smart economies search for smart citizens able to implement smart development. The creative class is a well-defined part of the population that retains the knowledge for the establishment of a smart city (Caragliu et al. 2011; Florida 2002), which thereafter become the "intelligent" base where the services are designed and where capital is deposited, but not necessarily the place where industry-related production is implemented. Digital economies run on schemes separate from those of the traditional economy. Invested capital and digital management often gather in areas disconnected from the physical places of production that still exist according to the standards of the traditional economy. In this scenario, the managerial class and productive class are brought to antithetical positions. In an ideal model, a smart city attracts the so-called smart citizens. These citizens find favorable living conditions and benefit from the smart growth that they contribute to generating. The nature of smart cities and the economic principles on which they are based cannot deviate from the physiological consequences of the process. If the creative class able to work at the accretion of smart cities finds itself in a privileged situation, the opposite occurs for the other people who are not sufficiently smart. The existence of people who are not sufficiently smart to contribute to the foundation and implementation of smart cities has to do with personal abilities and contextual conditions. Referring to personal abilities, in a quite simplistic and not exhaustive manner, one assumes that not everybody is meant to become a smart citizen (Caragliu et al. 2011; Florida 2002). "On the other hand, increased dependency on technology may marginalize portions of the population who are unable to adapt, which impedes their abilities to meet basic needs" (Monfaredzadeh and Berardi 2017).

The second term of exclusion is a direct consequence of the initial non-inclusiveness of the economic process. The intelligent economy cannot

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suffice by itself. It continues to rely on the manufacturing economy. Investment rules defined by the global economy render non-remunerable the location of capital, management, and production in the same hub. Manufacturing is therefore dislocated to parts of the world where production costs can be minimized. Smart citizens and traditional citizens never meet. Smart citizens meet with themselves only in virtual space. In the smart city, gentrification of space is doubled: it encompasses physical reality and virtual reality. The distinction made by the traditional economy on the physical ground is emphasized and perpetuated in virtual reality. The dislocation in two different spheres of smart citizens and traditional citizens minimizes the chances for interference and consequently nullifies any possible aspiration for equality.

Some authors have pondered the meaning of smart cities in ontological terms. Saskia Sassen sees in "event making" on the urban scene the ultimate desirable reason for being of the contemporary city (Sassen 2015, 1997). Other authors see the event as the actualization of the goal of smart cities but from a different point of view. For Picon, the event is not a spectacular goal but routine in smart cities. Unlike what he defines as a "networked" city, where the network is the base of the rationale for this model, in the smart city, the event—or better, the control of it—becomes the true essence of its nature. Material and immaterial flows connecting the city are monitored and controlled in a portion of their existence. The collection of monitored events builds up the operational framework in which the smart city finds its origin, its existence, and its future (Picon 2015).

Some of the literature on smart cities has emphasized the dichotomy between monitoring activities and citizens subservient to a higher form of control. Ingersoll ironically contraposed the alliterating nomenclatures of *polis* and *police*. He provided a political analysis of the dichotomy between the smart class and the rest of the citizens. In his eyes, the new class of techno-laborers resembles the proletarians who animated the fight against capitalism. ICT becomes an oppressive form of control, and an unfair reduction in the workforce opens the way toward an increasing population of jobless citizens (Ingersoll 2014).

Economic growth is an inexorable principle that accompanies all definitions of smart cities. In countries with GDPs largely based on tourism, some administrators see the opportunity to use a monitoring infrastructure that can provide tourists with easier access to the resources of the country (Testa 2014). Beyond the simplistic optimism permeating this

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form of management of the artistic and historical heritage of a nation, many counter-observations can be raised. First, such exploitive use of the beauty of a country to privilege only people who are potential buyers of that beauty deprives others of a resource that is nested in the cultural *raison d'etre* of that community. One additional counterargument originates from the banalization of cultural offers. In fact, a system that codifies and offers on a leveled base the richness and complexity of the historical resources of a region cooperates in a form of banalization of its heritage. People tend to see what the system tells them, not what they willingly might be interested in seeing. Smart cities trigger a process that extends the use of their own constituting systems to make them desirable and necessary to other locations (Caragliu et al. 2011). The commercialization of the system and its marketability create economic growth.

Our era is lenient to technology in the desire to control an uncertain world (Haque 2012). The diffusion of technology in many cases responds not to a need but more to a sense of emptiness or to an inferiority complex. Smart cities provide an answer to the major problems characterizing globalized society. Smart cities are the logical accomplishment of a networked society. Networked societies establish relationships based on affinities defined by the Web and no longer based on common interests, referring to clusters defined by culture, gender, ethnicity, and so on (Haque 2012). The destabilization of society itself mirrors relations supported by immaterial propinquity, contributing to the dematerialization of physical reality. The increased complexity of the contemporary world demands instruments of control adjusted to the new level of complexity. It is therefore logical to consider a new mechanism that is able to override a reality not always comprehensible. On the one hand, the sophistication of the mechanism appears to be a logical answer to the complexity of the world, but on the other hand, its extreme complexity leaves margins of uncertainness.

City and Place: Do "Smart Cities" Imply "Smart Places"?

Smart cities, like other contemporary city models, address "livability" goals. Defining the characteristics of a livable city is difficult, and the conclusions are never unique. The interpretation of livability is highly subjective. The livability logic of companies commercializing smart city platforms

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often differs from that of the common citizen. Panasonic, IBM, and Cisco, to name only some of these companies, have campaigned on the necessity of their products for better lives for citizens (Cisco 2017; IBM 2017; Panasonic 2017). The subtext common to all of the campaigns in favor of smart cities is that better connectivity means better quality of life. Assuming that what is shown as a dogma corresponds to reality, it is still unclear in which percentage better connectivity contributes to better quality of life and in which percentage better quality of life is instead substantiated by factors that smart cities usually do not consider.

Several organizations provide indicators of quality of life. The Mercer Quality of Living Survey ranks happiness, which is associated with a monitor system that evaluates each service. A service can be ranked low, medium, or high. A service ranked high corresponds to a high grade of happiness, while a service that scores low corresponds to a low grade of happiness. When a city offers services that are ranked high by citizens, it is considered a top city in the score of happiness. Efficiency of services is without a doubt an important ingredient of happiness for citizens, but it would be reductive to think that excellent services are sufficient for the happiness of the inhabitants of a city. In this sense, the relationship between quality of life and top-ranked cities appears to be distorted. Other approaches privilege a more sophisticated evaluating system consisting of multiple factors. For example, Smart District Guidelines Dubai considers a list of parameters aimed at achieving happiness. Smart cities have been proposed as a service for the happiness of citizens. Presenting smart cities as a service and not as a mere achievement substantiates a difference in understanding the needs of citizens (Smart Dubai 2017).

However, Smart District Guidelines Dubai is more an exception than a rule. Hence, in a view that pushes a technologically driven reality, smart cities and livability are linked by the responsiveness of information technology (IT). Smart cities draw their strength from the idea of the platforms of services being accessible to everybody. Definitions of smart cities list the services that intelligent platforms make accessible to citizens. The traditional city, which is a physical space innerved by services, is substituted by a city of services. Urban living therefore does not imply sharing a place, but, instead, it centers on sharing a net of services (Yigitcanlar 2015). The Internet designates the limit between the virtual space and the physical place. Virtual communications allow people living in dispersed areas to have better quality of life since connections do not rely on the physicality of space (Townsend 2000). Internet technology subverts the

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conditions of space as presented by positivist theories (Harvey 2008). The space of IT is not a rational part of reality or part of the postmodernist conception of its fragmentation. Space becomes an irrational contingency. The dematerialization of space brings with it the disintegration of place (Townsend 2000). Physical spaces make sense to citizens because the interaction between physical space and human perception generates a particular affection that is known as "sense of place" (Khandekar 2014; Rison 2014; Salvesen 2002; Yacobi and Shechter 2005). Virtual spaces are not eligible for physical existence. Therefore, among their limitations is that they cannot assure a sense of place.

Smart cities posit themselves in the realm of ambiguity. They facilitate connections between people on a virtual level and undermine connections on a physical level. Hinting at this dysfunctional relationship, Carlo Ratti referred to smart cities as an "incomplete picture" of the future city (Ratti 2014). This incompleteness resides in the lack of sensitivity to human conditions. He reminds us how, despite the installation of sensors and connecting platforms, a city is created by its physical conditions. He argues that cities—regardless of how smart—must preserve their material conditions. Smart cities are therefore made of matter that requires planning, exactly like the traditional city (Ratti 2014). Planning and the sense of place are not necessarily related. In many cases, they can be antithetical to each other, as many examples of modernist cities and urban renewal have shown. Despite contemporary urbanist theory continuing to the possibility of planning a priori a sense of place, there is evidence that a wisely designed urban space can make people more likely to identify themselves with the place in which they live (Cresswell 2015; Khandekar 2014; Assmann and Czaplicka 1995; Cox 1968).

Smart Cities and the "Sense of Place"

In a positive view of smart cities, in which the empowerment of citizens is real, economic growth creates equal opportunities. At the same time, the impoverishment of the environment generated by human activity is reduced to a minimum. However, in a scenario in which smart cities are successful in achieving growth, equality, and planetary preservation, a question persists. Growth, equality, and a clean environment are important but not sufficient to create conditions for the well-being of citizens. People develop intimate relationships with the places where they live independent of age, condition, culture, and gender. This intimate relationship

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is stronger when the place has a higher grade of personal connotation or identity (Cresswell 2015).

Traditional cities, whether pre-industrial or industrial, are commonly considered models of sustainable urbanism. Especially in the USA, where dense urban environments are currently desolate, the call back to city living is considered a solution for containing environmental consumption. "Walkable cities", "happy cities", "smart growth" and historic preservation as antidotes to sprawl all have in common re-pacification with a dense urban environment (Downs 2005; Montgomery 2013; Speck 2012; Duany and Speck 2010). The basis of this trend, in contrast to sprawl, is the need for the re-acquisition of a sense of place. The emphasis on the sense of place in most contemporary and recent urban theories shares disillusionment with the progressive ideals of the modernist city. The modernist city relied on the power of verticality (skyscrapers) and believed in the power of largeness (megastructures). The development of the modernist city generated the dream life of suburbia. In fact, because downtowns augmented by gigantic buildings and infrastructures were repulsive on the human scale, people searched for more comfortable environments in suburbia. Although different in scale and intentions, both the modernist city and suburbia share the dissolution of urbanity in its meaning of social enrichment. Traditional communities based themselves on strong identification with the place that hosted them. Over time, people shaped the place in which they lived, making it able to meet their needs. The continuous interaction between people and place facilitates a sense of belonging, which is fundamental to the human condition (Cresswell 2015; Assmann and Czaplicka 1995; Hayden 1995; Rossi 1978).

The "Sense of Place" in the Islamic-Arab City

Recognizing a sense of place in the traditional city exposed to the pressures of globalization is a difficult task. The contemporary city is deprived of its meaning, as a fragmented entity or as an unidentifiable generic amalgam (Auge 2009; Koolhaas 1995). Like many other Middle Eastern cities, the cities of the Gulf assimilated modernity through rapid abandonment of the principles of the Arab city. An urban structure that for centuries has replicated itself in the same manner, gaining its existence from local cultural values, lost its rationale in a few decades, accepting precipitously the innovations proposed by Western interpretations of the modern city. As early as the 1950s, some of the cities of the Arabian Gulf, such as Kuwait

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City, were rethinking their organization and planning principles (Elsheshtawy 2010; Gardiner 1983; Shiber 1964). The transition from medieval organization of society to formal assets founded on the principles of modernism occurred without the necessary phase of elaboration. Whereas the cultures that developed the guidelines for modernization experienced the transition from medieval society to industrial society over a lengthy interval of time, most of the countries of the Middle East did not have the opportunity for an in-depth analysis of the imported model. Sterile principles of modernistic theory disrupted a complex societal system that for centuries had anchored itself on family clusters and neighborhood vicinities (Elsheshtawy 2010; Shiber 1964). The revenue of oil empowered people with a more expensive lifestyle, somehow compensating for the distress of the dramatic changes in the physical environment.

Currently, the Gulf cities stand among the most futuristic examples of city making. The cities of the Arabian Peninsula are still experiencing a fascination with an amenity-driven reality that marked the neoliberal economies of the Western world in the 1980s. Skyscrapers, commercial centers, functional districts, and theme parks represent the structure of the new cities and, not differently, the skeletons of regional smart cities. In many instances, formal planning of contemporary cities in the Arabian Gulf has evoked excitement for a futuristic, vertically dominated environment.

In this setting, the space of the city has no other choice than to adjust itself to the principles of globalization, further disenfranchising the local culture. The projection toward bigness, a typical enunciation of the neoliberal societies in the recent past, permeates the currently growing cities of Asia. The semantics from which the aspiration for bigness takes its roots in the Gulf states differ from those in the Western societies. The aspiration for bigness in the monarchies of the Arabian Peninsula represents the ambition to express an identity, whereas in the democratically elected powers of the West, it is usually an emblem of corporate societies. Bigness in the Arabian Peninsula alludes to the success of a nation that has abandoned a history of poverty, while in the West, it tends to cap the economic achievement of a restricted group of powerful people (Barthel 2010).

In Europe and the USA, where the population does not experience exponential growth, the consumption of green land is considered a negation of sustainability. Since Western societies have dislocated most of their industrial production to developing countries, the axiom of “sustainable growth equals no consumption of territory” finds easy application. In contrast, the cities of Asia, the Middle East, and North Africa have undergone

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exponential increases in population and specifically population gravitating toward urban centers. Demographic pressure is associated with the need for competitiveness in the market of technological advancement. However, the West can still regain a terrain of disenchantment from the modernist city by applying smart city principles to the pre-industrial and industrial city that were previously disregarded. The same attitude is not plausible for the Gulf countries, the history of which cannot support a reflective-introverted attitude. The stone-made historical cities in the West stand as models for the requalification of sense of place. The fragile mud-brick cities of the Arabian Peninsula did not resist the test of time. Re-introducing meaning and the formal characteristics of the pre-oil city not only appears to be a preposterous act of resuscitation, but it is also an unnecessary effort. The pre-oil city in fact does not comply anymore with the needs of an emancipated lifestyle (Alawadi 2017). The unresolved conflict between the desire for a progressive lifestyle and regret over the disappearing values of belonging is a subject of reflection for urbanists and architects in the region (Anderson and Al-Bader 2006; Shiber 1964).

In a pilot survey that we conducted among a selected group of citizens of the Gulf countries, we attempted to identify their interpretations of sense of place. We selected a group of academics and professionals, all of whom were citizens of Gulf countries residing in Kuwait. We ensured that the concept of sense of place was part of their background. The questionnaire was composed of six questions. The first question directly addressed the existence or non-existence of a sense of place. In particular, we asked the respondents whether any urban area in their city communicates a sense of place. All of the respondents (14) answered positively. The second question addressed the sense of place as a component of the urban experience. The interviewees were asked to rate the importance of a place as a depository of particular emotions. All of the respondents rated the item with the maximum score: high importance. The third question investigated the sense of place in the contemporary Arab city. Precisely, the question was "Do you believe that particular sites of the contemporary Arab city could better communicate a 'sense of place'"? "Yes" was the unanimous answer. The next question was related to values of tradition: "Do you believe that urban features from the past, such as the *souk*, the *baraha*, the *fareej*, could have meaning in the contemporary Arab city?" In this case as well, all of the respondents answered "yes". The fifth question opened an interrogation directed toward the present design and conception of Arab cities: "Do you believe that it is possible to design a contemporary

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sustainable Arab city where people can develop a sense of belonging to the place ('sense of place')?" The answer here too was unanimously "yes". The last question listed models of urban sites and asked the respondents which of the listed models communicated a greater sense of place. Urban commercial hubs or streets rated first in the preferences, followed by sea-front promenades with commercial regions.

The pilot survey represents a preliminary study toward responding to a complex problem, such as the sense of place in the contemporary Arab city. However, what emerges, even in this initial phase, is that a pool of selected individuals, all of whom are Gulf citizens and all of whom have elevated awareness of the meaning of the sense of place, shares the acknowledgment that their attachment to the material and symbolic configurations of particular urban sites is important to their experience.

"Sense of Place": Unplannable Feeling or Plannable Reality?

Defining the sense of place with metrics is a difficult task. Since the sense of place does not qualify in quantitative metrics, its codification is challenging. A second limitation to planning a sense of place is the strong emotional value that participates in its definition. Emotional attachment partially responds to the physical components of the built environment, but it can operate with variable mechanisms from person to person. Despite the impossibility of a material definition, it is unquestionable to the majority of people that certain places result in repulsion or are not appealing while others are pleasant and attractive. The dense urban centers of traditional cities—with walkways, landmarks, and commercial amenities—attract people (Gehl 2013). Commercial malls in the USA are in a declining phase of their existence, while small- to medium-size commercial activities are again populating American downtowns. High-speed traffic routes have recently been diverted outside of city centers, restoring the physical and conceptual connectivity between center and periphery (Monfaredzadeh and Berardi 2017; Speck 2012; Duany and Speck 2010). In Europe, historical centers have been made car free, sometimes in such a massive way that the result has become counterproductive. Walkability is indeed a validating principle, but it is not the only one. Commercial activities, permeable street fronts, a variety of visual perspectives, and containment of the edges of pedestrian settings are components amply explained

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and anticipated for a long time (Gehl 2013; Duany and Speck 2010; Jacobs 1961; Lynch 1960).

Although it is impossible to inscribe place making in a set of rules, it is easier to point out the planning principles that should be avoided. Contemporary theories have posited the modernist city as an unsuccessful model. Decades of history of the functionalist city have proved its failure, while the historical model has shown its resilience and efficacy with the test of time (Meeks 2016). Nevertheless, many plans for contemporary cities in the Eastern world emphasize wide freeways and tall buildings isolated and disconnected at the base. The city is still organized according to schemes of functional zoning, with each district dominated by a prevailing function. Emerging cities combine an oxymoronic relationship between the obsolete physical model and the ambition for technological innovation.

The Islamic-Arab City Between Past and Present

The historical Arab cities of the Gulf have certain semantic values that stand apart from the wider framework of the Islamic-Arab city. Since the 1950s, the period of massive oil extraction and subsequent generous revenues, the countries of the Gulf have experienced pressure toward modernization. Kuwait City, Manama, Doha, Dubai, and Abu Dhabi faced at different times and in different ways the push for the future (Elsheshtawy 2010). The change from the values of a pre-industrial society to those of a post-industrial society has been occurring rapidly here compared to the slow transitions of the West (Gardiner 1983). Western countries, in fact, and Europe in particular, have experienced the evolution of the city as an interrupted and linear process from the Middle Ages to the present. The linearity of historical evolution does not apply to the city of the Arabian Gulf, where modernization challenged the preservation of values that had been immutable for centuries. The homogeneity of the urban fabric became, in many cases, a synonym for poverty. With these optics, it is understandable that the modernizing cities of the Gulf want to detach themselves from the regional tradition (Faleh 2013). Futuristic buildings and technological assets contribute to the process of emancipation. Some authors have questioned the reasons and possible ambiguities of this urgency for modernization. In fact, modernization certainly embodies a desire for emancipation, but it also represents a profitable opportunity for commercial corporations (Faleh 2013; Elsheshtawy 2010). According to

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Faleh, "Most cities are not controlling technology, but technology is shaping the city and making of it a repetitive uncreative system in some cases" (Faleh 2013).

The form of the traditional city of the Arabian Peninsula was modeled on the leading principle of containment of resources. The modernist city, raised up to a symbol of redemption from the past, replaced the traditional city. As Alawadi noted, "Dubai's approach to urbanism emphasizes 'bigness', the monumental and spectacular, and for many this idea is so rooted in the present culture that a consideration for a more somber building approach would not have found any fertile ground" (Alawadi 2017). Monumental and spectacular size is promoted with sustainability. A question might arise at this point: "How much do people really like the model on which the present smart cities are based?" The pilot study provides a hint that offers a reflection point on the propriety of some of the branded initiatives in the region. As said before, the respondents to the pilot survey were Kuwaiti residents, and the modernization of Kuwait occurred three decades earlier than that of Dubai (Elsheshtawy 2010). It is possible that Kuwaiti people manifest a disillusionment that it is not yet part of the vision of Emirati citizens. Furthermore, the respondents to the survey were all people with higher education degrees in architecture, making them more attentive and sensitive to problems of urban development. With all of the restrictions explained above, the pilot survey provides evidence of the discontent of this group of people based on the common methods of urban development implemented in the Gulf states. It indicates that the desires for national promotion and for an intimate relationship with the place do not always coincide.

Masdar and Lusail: Is the "Sense of Place" Part of the Planning Agenda?

Masdar and Lusail present similar foundational principles and similar projections toward the future. They are both contemporary planned cities not connected to pre-existing centers, and both are surrounded by the desert. They both aim at a sustainability agenda and the smart city status.

The Masdar sustainability agenda refers to Leadership in Energy and Environmental Design (LEED), while Lusail refers to Gulf Sustainability Assessment System (GSAS). While LEED is an American agency that assesses problems and solutions tailored on the American reality, GSAS is a local agency specifically designed to serve the needs of the region.

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Both cities promote themselves with a vision encompassing sustainability and technological advancement as engines for success and the well-being of inhabitants. On the Internet page of Masdar City, we read, "The ground-up approach that Masdar city has taken to creating an enduring, sustainable and enjoyable way of life for residents demonstrates that environmental responsibility need not be a hardship" (Marcial et al. 2012). Sustainability and enjoyability are considered interdependent, but the connection is not clear.

The Dubai Silicon Oasis Authority considers legacy, society, and collective happiness to be the leading values of Dubai as a smart city. In contrast, Masdar, the urban form and architectural design of which speak of a search of societal values, does not appeal to a socially sustainable agenda. The absence does not do justice to the plan of Masdar, where much attention is paid to possible ways of interpreting in a modern sense the composure of a traditional city. The dense nature of the center of Masdar actualizes the form of cities in the Arab world, obtaining at the same time the reduction of air-conditioning in the side buildings. Narrow streets minimize the solar exposure of facades and allow for walking in the shade, and sensible use of glass reduces reflection and thermal transmission, while *masharabiyas* further screen against the penetration of light. The use of passive systems of thermal control represents an effective manner to limit the use of air-conditioning, and at the same time, it evokes a form of city that belongs to the culture in which the Gulf cities originated (Marcial et al. 2012).

The map of Masdar, and particularly the part of it that has been implemented, shows a marked sensitivity to the construction of a place that is accommodating to its occupants, with shadowed routes, containment of the width of the streets, and limits on the height of the buildings. The canalization of vehicular traffic underground and around the city has made the center of the city enjoyable for pedestrians. The compactness of urban form and the tight-knit nature of the blocks are viable instruments for the fabrication of a space that can generate in users mechanisms of emotional connections.

The planning of Lusail is more conventional. Large highways cut through districts identified by prevailing functions. The urban fabric is disconnected and fragmented and is pervaded by numerous unbuilt areas. Only a smaller part of the city seems to be more human oriented, with pedestrian areas, smaller buildings, and commercial activities. The Web site of Lusail emphasizes telecommunications, safety systems, security systems, facility managements, parking systems, surveillance systems, and

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waste-collection systems. The city appears to be focused on an effort of "systematization" more than an effort to create the physical conditions for the basic needs of people (Lusail 2017).

Conclusion

This chapter examined different meanings and interpretations of smart cities, with a particular emphasis on how smart cities address or do not address the concept of a sense of place. The sense of place is recognized as one of the prior conditions granting a satisfactory urban living experience for urban dwellers. This assumption, shared by most of contemporary theory and urban studies (Cresswell 2015; Assmann and Czaplicka 1995; Hayden 1995; Rossi 1978), was validated by a pilot study designed for the Gulf region. Smart cities are a concept full of applications, possibilities of growth and opportunities, but their use must be calibrated and adjusted according to the needs of people. The accomplishment of efficiency and ease of use of services is pivotal for the well-being of citizens, along with the satisfaction of their emotional needs enhanced by the correct planning of the physical reality. This chapter presented some of the challenges that a restrictive application of smart cities might pose. In particular, this chapter reflected on the importance of a balanced use of smart cities as a service that can enhance the livability of an urban place. Smart cities, if considered a parallel reality, can have unwanted consequences and can disconnect, more than connect, the majority of people from reality. A reconsideration of the meaning of urban living, of the importance of material space, and of the pleasantness of space for everyday life cannot be disjointed from a view of the city that considers efficiency and growth.

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CHAPTER 13

Transnational GCC Triple-Helix Relations for Building Smart Cities Under Globalization

Rasmus Gjedssø Bertelsen

Introduction

It is crucial for Gulf Cooperation Council (GCC) states to maintain dense networks with foreign current and future decision-makers in academia, business, politics, military and the like with a deep understanding of GCC affairs. Such relations take decades to build up and are long-term investments. Universities play an important role here. The GCC is also facing international power transition with the rise of China reflected in China as energy customer, its Belt and Road Initiative and the country as a diplomatic actor for climate change and sustainability. The GCC states have not cultivated long-term and deep-knowledge relations with China, especially not in areas of sustainable development, including smart cities. Equally China lacks networks, knowledge and understanding of GCC. Therefore, it is an important research and policy question for transnational public and private GCC universities to build transnational knowledge relations with academia, business and government in China in a wide range of fields, where focus here is on smart cities and sustainable development.

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_13

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Both GCC countries and China are faced with important sustainability challenges and demands of building smart cities. The GCC and China are a region and a country, respectively, that have close connections in the area of energy trade, but they do not have the very close knowledge relations between academia, business, government, military and the like, as have the GCC and the USA and Europe.

The chapter will compare Sino-GCC and GCC-USA/Europe relations. Globally well-connected centers of smart city triple-helix innovation stand the best chances of building strategic knowledge relations in climate change and sustainability diplomacy.

The structure of the chapter follows the outline which is in line with the title of this book, where the *current state*, *opportunities* and *challenges* are discussed. The current state is highly historically contingent. Therefore, the broader international systemic historical basis for the current state of Middle East and North Africa (MENA) and GCC transnational knowledge relations is set out and explained. The chapter looks in depth at how MENA and GCC transnational knowledge relations reflect this international systemic background, through the example of American and French universities in the Middle East as "information and resource bridges" between East and West.

The transnational knowledge and triple-helix relations of the MENA and GCC with the West have clearly reflected the historical development of the international system and the place of MENA and GCC therein. MENA is a penetrated region in the sense of a heavy Western influence—political, military, economic, linguistic and cultural—since the French invasion of Egypt in 1798 (Ehteshami and Hinnebusch 2002). Initially, European colonialism shaped MENA and GCC to a significant degree, including intellectual relations between MENA, GCC and Europe. With the rise of the USA as a global superpower, the country came to dominate large parts of MENA and GCC politically, economically, militarily, and not least, culturally and educationally.

The *current state* is also ongoing and emerging global processes of globalization and power transition from West to East. The world is experiencing a shift from a Western-led international system. This shift is driven by the rise of China and other Asian emerging economies. In parallel, globalization is compressing time and space between societies (Harvey 1989). Power is shifting from Western to Eastern states and from state to non-state actors, driven by the rise of China and especially other Asian growth economies (Nye 2011). This shift in the first and foremost economic

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power has also affected the GCC for decades with first Japan and now China as major energy customers.

There are *opportunities* in this rise of China and Asia for the GCC with its location connecting Europe, West Asia and Northeast Africa. The grand strategy of China in this shift is the Belt and Road Initiative, where the GCC is well-connected both to the new Silk Road across Central Asia to Western Asia and the new Maritime Belt through the Malacca Strait and across the Indian Ocean. The opportunities of interest to this book and this chapter are in Sino-GCC triple-helix relations for developing smart cities, which are mentioned as key sustainability interests also for both China and the GCC.

These global processes and transitions hold risk and *challenges* for countries around the world, and also for the GCC. The GCC has for almost half a century operated in a geostrategic context, where the USA guaranteed the security of the GCC in exchange for stable oil supplies to itself and its allies. Today, the USA is much less dependent on GCC oil because of shale oil. China as the strategic peer competitor of the USA has at the same time become the predominant energy customer in the GCC and Gulf region. The USA is a quintessential maritime power basing its grand strategy on naval-power projection and seaborne trade. China is a quintessential continental power as is reflected in its grand strategy of the Belt and Road Initiative across Eurasia. The GCC as countries across Asia, Oceania and wider must navigate between these two competing grand strategies of the two—by far the largest economic and military powers of the international system. Transnational knowledge relations between the GCC and the West have been with Western open societies with academic freedom, which even more closed GCC societies benefit from. Transnational knowledge relations between the GCC and China will be between closed societies to varying degrees, which poses problems for academic quality.

Today the international system is shaped by globalization (the compression of time and space between societies around the world) (Harvey 1989) and the twin power transition: from Western states to Eastern states and from state to non-state actors (Nye 2011). Both globalization and power transition shape the GCC and MENA today and are the international systemic frameworks for pursuing GCC smart cities. GCC cities are very much the products of and contributors to globalization. The GCC is caught in power transition as the USA is increasingly replaced by China (and Asia) as the energy customer, while the USA remains the security

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guarantor, and political-military relations with China and Asia are uncertain and underdeveloped. Equally, the GCC (as many other regions) must navigate between US maritime-based grand strategy of Trans-Pacific Partnership (TPP) and Transatlantic Trade and Investment Partnership (TTIP) and the Chinese continental grand strategy of the Belt and Road Initiative, where China is steadily approaching West Asia through Central Asia. The chapter will therefore place transnational knowledge and triple-helix relations for smart cities within the international systemic historical and current context with its challenges and possibilities.

With that, the topic of smart cities and transnational knowledge relations to develop and sustain such cities will be discussed, as those hold possibilities and challenges for the GCC. The topic of smart cities for comprehensive sustainability is a topic where GCC countries, cities and universities can build relations with both China and traditional Western partners without threatening strategic balances in hard security in the region. China needs to vastly expand sustainable urbanization, not least as part of its Belt and Road Initiative. Triple-helix smart city knowledge relations are well suited to connect GCC actors with Chinese actors within the context of the Belt and Road Initiative and with little threat to US maritime grand strategy. Finally, sustainable smart city developing is a topic which allows for less constrained academic activities in research and teaching.

The background of this chapter is the author's main research on how public and private transnational universities in the Gulf create transnational relations with academia, government, business and civil society in both the USA and Europe (Bertelsen 2015; Bertelsen et al. 2014a, 2016a, b, 2017b). Other relevant research looks at China as a case of emerging market science, technology and innovation systems and its transnational knowledge relations to the West (Bertelsen 2016b, 2017; Bertelsen et al. 2013, 2014, 2016a, b, 2017a). These transnational knowledge relations build transnational triple-helix innovation systems in Gulf cities, with connections to both the existing Western strategic partners and centers of science, technology and innovation and the future partners.

The historical transnational universities in the Middle East, the American University of Beirut (AUB), the Université Saint-Joseph de Beyrouth (USJ) and the American University in Cairo (AUC), show that these universities are exceptionally influential transnational actors, moving ideas, information, talent and financial resources of high quality and inten-

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sity. The Beirut universities made Beirut into an intellectual regional hub. The historical transnational universities are particularly interesting for their ability to build strong and long-lasting knowledge connections with high-ranking academia, business and government, especially in the USA and France.

This chapter uses Henry Etzkowitz' well-known term of triple-helix (academia-industry-government cooperation for innovation) (Etzkowitz 2008), even though there may well be four or more strings to the helix. Other important strings to the helix can be civil society or customers creating the—still less well-known—term of quadruple-helix (Carayannis and Campbell 2009). The term transnational refers to flows of ideas, information, people and resources between typically non-state actors (although state and state-affiliated actors, such as state-owned enterprises are also included) (Nye and Keohane 1971).

Transnational knowledge and triple-helix relations through higher education institutions and general capacity building in education and research are important elements in GCC policy to develop and diversify their economies. Such transnational relations are also key elements in pursuing the smart city concept and strong transnational knowledge and triple-helix relations, as flows of information, ideas, talent and resources will be a very important part of future GCC smart cities. Successful GCC smart cities will therefore require strong research and higher education institutions. GCC smart cities will equally require strong transnational knowledge and triple-helix relations between local academia, business, civil society and government, with foreign counterparts crisscrossing national and sectorial borders.

The focus in this chapter is on transnational relations through universities in the GCC since universities can play a particularly effective role as bridges carrying information, ideas, talent and resources in both directions between societies. The history of transnational universities in the MENA—with prominent historical cases especially in Istanbul, Beirut and Cairo—illustrates this two-way bridge role well and offers important lessons for current and future policy. This longer history is carried on to the present day where the GCC and MENA regions in the recent decades have seen a great expansion of transnational, more or less private, higher education institutions as parts of capacity building and pursuing economic development (Bertelsen 2012a, b, 2014a, b).

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Transnational GCC Triple-Helix Relations Embedded in the International System

It is necessary to put current GCC triple-helix relations with foreign countries into a broader historical context because these relations reflect the place of the GCC and the broader Middle Eastern and North African region in the international system at a given historical point. Therefore, this chapter will initially outline the modern transnational triple-helix history of the GCC and MENA. The Gulf and the wider MENA has of course been at the crossroads of civilization for millennia, with ideas and people moving in all directions. This short historical basis starts with the initial modern Western colonialization of the Middle East: Napoleon's conquest of Egypt in 1798.

Cities have played a central role in the relations between the MENA and GCC regions and the West throughout history. Cities such as Istanbul, Beirut, Cairo and Alexandria were key points of commercial, intellectual and other contact between East and West. These cities were and often remain very cosmopolitan in nature (Sluglett 2011). Urban history in the GCC is much more recent. But GCC (smart) cities are and will be key meeting places between the GCC, the West and Asia (Kamrava 2016). Cosmopolitan urban life is a crucial part of transnational knowledge and triple-helix relations (Sassen 1991), which are the topic of this chapter for their role for GCC smart cities.

MENA has been during the historical period under view here—and remains today—a penetrated region in the sense that the West deeply affects the region politically, economically, culturally, linguistically, militarily and in other ways (Ehteshami and Hinnebusch 2002). This Western penetration of the Gulf and the wider MENA reminds us how the region and its societies are extensively shaped by the broader international system. In this chapter and this short historical introduction, it is a question of how the place of the region in the international system of the time shaped transnational triple-helix relations. Such a brief historical introduction will also show how the state and development of the current and future international systems shape current and future transnational GCC triple-helix relations (with the focus here on smart cities).

Western imperialism entered the MENA with Napoleon's conquest of Egypt in 1798. Napoleon was defeated and removed from Egypt, but this event led to the first Egyptian-French scientific and technical relations in such fields as archaeology, and also to Egypt seeking education and

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technology from France (and Europe) for modernization. This early history is an early example of a Middle Eastern state pursuing development and modernization through academic and technological relations with the West.

The next step in the Western imperial penetration of the MENA region is France's conquest of Algeria in 1830. What is of relevance for this chapter is how France subsequently—in the 1800s and early 1900s—created colonial academic institutions in the Maghreb. These institutions were the kernels of academia in the later independent Maghreb countries. Maghreb academia and business remains closely connected to France through the French language and the flow of information, talent and resources.

The Ottoman Empire was the site of intense educational relations between the provinces of the empire and the West (including Russia), which has left a transnational intellectual legacy of continuing relevance. Through Western (including Russian) protection of religious minorities in the Ottoman Empire, there grew an extensive foreign educational system. Perhaps the most widespread was French-language Catholic education, but there was also Italian and even Russian-sponsored Orthodox education. These capitulations (the extraterritorial rights accorded by the Ottoman Empire to foreign powers inside the empire) and protections naturally reflected the development of an international system with increasingly weakened Ottoman Empire and increasingly powerful West (including Tsarist Russia).

Onto this stage of Western colonialism and imperialism entered the young USA, which over the course of the 1800s spread across the North American continent and with the Spanish-American War of 1898 became a world power that would also enter the MENA region and shape it heavily. The early American involvement with the MENA region was partly intellectual—of great importance here—and also commercial-military (the Barbary expedition). In the mid-1800s there was a great religious awakening in the USA which led to widespread missionary activity in both the Middle East and Asia. The early missionaries in both these regions initially focused on proselytizing, but with very little success, so they increasingly turned to education. Thus, American Protestant educators were now increasingly among the traditional French and Italian Catholic and Russian Orthodox educational missionaries in the Ottoman Empire. Now we are at the point when very powerful transnational triple-helix relations are established between the Middle East and the West, which continue to be of key importance even today for intellectual relations between the regions (Makdisi 1997, 2008).

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In 1863, the American Protestant educator and missionary Cyrus Hamlin established Robert College in Istanbul as the first undergraduate institutions in the Ottoman Empire. This American-style liberal arts college became a prominent college for the Turkish elite until it was nationalized as a Turkish public university in 1971, although still with a distinct identity and flavor from its American liberal arts days. Robert College lives on as an elite American high school—supplementing the French elite high schools with a longer history in Turkey.

In 1866, American Protestant educators in Beirut founded the Syrian Protestant College (AUB since 1920) as a liberal arts college and medical school. The AUB is of course extremely well known among all scholars and practitioners concerning the Middle East: as a key academic institution in the region and bridge of ideas, talent and resources between the Middle East and especially the USA. Other American Protestant educators in Beirut focused on girls' education, which developed into a girls' college in 1924, today the coed Lebanese American University (LAU). In 1919, American Protestant educators in Egypt founded the AUC on similar lines and with similar motivations and supported by similar networks as 50 years before in Istanbul and Beirut. Compared with the French story below, the US government did not support the AUB—earlier temporarily during World War II, and then permanently since the 1950s (including LAU and AUC) (AUB 2015a, b, 2007; Anderson 2011; Bliss et al. 1989; Murphy 1987; Hanna 1979; Munro 1977; Penrose 1970; Dodge 1958).

Already in the 1840s, the French consul in Beirut had expressed concern about the rising influence of American, English-language, Protestant education competing with French-language Catholic education. The French consul urged the French-speaking Jesuit educators to increase their activities to maintain the privileged position of French language in the Levant. This diplomatic attention to French-language and English-language education in the Levant reminds us of the foreign policy and strategic importance of transnational educational, intellectual and triple-helix relations (Eddé 2000).

As response to the Syrian Protestant College (AUB), opened in 1866, the Jesuits opened the USJ in 1875. As soon as 1883, the Jesuits entered into a close agreement with the French Republic and the University of Paris to establish a French medical school at USJ, which was academically and financially sponsored by France and the University of Paris, issuing French degrees. Around 1912, a similar agreement was made between the Chamber of Commerce and Industry of Lyon (there were very significant

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Lyonnais interests in Lebanese silk), the University of Lyon and the French government to establish an engineering school and a school of political science and law. The medical faculty was a faculty of the University of Paris and the faculties for engineering, political science and law were of the University of Lyon, federated under a Jesuit university. It should be remembered that at this time the French Republic was strictly laic, not supporting any religious education in France, which shows the foreign policy strategic emphasis put by France on the USJ as key French-speaking university in the Levant. The saying around this arrangement was that "the Republic educates, the Jesuits administrate." This arrangement continued to the late 1970s during the Lebanese civil war, when USJ took over the faculties as its own, issuing its own degrees, which are recognized in France (Eddé 2000).

Triple-Helix Before Its Time

Smart cities are the logical present and future steps for the role of urban centers for the GCC and the wider MENA regions for seeking environmentally, socially and culturally sustainable environments for the population. Urban centers have a prominent history in the MENA region, as alluded to above, as great centers of knowledge, learning and scholarship, which at different times were the smart cities of their age. Transnational flows of knowledge, talent and resources were always a key aspect of these urban centers, and will be so for future GCC smart cities. Therefore, this section will briefly outline how transnational MENA and GCC universities have played important roles since the 1860s, making MENA and GCC urban centers transnational hubs. Transnational universities have played and continue to play strong roles for these centers by being bridges between the MENA and GCC regions and the USA and Europe carrying information, ideas, talent and money in both directions (Bertelsen 2014b, 2016a).

As mentioned above, American Protestant and French-language Jesuit educational missionaries built universities in Istanbul, Beirut and Cairo, which continue to be key academic institutions in Turkey, Lebanon and Egypt as well as the broader region. The concentration of high quality American and French education in particular contributed to making Beirut an intellectual center of MENA. AUC has also played an important role as an elite bridge between the Egyptian and American societies. However, Egypt is a much larger society than Lebanon, and AUC has had

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less of a regional recruitment and impact than AUB. The author's findings on the AUB, USJ and AUC for their roles as information and resource bridges are outlined in Fig. 13.1.

What this image shows is how the AUB, USJ and AUC historically and today have played key roles for Beirut and Lebanon, Cairo and Egypt and the wider MENA, connecting a range of academic, business, civil society and government actors in the Middle East and the USA/France. It is also clear that these institutions since the late 1800s or early 1900s were engaged in transnational triple-helix relations between Middle Eastern and American or French societies connecting academia, business, civil society and government.

The AUB and the AUC have ensured strong connections with prominent American academia since their founding. They have recruited faculty and leaders from leading American universities as is clear from, for instance, their lists of presidents. AUB and AUC have also exported Middle Eastern talent to the USA for graduate studies, which has either returned to the region or remained in the USA as part of academia or professional life. Initially, AUB and AUC were funded by American Protestant missionary societies. With secularization of the institutions and of American society, the universities managed to replace this missionary philanthropic funding with secular philanthropic funding from the Ford or Rockefeller Foundations. The AUB and AUC boards of trustees in New York have

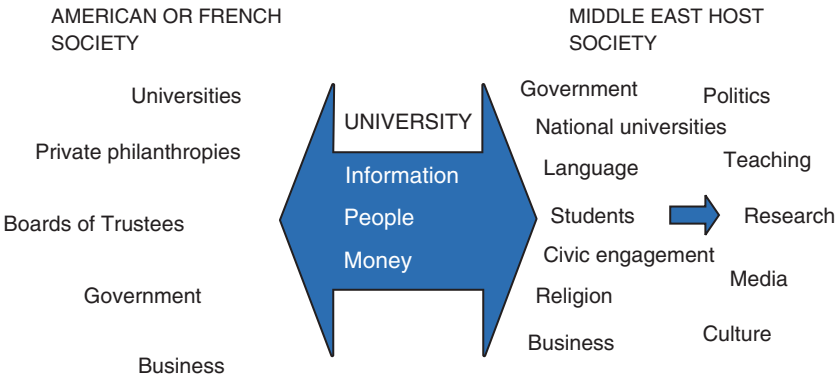


Fig. 13.1 Information and resource bridge (Reprinted with permission from Bertelsen 2014b © American Political Science Association, published by Cambridge University Press)

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brought and continue to bring together American and Middle Eastern elites from academia, business, civil society and government. Unlike the old global great power of France, the US government did not support the AUB earlier, during World War II, but from the 1950s the US government has understood that AUB and AUC are important points of access to Middle Eastern talent and elite. The students have often been highly critical of the US foreign and Middle Eastern policy, but they have known American society and often appreciated American values. AUB and AUC have trained much human capital for working for American companies in the Middle East, which is recognized by such companies, for instance, by the Bechtel engineering building at AUB.

Equally, the USJ has connected and continues to connect Beirut, Lebanon and the Middle East with France and the broader French-speaking world. This role has been recognized by the French government since the opening of the French medical school in Beirut in 1883 until the present day. Only a few years ago, a French diplomat described to the author the USJ as the flagship of the Lebanese Francophonie, keeping together a fleet of smaller institutional vessels that would scatter without the flagship. The connections with French academia were very explicit through the branch faculties of the University of Paris and the University of Lyon from the 1880s and early 1900s until the Lebanese civil war. These connections remain close through French accreditation of USJ and circulation of faculty and students. France does not have the American tradition of philanthropy and boards of trustees, but the USJ has a strategic council connecting it with prominent francophone academics, business people and the like around the world. The very close connection with the French government is in line with France's centuries-old strategic use of French-language Catholic education as a soft-power instrument. Finally, the USJ has a long triple-helix connection with the French business, going back to the engineering and political science/law schools founded with the Chamber of Commerce and Industry of Lyon and the University of Lyon before World War I.

The MENA and GCC regions have witnessed a great expansion of private higher education since the 1990s, which is typical of the Global South—in Latin America, Africa and Asia (Altbach 1999; Altbach and Levy 2005). There has been a great expansion of private higher education institutions in the GCC states. While these institutions are referred to here as private, there may be significant public sponsorship to separate them from traditional national institutions. Many of these institutions have a transnational element and refer

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to being the "American University of…" or are branch campuses of North American, European or Australian universities. Applying the illustration above to the new universities, it is also clear that they play a role—to widely varying degrees—as two-way bridges carrying information, talent and resources between the GCC and the outside world.

Sino/Asia-GCC Triple-Helix Today

There are deep transnational knowledge and triple-helix relations between MENA, GCC and the West, especially the USA, today, which reflect centuries of European imperialism and almost a century of American superpower hegemony. The world keeps changing, and China and other large emerging Asian economies are returning to their historical relative position in the world economy (two centuries ago, Asia had close to 60% of the global GDP) (Asian Development Bank 2011). The future of transnational knowledge and triple-helix relations of GCC societies and (smart) cities will increasingly be with East-Asian partners. Emphasis on East-Asian here, since the Gulf naturally has very long historical and also close current ties with South Asia.

There are two generations of Asian transnational knowledge and triple-helix connections. The first generation is dominated by Japan since the 1970s. Japan was and remains a large energy customer of the GCC. The 1970s oil crisis hit Japan hard, which is greatly dependent on energy imports (besides nuclear power). Japan therefore started to invest in an intellectual and soft-power relationship with MENA through a department of Japanese studies at Cairo University since the 1970s, which has trained Arab Japanese scholars and teachers serving around the region. One example is the Marubene Chair of Japanese Studies at Qatar University, Professor Isam Hamza (Hamza 2017; Nellemann 2017). For the comparison with Sino-GCC relations, it is of course important to keep in mind how post-war Japan was and remains a key ally of the USA and therefore does not upset the position of the USA in the GCC.

The second generation of Asian-GCC transnational knowledge and triple-helix relations concern China as the rising power of the international system. China, with the world's largest population and becoming—after 30+ years of phenomenal growth—one of the world's by far two largest national economies (with the USA), has become the world's largest energy importer and a large energy importer from the GCC. Two things must be kept in mind while looking at the Sino-GCC transnational knowledge and

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triple-helix relationship. First, China is the strategic peer competitor of the USA, so any additional role for China anywhere in the world might very well be at the relative expense of the USA, also concerning triple-helix relations with the GCC. Second, China and its research and education world was greatly damaged by the Cultural Revolution and has been recovering since. Together with being a closed society, it makes Chinese intellectual engagement with the outside world much less impactful than American or Western engagement.

One area of emerging Sino-GCC transnational and triple-helix research, development and innovation is such work by Chinese state-owned energy companies as the China National Petroleum Corporation and China National Offshore Oil Corporation in the Middle East and beyond (Gao 2017).

The Belt and Road Initiative and Sino-GCC Triple-Helix Relations

The GCC, as countries around the world, must navigate a changing world marked by the relative rise of China and other, especially Asian, emerging markets compared to the Western powers that have dominated the international system for two to three centuries. Navigating this changing world holds both opportunities and challenges, especially when it comes to GCC smart cities. The opportunities are touched upon here, and the challenges below.

For the topic of GCC smart cities, a few points concerning opportunities should be highlighted. The first point is the Belt and Road Initiative, which is China's grand strategy of expanding infrastructure and trade westward through Western China to Central Asia and West Asia and wider to the Europe and the Middle East. The Western view of the world for centuries has been distinctly maritime, and connections between the West and MENA and GCC have been maritime in nature (although individuals today travel by plane). The Chinese logic is continental. As China expands its infrastructure and trade westward, toward the Gulf, countries around the Gulf will increasingly have access to a continental Eurasian world unlike that provided by the maritime connections to the West for centuries (not ignoring historical connections to Eurasia, but pointing out relative changes). GCC smart cities of sustainability, research, development, education and innovation will connect with such a Chinese-led continental order, which will offer new opportunities.

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Another opportunity to discuss is that China as one of the world's two largest national economies and the largest polluter is keenly concerned with sustainability. China's phenomenal economic growth since 1978 has come at a very high environmental price, which the population will no longer pay. China is at the same time witnessing an enormous migration from countryside to cities and unprecedented urbanization. Therefore, China has to rapidly achieve sustainable urbanization, where the smart city concept naturally is central. There is therefore, every reason to believe that a large number of Chinese cities with their academia, business, civil society and governments will be interested partners of GCC smart cities for developing sustainable smart cities in transnational triple-helixes (Cong et al. 2016; Song et al. 2009).

Challenges

GCC Between US Protection and Chinese Oil-and-Gas Consumption

There are three geostrategic challenges to the GCC transnational triple-helix relations in general and concerning smart cities here that are discussed. Moreover, the transnational knowledge relations on smart city development between the GCC and China on one hand and the West on the other hand may help ease these three geostrategic challenges for the GCC under globalization and power transition. The first challenge is the GCC as energy supplier between the USA and China. Second, and related to the first, is the GCC between the American maritime grand strategy of TPP (abandoned) and the Chinese continental grand strategy of the Belt and Road. Third, it is the challenge of academic freedom and credibility for strong transnational triple-helix relations.

The GCC must navigate the transnational knowledge and triple-helix relationship with these parties as part of this changing energy and security relationship with the USA, and China and other emerging Asian economies. As pointed out throughout this chapter, the transnational knowledge and triple-helix partnership is an integral part of the wider strategic relationship, which reflects the state of the international system at any historical point. Smart city triple-helix research and development across the GCC, China and the West does not upset these geostrategic balances of security and energy, while building dense knowledge networks. Such smart city triple-helix research and development is the science for diplomacy dimension of science diplomacy,

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where scientific cooperation builds mutual knowledge, understanding and trust under political strain (The Royal Society and AAAS 2010).

The first challenge is how the GCC is shifting from the security-energy partnership with the USA toward an energy-trade partnership with China and Asia, with much more uncertain security relations with the USA and Asia. The GCC as a central energy supplier of the USA and its allies in Europe as well as Japan and South Korea has had a key security relationship with the USA since the British withdrawal from the GCC Trucial States and east of Suez and the US commitment to Gulf security through the Carter Doctrine. With the economic rise of China and other Asian emerging markets and the development of domestic US shale oil and gas production, this relationship is shifting. The GCC is more of an energy supplier to China and Asia and less so to the USA. This shift in energy trade is coupled with a much less developed political-security relationship with Asia and China (which is the strategic competitor of the USA). The USA remains deeply engaged politically and militarily in the GCC and the wider MENA region.

The current international systemic context for the GCC smart city development and transnational triple-helix relations is globalization and power transition, which are the two dominant trends of the international system today. Globalization is a wide topic, and defining globalization is an extensive debate. For the purposes here, globalization is viewed as the compression of time and space between societies around the world (Harvey 1989). Societies today affect each other more strongly and much faster than before. This compression of time and space is driven by technological changes in the information, communication and transportation technologies, financial deregulation and the end of the Cold War. The GCC and the wider MENA region are heavily affected by globalization and the flows of people, goods and money through them.

The other great systemic change today is the twin power transition from Western states to Eastern states and from state to non-state actors. The power transition from Western to Eastern states is driven by the phenomenal economic growth of China since the opening of the Chinese economy to the world in 1978 by Deng Xiaoping and other emerging markets (Nye 2011). Power transition is a recurrent phenomenon in international politics, where great powers grow at different rates or stagnate so that a new power overtakes or attempts to overtake the existing leading power (hegemon). Great power conflict has often been driven by (attempts of) power transition, where examples are the Napoleonic Wars, World War I and II and the Cold War (Organski 1968).

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The MENA region has historically been deeply affected by power transitions and international systemic developments, as outlined above. It was greatly influenced by British and French imperialism in the 1800s and 1900s. The MENA region was deeply affected by the two world wars and subsequently Cold War. Today, the MENA region and the GCC are also deeply affected by the power transitions from Western states to Eastern states and from state to non-state actors, and the effect of power transition on the GCC is exactly driven by the strong economic growth of China and other, especially Asian, emerging markets that drive power transition globally. China, with the world's largest population and now being one of the two by far largest national economies in the world with the USA (the European Union together is a comparable economy), has also become the world's largest importer of energy.

China thus has become a very important importer of oil and gas from the GCC. Energy trade is one of the two geostrategic factors affecting the GCC's position in the international system between the current hegemon of the USA and the rising power of China. The other geostrategic factor is the competition between the USA's maritime grand strategy around the (now abandoned) TPP and China's continental grand strategy of Belt and Road.

Smart city triple-helix transnational research and development between the GCC, China and the USA/Europe does not upset these energy-security partnerships. In comparison, research and development cooperation in, for instance, defense technology or nuclear energy would be much more controversial.

The GCC Between American Maritime Grand Strategy and Chinese Continental Grand Strategy

The GCC, as many other regions around Eurasia and the Indian Ocean, finds itself between two competing grand strategic projects of the two largest national economies of the international system, the USA and China (the EU is the third comparable economy at aggregate level, but not considered here, since the EU is a different type of international actor than the USA and China). The USA has been an essentially maritime power ever since it came to dominate all of North America (directly or indirectly) in the 1800s. The USA being a global maritime power—including in Asia—was clear from the Spanish-American War of 1898, with the conquest of the Philippines and Guam. In comparison, China is fundamentally a continental power, which has dominated large territories but not

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projected overseas power since the expeditions of Admiral Zheng He in the early 1400s.

The fundamentally maritime nature of American global power today is reflected in its TPP with Pacific rim countries (canceled by President Donald Trump for American domestic political reasons) and the TTIP with the EU. It is natural for the USA to base such grand strategic partnerships on transoceanic ties guaranteed by the US Navy, which by far dominates the world's oceans.

In contrast, the Chinese grand strategy today is naturally predominantly continental and based on the Eurasian landmass, although with a maritime component, which is much more vulnerable to the US, Japanese and Indian balancing. It is the Belt and Road Initiative which combines the overland road through Central Asia, following the historical Silk Route from Western China to Europe and the Middle East and the traditional sea route through the Malacca Strait and the Indian Ocean to the Middle East and East Africa and onward to the Mediterranean and Europe. The Belt and Road also combine with special relevance for the greater Middle East. China has invested in Gwadar port in Pakistan and seeks to construct a China-Pakistan Economic Corridor connecting Western China with Gwadar port, although there are serious security issues surrounding the project. The Belt and Road Initiative connects further north to the greater Middle East to Iran and West Asia.

Smart city development between the GCC, China and the West neither upsets the US maritime grand strategy around the (aborted) TPP, nor the Chinese continental Belt and Road Initiative. The GCC dimension of the Belt and Road Initiative is the Black Pearl Chain (Lokhande 2017). A particular geostrategic challenge for China in its relations with the Gulf region is to balance its relations with the GCC states with its relations with Iran—with both Russia and the USA as third parties to these relationships. Smart city triple-helix relations are on a topic that does not threaten the balances and between the GCC states and Iran and their external partners. As such, smart city transnational knowledge relations are a useful field to develop such relations.

Academic Freedom and Quality for Strong Transnational Triple-Helix Relations

The third challenge discussed in this chapter for GCC transnational knowledge and triple-helix relations in general and concerning smart cities in

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particular is the centrality of academic freedom and quality for strong transnational relations. Academic freedom and quality is of key importance for the GCC to build the highest quality transnational knowledge and triple-helix relations with both the West and Asia. The transnational knowledge and triple-helix relations of MENA universities with Western academia, business, government and civil society is—as mentioned above—of widely varying quality. This variation in the quality of relations and partners has important consequences for the GCC universities and their wider societies, including other academia, businesses, civil societies and governments. This relationship between academic freedom and quality of transnational knowledge and triple-helix relations is also of importance for developing smart cities in the GCC. Discussing this challenge draws on my own research on the connection between the governance of transnational universities in the MENA region, and research by Neema Noori and Pia Andersson on academic freedom and governance in the GCC (Noori 2014; Noori and Anderson 2013; Bertelsen 2012a).

My research shows that there is a relationship between the governance of the transnational universities in the MENA region and the quality of the transnational knowledge and triple-helix relations with Western academia, business, civil society and government (Bertelsen 2012a). Andrés Bernasconi presents three categories of private universities in the Global South: (Bernasconi 2006) Independent universities, which are self-governed; affiliated universities, which are controlled by an external non-profit body as a foundation or board of trustees; proprietary universities, which are controlled by investors directly or indirectly seeking a return on their investment. The MENA region, with the wider Global South, has in recent decades seen a great expansion of private higher education, so the effects of governance models of private higher education on the quality of teaching, research and triple-helix connections is an important question (Altbach and Levy 2005).

In the MENA region, it has been shown that the important difference is between the affiliated universities and the proprietary universities. The old American missionary universities, AUB, LAU and AUC are clear-cut affiliated universities. They are clear non-profit organizations, registered and run by boards of trustees based in New York. There is only one partly independent university, USJ, which is partly self-governed and partly governed by the Jesuit Order. Because of the clear combination of academic freedom and quality of USJ, it is included with the affiliated universities. All the old missionary universities in Beirut and Cairo stand out for their

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research and teaching quality and strong transnational knowledge and triple-helix relations with American and French academia, business, civil society and government. The quality of these transnational knowledge and triple-helix relations stands out as an inspiration and important lesson for all private higher education institutions in the Global South, which is also the reason why these Beirut and Cairo institutions continue to serve as important inspirations in the GCC and the wider MENA.

The modern-day affiliate universities are the well-funded government-sponsored institutions in the GCC countries such as the American University of Sharjah, the New York University Abu Dhabi, Sorbonne Abu Dhabi, Masdar, Rochester Institute of Technology—Dubai and the (what was generally known as) Education City institutions in Qatar. These institutions are characterized by qualitatively strong US and European transnational connections with leading academia, and with business, civil society and government to some extent, but not that of the historical missionary universities. The contrast is the range of more or less proprietary universities in the region, which serve to earn a return on investment for their owners and are heavily dependent on tuition for income. These universities have much weaker transnational ties to American and European academia, business, civil society and government.

Comparing the affiliated and the proprietary private universities in the MENA region and the quality of their transnational knowledge and triple-helix ties shows a connection. The affiliate universities, which are non-profit and ideally governed by an independent non-profit-seeking board of trustees, can focus fully on their mission of quality research and teaching. This focus gives them academic credibility, which in turn has given them access to financial resources from (besides tuition) missionary societies, American and French governments, philanthropic foundations and business. In contrast, the proprietary universities struggle for gaining such academic credibility and thus access to academic and financial resources (Bertelsen 2012a).

These findings remain relevant in the context of building transnational GCC knowledge and triple-helix relations in general and concerning smart cities in particular. The GCC countries are pressed to—and seek to—diversify and develop their societies and economies from oil- and gas-based to more knowledge-based and to more comprehensively sustainable societies (where smart cities are key) (Bertelsen et al. 2017b). Both for the economic transition and for developing more sustainable societies, high-quality transnational knowledge and triple-helix relations with Western

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and Asian academia, business, civil society and government will be very important for the GCC societies and institutions.

In light of the connection between the affiliate (non-profit) governance model of universities, quality transnational knowledge and triple-helix relations (and likewise proprietary university governance and weaker relations), it is important that the GCC states, civil society (families and foundations) and private sector strive to create universities that have the academic freedom and quality to ensure the academic credibility in order to build strong transnational knowledge and triple-helix relations with both Western and Asian academia, business, civil society and government.

Noori and Andersson have looked into the individual academic institutions in GCC settings, concerning conditions for academic freedom in institutions, which should follow American accreditation and governance traditions. Their findings are that there are various threats to academic freedom in the American sense from lack of tenure and political interference. These threats to academic freedom compound the governance threats above concerning academic credibility and, through that, transnational relations (Noori and Anderson 2013).

The risks from for-profit university governance identified by the author and from internal threats to academic freedom identified by Noori and Andersson are well known in the GCC-USA-Europe context. However, these risks have not been analyzed concerning the emerging GCC-Asia and especially GCC-China transnational knowledge and triple-helix relations. Many of the involved countries in GCC-Asia relations will be relatively closed societies compared to the USA and Europe, which will pose challenges to the academic freedom, quality and credibility at the basis of strong transnational knowledge and triple-helix relations. Both the GCC and Asian partner countries operate in domestic and international political contexts where openness may be sacrificed for maintaining domestic political stability. Closing societies to smaller or greater extent may threaten the transnational knowledge and triple-helix relations that are necessary for both economic diversification and transition in the GCC countries as well as comprehensively sustainable development, including of smart cities.

Smart city research and development may be an area of research where a greater degree of openness is possible than that regarding questions of greater consequences to domestic political stability. Lokhande compares what he sees as disruptive American democracy promotion with Chinese promotion of socioeconomic development for political stability (Lokhande 2017).

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Conclusion

This chapter seeks to place the GCC pursuit of smart cities in a longer historical time frame and the international systemic framework. The GCC smart city designs operate in an international systemic context of balancing a strategic competition between the USA (the traditional energy customer and security provider of the GCC) and China (the new energy customer). The GCC smart city pursuits also happen in the cross field of American maritime-based grand strategy and Chinese continental-based grand strategy of expanding infrastructure and trade across Eurasia and along the Malacca Strait-Indian Ocean sea lanes through the Belt and Road Initiative. China is balancing its relations with Iran and the GCC. Finally, a balance between openness and closeness of societies may hold trade-offs between academic quality and domestic political stability.

The Middle East (less the GCC) has a long history of cosmopolitan urban centers, where transnational universities have played a key role as information and resource bridges to the West carrying information, ideas, talent and resources in both directions. The history in Istanbul, Beirut and Cairo going back to the 1860s and early 1900s holds important lessons for how transnational universities with strong global ties have contributed to "smart" urban development and triple-helix relations—before anyone knew the terms. From the 1990s, MENA and the GCC have also seen the general Global South expansion of private higher education, with varying qualities of transnational knowledge and triple-helix relations, which holds a cautionary tale of the importance of non-profit university governance and academic freedom for strong transnational knowledge and triple-helix relations.

Smart city triple-helix transnational relations hold possibilities for the GCC to contribute to balancing three geostrategic challenges: between energy (China)/security (USA), ocean (USA)/Eurasia (China) (including Sino-Iran/Sino-GCC relations), and openness/closedness.

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PART VI

Conclusion

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CHAPTER 14

Outlook of the Future of Smart Cities in the Gulf

Wael A. Samad and Elie Azar

Summary

The concept of smart cities is one of the most rapidly evolving topics in recent sustainability, governance, and modern-city trends. Although the term "smart city" has been used in literature as of the late 1990s, there still is a considerable amount of confusion with regard to its exact meaning, context, and methods of evaluation. However—and irrespective of its exact definition—smart city initiatives have become a primary pillar of various Gulf Cooperation Council (GCC) visions and strategies, while their application remains fairly limited in general. Plenty of challenges are ahead, which include political, socio-economic, technological, local talent resources, policy, cyber, and infrastructural aspects, with their proper integration being an essential element.

This edited volume provides a broad compilation of research regarding the current state, opportunities, and challenges related to smart cities in

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8_14

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the GCC. This comes as a consequence of some of the interesting papers, presentations, and discussions during the 8th Gulf Research Meeting, which was organized by the Gulf Research Centre and held at the University of Cambridge in August 2017. The meeting drew in more than 25 international experts in various areas of smart cities—urban planning, public policy, government strategy, Internet of Things (IoT), big data, cyber security, and sustainable engineering—from various research institutes and government entities, including the Golisano Institute of Sustainability at the Rochester Institute of Technology (RIT), Masdar Institute, RIT—Dubai, Smart Dubai Office, Carnegie Mellon University, Arctic University of Norway, National Technical University of Athens, Heriot-Watt University, the University of Bahrain, and Qatar University.

Key takeaways are summarized in the upcoming section and organized along the four main parts of this book: Frameworks and Governance, Resources and Infrastructure, Information and Communication Technology, and Social Perspective.

Major Takeaways and Challenges

Frameworks and Governance

Smart and sustainable city initiatives are complex large-scale initiatives that involve a great number of stakeholders. Given the broad scope and spectrum of city activities they entail, this section offered different general frameworks and case studies to address the matter. An impact-driven framework is proposed and is intentionally articulated as a generic one to ensure applicability to different cities. The notion of impact is identified as a focal point, as this provides city officials with an understanding of the positive and the adverse consequences of their smart and sustainable city initiatives. Three areas of impact are detailed—namely social, economic, and environmental—aiming to have a broad-spectrum and complete perspective of the effects and consequences of the sustainable city initiatives at the city level.

A major takeaway is that despite the debate regarding the exact definition of a smart city, a common theme emerges: the need for a holistic impact-driven framework that encompasses four city constituents, namely, government, economy, society, and resources and infrastructure. In parallel, it is equally important to identify key performance indicators (KPIs) on a holistic city level. This is crucial as the difference between the current and the target values for KPIs determine the strategic gap, which dictates the necessary actions. Other factors for the success of the smart city frame-

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work are found to depend on its acceptance and endorsement by the various governing entities of a city. Moreover, it is argued that a government's ability to govern in the future depends to a large extent on its success in achieving greater outreach to its citizens, and thereby realizing what is often referred to as citizen-centric government.

Resources and Infrastructure

Smart city resources and infrastructure are addressed in Part III of this edited volume, with the focus being on the water-energy-food nexus, and transportation and mobility infrastructure, as well as an intelligent energy-management framework. The link between smart cities and the water-energy-food nexus is discussed via the case study of Masdar City in Abu Dhabi, United Arab Emirates, finding that the notions of a smart city and of a sustainable city highly overlap. A common theme is the important role that technology has in optimizing the efficient management of resources and improving the well-being of the city's inhabitants. Moreover, legal and regulatory amendments are identified as necessary measures to support the adoption and integration of smart city technologies, such as in the case of electric vehicles.

This part also sheds light on the often-ignored but important role of people in the urban energy-transformation scheme, particularly through energy-conservation behaviors in the building sector. Promising examples of how technology can be applied to induce energy-saving habits among people are presented, reiterating the role of people and technology in the transition toward a smarter city.

Information and Communication Technology

The surplus of data provided by the increasing number of connected sensory devices in these cities give rise to challenges related to data handling and security. Cybersecurity vulnerabilities of promising concepts such as IoT are particularly discussed. It is found that a vision of unification and cooperation of public safety agencies in the GCC is needed in order to address the economies of scale obstacle that the industry is facing. Moreover, it is argued that the integration cost of the smart city technologies is a major obstacle due to the variety of hardware and software platforms currently in use. This necessitates the need for research and development to develop robust open-standard frameworks for proper integration of smart technologies and thereby reducing costs.

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Social Perspective

With inhabitants being at the core of smart cities, their lifestyles and overall sense of belonging are essential for the proper transition of a city to a smart one. In this part, the notion of happiness is covered and organized in terms of the types of needs that people have (e.g., affective, cognitive, and enabling), and the variety of ways these needs may be fulfilled. An attempt at developing an equation to quantify happiness is introduced and discussed. Engineering the happiest city on earth was explained through the case study of the Dubai Happiness Agenda, which is currently undertaken by the Smart Dubai Government. On the other hand, and away from the quantification of citizen happiness, this part also emphasized the importance of the sense of place in the implementation of Smart Cities in the Arabian Gulf. The ease of use of the smart city technologies and services is found to be pivotal for the well-being of citizens. Moreover, unwanted consequences of smart cities are highlighted, such as the growing disconnect of people from reality when technologies are adopted at an abrupt rate. These give rise to excellent observations that question the true meaning of urban living and the importance of the pleasantness of space and sense of being.

Final Thoughts

To conclude, Fig. 14.1 presents the *Wordcloud* of the book, a diagram that illustrates the most frequently used words in the book. The size of each word corresponds to its frequency of occurrence.



Fig. 14.1 Book *Wordcloud*

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As the figure reveals, the dominant keywords include Government, Technology, Energy, Happiness, Initiative, Transformation, Innovation, Education, information and communication technology (ICT), Citizen, Infrastructure, Environment, Security, Masdar, and the city of Dubai. These dominant keywords reflect dominant themes and focal points around the concept of smart cities in the GCC. Government is one such theme, reiterating the needed support and role of the public sector institutions to create the supporting environment and infrastructure needed for the implementation of a smart city approach. In fact, this implementation is heavily dependent on technology, ICT in particular, keeping in mind the implications this has on security. While the focus has been purely on energy, it is quite interesting to see the emergence of themes such as environment and happiness, confirming the increasing focus of smart city initiatives on the environmental and social pillars of the sustainability triple bottom line. This is in line with the vision of many GCC cities to transition from oil-based to knowledge-based economies. The frequent appearance of the words Masdar and Dubai confirm the leading role of the United Arab Emirates in pushing toward sustainable smart cities and these can serve as model cities for others in the region.

The frequent occurrence of the word citizen (122 times throughout this book) is a great reminder of what cities are all about and the purpose they serve. Citizens are right at the core of this technology-based transformation we are witnessing today. The use of technology shall solely be centered on improving people's lives, happiness, and well-being. As the ancient Greek philosopher *Plato* once said:

This City is what it is because our citizens are what they are (Plato)

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W. A. Samad, E. Azar (eds.), *Smart Cities in the Gulf*,
https://doi.org/10.1007/978-981-13-2011-8

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