ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

EVALUATION OF ARCHITECTURAL MODELS AND APPLICATIONS OF SMART CITIES

M.Sc. THESIS

Emre BAŞTÜRK

Department of Geomatics Engineering

Geomatics Engineering Programme

DECEMBER 2019

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

EVALUATION OF ARCHITECTURAL MODELS AND APPLICATIONS OF SMART CITIES

M.Sc. THESIS

Emre BAŞTÜRK
(501161655)

Department of Geomatics Engineering

Geomatics Engineering Programme

Thesis Advisor: Prof. Dr. Nesibe Necla ULUĞTEKİN

DECEMBER 2019

<u>İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ</u>

AKILLI ŞEHİRLERİN MİMARİ MODELLERİNİN VE UYGULAMALARININ DEĞERLENDİRİLMESİ

YÜKSEK LİSANS TEZİ

Emre BAŞTÜRK
(501161655)

Geomatik Mühendisliği Ana Bilim Dalı

Geomatik Mühendisliği Programı

Tez Danışmanı: Prof. Dr. Nesibe Necla ULUĞTEKİN

ARALIK 2019

Emre BAŞTÜRK, a M.Sc. student of İTU Graduate School of Science Engineering and Technology student ID 501161655, successfully defended the thesis entitled "EVALUATION OF ARCHITECTURAL MODELS AND APPLICATIONS OF SMART CITIES", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor : **Prof. Dr. Nesibe Necla ULUĞTEKİN** ....
İstanbul Technical University

Jury Members : **Prof. Dr. Melih BAŞARANER** ....
Yıldız Technical University

PhD. Teach. Assist. Caner GÜNEY ....
İstanbul Technical University

Date of Submission : 12 January 2020
Date of Defence : 12 December 2019

To my family,

FOREWORD

I thank so much my thesis advisor Prof. Dr. Nesibe Necla Uluğtekin who guide me about the selection of my thesis subject, share her precious knowledge and experiences with me and always support me during the thesis term.

Moreover, I thank my family to leave never alone me and always give me courage in order that I get over every hardship throughout my life. I also thank the jury members for their precious recommendations to improve my thesis.

December 2019 Emre BAŞTÜRK
(Geomatics Engineer)

TABLE OF CONTENTS

Page

ABBREVIATIONS

API	: Application Programming Interface
BIM	: Building Information Modelling
BSI	: The British Standardization Organization
CAD	: Computer-Aided Design
CDMA	: Code Division Multiple Access
CDMS	: Central Data Management System
CEOC	: Command Emergency Operation Center
CIM	: City Information Model
CPU	: Central Processing Unit
3D	: Three-Dimensional
DEM	: Digital Elevation Model
DGM	: Digital Ground Model
DHM	: Digital Height Model
DMA	: Defense Mapping Agency
dSaaS	: data Storage as a Service
DSM	: Digital Surface Model
DTEM	: Digital Terrain Elevation Model
DTM	: Digital Terrain Model
EDCS	: Environmental Data Coding Specification
EIP-SCC	: The European Innovation Partnership on Smart Cities and Communities
ETSI	: The European Telecommunication Standardization Institution
EVDO	: Evolution Data Optimized
FC	: Fog Computing
FN	: Fog Node
FOCAN	: Fog Computing Architecture Network
2G	: Second Generation
3G	: Third Generation
4G	: Fourth Generation
5G	: Fifth Generation

GIF : Governmental Interoperability Framework
GIS : Geographic Information Systems
GPRS : Genaral Packet Radio Service
GPS : Global Positioning System
GSM : Global System for Mobile communication
HIFI : Height Interpolation by Finite Element
IaaS : Infrastructure as a Service
ICT : Information and Communication Technologies
IEC : International Electrotechnical Comission
IEEE : Institute of Electrical and Electronics Engineers
INFINET : Integrated Factory Information Network
INSPIRE : Infrastructure for Spatial Information in Europe
IoE : Internet of Everything
IoT : Internet of Things
IP : Internet Protocol
I-SCOPE : Interoperable Smart City Services through an Open Platform for Urban Ecosystems
ISO : International Organization for Standardization
IT : Information Technology
ITU : International Telecommunication Union
JTC : Joint Technical Committee
KNN : k-nearest neighbor
KPIs : Key Point Indicators
KW : Kilo Watt
LAN : Local Area Network
LED : Light Emitting Diode
LoWPAN : Low-power Wireless Personal Area Networks
LP-WAN : Low Power Wide Area Network
LTE : Long-Term Evolution
MAR : Mixed and Augmented Reality
M-BUS : Meter-Bus
MEOC : Mobile Emergency Operation Centers
MIT : Massachusetts Institute of Technology
M2M : Machine-to-Machine communication
MW : Mega Watt

nD : n-Dimensional
NDN : Named Data Networking
NFC : Near Field Communication
NIST : National Institute of Standards and Technology
NSDI : National Spatial Data Infrasructure
OECD : The Organization for Economic Cooperation and Development
OGC : Open Geospatial Consortium
PaaS : Platform as a Service
PC : Personal Computer
PDA : Personal Digital Assistant
PDAP : Pattern-Driven Architectural Partitioning
PLC : Programmable Logic Controller
PoW : Proof-of-Work
RAM : Random Access Memory
RFID : Radio Frequency Identification
ROM : Read-Only Memory
SaaS : Software as a Service
SCW : Smart Cities Wheel
SDI : Spatial Data Infrastructure
SDN : Software Defined Networking
SEDRIS : Synthetic Environment Data Representation and Interchange Specification
SIM : Subscriber Identification Module
SOA : Service-Oriented Architecture
SRD : Short Range Devices
SRM : Spatial Reference Model
SVM : Support Vector Machine
UIM : Urban Information Model
UK : United Kingdom
UN : United Nations
USGS : United States Geological Survey
UWB : Ultra Wide Band
VN : Vehicular Network
VM : Virtual Machine
VPN : Virtual Private Network

WAN **:** Wireless Area Network
Wi-Fi **:** Wireless Fidelity
WSN **:** Wireless Sensor Network
X3D **:** Extensible 3D
XML **:** Extensible Markup Language

LIST OF TABLES

Page

LIST OF FIGURES

Page

EVALUATION OF ARCHITECTURAL MODELS AND APPLICATIONS OF SMART CITIES

SUMMARY

With the advancement of technology and the expansion of urban areas in the world, various and new requirements have been shown up. Particularly, the modern era we live is obliged the people to take some concrete steps for having a better life. Benefitting from the products of technology during the casual life has been indispensable for not only people, but also countries at larger scale. This situation is one of the most important basics of modern life. The rapid growth in urban areas results in some important problems which affect also adversely the life quality at the same time. To have a better life in a sophisticated urban environment, constituents of the urban structure should be orchestrated in the way of what facilitates the life of citizens. To this end, the term of smart city has been emerged to meet the needs of people living in ever-growing urban areas.

In this thesis, it has been firstly emphasized what the smart city means, why the concept of smart city is important and which aspects make a city smarter. Following, it has been investigated the technical structure of smart city concept which composes of certain system architectures. The concept of smart city is embodied different characteristics and systems. Appropriate design of these systems is seriously important. In this regard, various system architectures proposed in the literature oriented to the implementation of smart city services in the best way has been studied. It has been expressed in depth which components form the relevant system architectures and what these system architectures are used for.

Afterwards, it has been tackled the relationship between the smart city concept and the technology, because understanding of this relationship in a good way will shed light upon the solution of this complicated puzzle composed of numerous technologic factors. To this end, information and communication technologies constitute the most dominant factor. Smart city systems are comprehensive structures in which there are lots of tools, sensors and other kinds of devices. A ubiquitous and simultaneous communication between these components is vital for sustainability and effectiveness of smart cities. Handling and storing of big data, the management of urban data, the assessment of big data analytics or the utilization from cloud computing with expected productivity are other remarkable subjects which have been studied within this thesis related to the smart city concept in technologic perspective.

Thereafter, the general situation of the smart city development has been handled in terms of 3D visualization, since 3D visualization and its components are other basic parts of a qualified smart city system. Today, 3D city modelling is a rising trend which attracts the researchers. These models are quite important to have enough information about the urban fabric, specific dynamics or problematic zones of it in terms of the urbanization. Besides, it has been highlighted the importance of the establishment of expected spatial data infrastructures that will meet principal requirements of not only

smart city modelling, but also 3D visualization. Moreover within this thesis; it has been clarified the basic terms giving way to the development of 3D visualization associated with the smart cities, the coverage and mission of I-SCOPE projects being carried out to be produced the smart city models with 3D visualization by European countries.

Finally, some existing smart city projects have been scrutinized within the body of the thesis for mapping out the level of consistency among the vision of smart cities and ongoing application studies. The evaluation of smart city projects around the world and in Turkey has shown existing deficiencies associated with the characteristics of the vision of smart cities. These deficiencies have been individually expressed in the tables. Besides, the recommendations, which may be considered as the constructive solutions and future works have been specified in the last chapter of the thesis.

AKILLI ŞEHİRLERİN MİMARİ MODELLERİNİN VE UYGULAMALARININ DEĞERLENDİRİLMESİ

ÖZET

Teknolojinin ilerlemesi ve dünya üzerindeki kentsel alanların genişlemesiyle beraber, farklı ve yeni ihtiyaçlar ortaya çıkmıştır. Özellikle içinde yaşadığımız modern çağ, daha iyi bir yaşama sahip olmak için toplumları bazı somut adımlar atmaya teşvik etmektedir. İçerisinde farklı işleyiş mekanizmaları barındıran kentsel yaşam kavramı, gün geçtikçe daha karmaşık ve kontrol edilemez bir hale gelmektedir. Yoğun nüfus ve bunun paralelinde ortaya çıkan ek ihtiyaçlar, yönetim sistemlerinin ve karar verme makamlarının iş yükünü ciddi surette artırmaktadır. Büyük toplumlar, büyük ekonomiye ve bu doğrultuda kullanıma açılması beklenen büyük hizmetlere gereksinim duymaktadır. Var olacak hizmet sisteminin kurulabilmesi için, bu konuların ileri gelen uzmanlarına önemli görevler düşmektedir. Hedeflenen noktalara ulaşabilme ve yüksek beklentileri karşılama yolundaki en büyük yardımcılar ise hiç şüphesiz, teknoloji ve onun sunduğu imkânlardır. Günümüz şartlarında insan hayatı, teknolojiyle iç içe geçmiş vaziyettedir. Geçmişte insanoğlunun kendi imkânlarıyla yapmak zorunda olduğu pek çok şey artık, teknolojinin sağladığı kolaylaştırıcı unsurlarla yapılmakta ve bu durum gün geçtikçe etkisini artırmaktadır.

Öte yandan, günlük hayatı yaşarken teknolojinin nimetlerinden yararlanmak sadece insanlar için değil, daha geniş ölçekte ülkeler için de vazgeçilmez bir hale gelmiştir. Temelde bireysel olarak ortaya çıkan ihtiyaçlar, insanların bir arada yaşama zorunluluğunun etkisiyle genişleyerek toplumlara ve akabinde ülkelere sirayet etmektedir. Geçmişten günümüze kadar artarak devam eden bu durum, teknolojinin hâkim olduğu modern çağın da en önemli esaslarından birisi haline gelmiştir. İlerleyen zaman içinde değişen şartlar, insanların tarihi süreç içerisine yayılan göç faaliyetlerini etkisi altına almakta, kentsel alanların cazibe noktası haline gelmesine sebep olmaktadır. Kırsal alanların kısıtlayıcı şartlarından sıyrılıp kentsel yaşama merhaba diyen insanlar tarafından gerçekleştirilen yoğun göç dalgaları, demografik yapının kısa zaman içinde kentsel alanlar üzerinde yoğunlaşmasına neden olmaktadır. Kentsel alanlardaki bu hızlı büyüme aynı zamanda, kent hayatının kalitesine zarar veren ve dikkat edilmesi gereken ciddi sorunlara yol açmaktadır. Bu noktada incelenmesi gereken en önemli husus, geniş bir payda üzerinde yayılım gösteren kentsel yapı olgusunun meydana gelmesini sağlayan farklı dinamiklerdir. Söz konusu durum kentsel yapının ve buna olarak kentsel hayatın çok yönlülüğü olarak da ifade edilebilir. Sözü edilen bu çok yönlü kentsel çevrede daha kaliteli ve yıpratıcı faktörlerden arındırılmış bir hayatın yaşanabilmesi için, kentsel yapıyı oluşturan bileşenler, kent sakinlerinin hayatlarını kolaylaştıracak biçimde düzenlenmelidir. Bu doğrultuda, durmadan büyüyen kentsel alanlarda yaşayan insanların ihtiyaçlarına daha iyi cevap verebilmek maksadıyla projeler geliştirilmiş, çalışmalar yapılmış ve netice itibarıyla akıllı şehir kavramı ortaya çıkmıştır.

Bu tezde öncelikli olarak; akıllı şehir kavramının ne demek olduğu, akıllı şehir kavramının niçin önemli olduğu ve hangi özelliklerin bir şehri akıllı hale getirdiği vurgulanmıştır. Akıllı şehir kavramı hakkında sabit ve bilim çevresinin mutabık kaldığı belirli bir tanımlama bulunmamaktadır. Bu konuda çalışma ve araştırmalar yapan uzmanlar, akademisyenler, araştırmacılar ve kuruluşlar tarafından farklı tanımlamalar geliştirilmiştir. Literatürde bu açıdan büyük bir zenginlik ve çeşitlilik söz konusudur. Akıllı şehirlerin önemi, sahip olduğu anlamsal muhteva ile doğrudan ilişkilidir. İlgili muhteva kapsamında öne sürülen karakteristik özellikler, aynı zamanda akıllı şehircilik hareketinin vizyonunu ve misyonun belirlemektedir. Bu bağlamda yapılan literatür araştırması ile bahsi geçen belirgin özellikler vurgulanmış, bir şehrin niçin akıllı olması gerektiği ifade edilmiştir.

Devamında, akıllı şehirlere dönüşüm teknik açıdan ele alınarak belirli sistem mimarilerinden oluşan akıllı şehir kavramının teknik yapısı irdelenmiştir. Akıllı şehirlerin inşa edilmesinde gerekli olan bu teknik yapı, hali hazırda devam eden ve devam edecek olan çalışmaların çerçevesini teşkil etmektedir. Teknolojik ilerlemelere paralel olarak geliştirilen bu yapı farklı mimarileri içermektedir. Verinin nasıl ve nerede işleneceği, nerede depolanacağı, nerede revize edileceği, veri bazlı ilişkisel düzenin nasıl kurulacağı, verilerin uygulama sahalarına nasıl aktarılacağı ve somut hizmet faaliyetlerine nasıl dönüştürüleceği farklı katmanlar vasıtasıyla tanımlanarak akıllı şehir mimarileri tasarlanmaktadır. Bu sistemlerin uygun şekilde tasarımlanması ciddi manada önem arz etmektedir. Kentsel dokuların kendi içlerindeki özgün yapıları ve karakteristik özellikleri göz önünde bulundurularak tasarlanan akıllı şehir mimarileri, çalışma sürecinde hem zamandan hem de bütçeden tasarruf sağlamaktadır. Uygulama sahasında istenen sonuçların elde edilmesi, akıllı şehircilik hareketi kapsamındaki teknik altyapının kavramsal açıdan iyi bir şekilde anlaşılmasına bağlıdır. Bu doğrultuda, literatür kapsamında akıllı şehir hizmetlerinin en iyi şekilde uygulanmasına yönelik olarak önerilmiş çeşitli sistem mimarileri incelenmiştir. İlgili sistem mimarilerinin hangi kısımlardan oluştukları ve yararları detaylıca ifade edilmiştir.

Ardından, akıllı şehir kavramıyla teknoloji arasındaki ilişki ele alınmıştır. Çünkü mevcut ilişkinin yeterli bir biçimde anlaşılması, pek çok teknolojik yapıyı içeren bu karmaşık bilmecenin çözümüne ışık tutacaktır. Bu bakımdan, bilgi ve iletişim teknolojisi en belirgin temeli teşkil etmektedir. Akıllı şehir sistemleri; içerisinde pek çok aracın, sensörün ve farklı türlerde aygıtın bulunduğu kapsamlı yapılardır. Bu bileşenler arasındaki eş zamanlı ve geniş kapsamlı bir iletişim, akıllı şehirlerin sürdürülebilirliği ve verimliliği açısından hayati bir önem arz etmektedir. Bu iletişim esnasında meydana gelen veri alışverişleri sonucunda, çok yüksek boyutlara sahip veri havuzları oluşmakta ve bu durum yeni sorunları beraberinde getirmektedir. Teknolojik bileşenlerin en önemlilerinden biri olarak kabul edilen veri çeşitlerinin anlaşılması ve bunların rasyonel adımlarla yönetilerek kontrol edilebilir bir şekle sokulması, en çok dikkat edilmesi gereken konulardan biri olarak göze çarpmaktadır. Bahsedilenler doğrultusunda; büyük verinin idare edilmesi ve depolanması, kentsel verinin yönetimi, büyük veri analitiklerini değerlendirilmesi, açık verinin ne olduğu, hedeflenen verimlilikte bulut bilişim teknolojisinden faydalanma ve veri temelli sorunlar bu tez kapsamında akıllı şehirlerin teknolojik boyutuyla alakalı incelenen diğer konulardır.

Yine bu tez kapsamında, akıllı şehir gelişiminin genel durumu 3B görselleştirme açısından ele alınmıştır. Çünkü 3B görselleştirme ve onun bileşenleri, nitelikli bir akıllı şehir sisteminin diğer temel öğeleridir. 3B şehir modelleme; günümüzde araştırmacıların ilgisini çeken, yükselen bir eğilimdir. Bahsedilen bu modeller şehir topografyası, kentleşmeye dayalı özel dinamikler ya da kentleşme açısından sorunlu bölgeler hakkında yeterli bilgi elde etmek bakımından oldukça önemlidir. Bunun yanında, sadece akıllı şehirlerin modellenmesiyle ilgili değil, aynı zamanda 3B görselleştirmeyle de alakalı birincil ihtiyaçları karşılayacak, hedeflenen mahiyetlerde konumsal veri altyapılarının tesis edilmesinin önemi ifade edilmiştir. Dahası, akıllı şehirlere yönelik 3B görselleştirme gelişiminin önünü açan temel kavramsal tanımlar, 3B görselleştirme destekli akıllı şehir projelerinin üretilmesi için Avrupa ülkeleri tarafından yürütülen I-SCOPE projelerinin kapsam ve misyonu bu tez kapsamında açıklanmıştır.

Son olarak bu tez bünyesinde; akıllı şehirler vizyonu ile devam eden uygulama çalışmaları arasındaki tutarlılığı detaylarıyla ortaya koyabilmek için, bazı mevcut akıllı şehir projeleri mercek altına alınmıştır. Dünyanın ve Türkiye'nin farklı yerlerine ilişkin yapılan akıllı şehircilik çalışmaları; akıllı hareketlilik, akıllı ekonomi, akıllı insan, akıllı yaşam, akıllı çevre ve akıllı yönetim parçalarından oluşan ve akıllı şehircilik hareketinin odak noktası olarak değerlendirilen akıllı şehirciliğin karakteristik özellikleri ışığında irdelenmiştir. Dünya çapındaki ve Türkiye'deki akıllı şehir projelerinin bu metotla değerlendirilmesi, sözü edilen karakteristik özellikler bakımından önemli eksiklikleri gözler önüne sermiştir. Bu eksiklikler sonuç bölümünde iki ayrı tablo halinde belirtilmiştir. Ayrıca yine tezin sonuç bölümünde, yapıcı çözümler olarak göz önünde bulundurulabilecek bazı öneriler ve geleceğe dönük çalışmalardan bahsedilmiştir.

1. INTRODUCTION

The human population increases in the world year by year. This situation that is unavoidable rises lots of negative consequences affecting on human life, especially in terms of quality. On the other hand, technological developments that are ongoing triggers migrations from rural to urban areas. New members of cities who come from rural areas with hopes such as getting a new job, living more comfortably or making more money cause the population growth in cities. More crowded cities need more basic supportive and helping functions which must be performed to better manage their issues becoming bigger because of the over population. Unfortunately, some adverse circumstances might be more frequently occurred in governance and management of city services in many countries throughout the world. It is clear that the increased population in urban environment may not be decreased by being turned back the flow of migrations. That's why the only solution is to develop new solution techniques utilizing the advantages of technology which allow creating more efficient city services by providing the coordination between different stakeholders interested with the city governance. These solution techniques may consist of a wide range of urban issues that are from traffic jamming to environmental protection for sustainable city development. The aim of inventing novel tools is to enable high quality life for citizens. The transition from traditional cities to smart cities provides taking concrete footsteps going to the targeted prospect. As every works being built up from nothing intrinsically face numerous problems, the creating of smart cities to make them better accommodable places for residents are being challenged with different problems that need to be overcome. The most important matter and target is how these problems will effectively be solved by latest technologic techniques.

In this thesis, it has been focused on the smart city modelling and 3D visualization of smart cities with the aim of meeting the aforementioned requirements. In the second chapter of the thesis, the general understanding about the term of smart city in the literature has been presented. Moreover, the basic aspects which transform a traditional city into the smart city have been investigated and shown.

Thereafter, the technical requirements for a smart city modelling have been investigated in a detailed way in the third chapter. The fundamental architectures of smart city systems have been defined by considering the exact needs of urban areas. These architectural systems are the technical frameworks of the smart city systems which are necessary for operating of smart services. Different layers and relations have been described within the relevant architectures. Shedding light upon the technical details related to the smart cities is extremely necessary for the understanding of these architectures. A better architecture means a better performance, better services and a better quality in the urban areas in terms of all critical points.

In the fourth chapter, the technologic components within the smart city phenomenon have been examined. As it is known, the smart cities are technically composed of a multifaceted structure. One of the most important faces is also the technology. The concept of smart city can be evaluated as a synthesis or an intersection of different technologies within the body of urban environment. The development of smart city concept requires benefitting from technology in a wide range. In this context, the analysis of latest technologies, which are the cornerstones for the smart city solutions, such as Information and Communication Technology (ICT), Internet of Things (IoT), cloud computing, open data, big data and urban data has been meticulously done to figure out the technologic side of smart cities.

In the fifth chapter, 3D visualization process within smart cities has been studied. Because a smart city model of high quality cannot be acceptable without a 3D city modelling. A better visualization provides making better and constructive decisions related to forward-looking policies and plans about the city management. The visualization also enables diverse fundamental insights about the building up process of smart city services by means of spatial data infrastructure. The above mentioned matters allow creating desired smart city models. Additionally, the basic definitions about the background of smart city visualization and ongoing I-SCOPE projects oriented to 3D visualization in smart cities have been explained in this chapter.

In the sixth chapter of the thesis, the general evaluation of international smart city projects developed or being developed around the world have been made to demonstrate the current situation of the world in smart city modelling. Deficiencies of these projects have been identified according to the smart city characteristics.

Following, the general evaluation of smart city projects in Turkey has been made to come into prominence the current situation of the national smart city vision in the seventh chapter. The evaluation has shown that there is no a holistic smart city approach that covers all basic smart city characteristics at application stage in Turkey.

In the final chapter of the thesis, the recommendations and future works that can be helpful for eliminating the deficiencies and hardships connected with the design of expected smart city models have been expressed. Main deficiencies of existing smart city studies around the world and in Turkey have been demonstrated in the tables by considering the smart city characteristics.

2. WHAT IS THE SMART CITY?

The increase of expectations of people concerning with a better life has been induced coming up the term of smart city. Particularly, this term is being repeated by experts in last decade. Smart city was proposed as a term by Oxford University in charge of Oxford Program for the Future of Cities at first. The people affiliated with the science environment have been searching the true definition about what the smart city really is. Actually, there is no an absolute definition of smart city. Experts who study on the establishment of a smart city model have differently defined what the smart city is. According to Roche (2014), “A smart city is a city that is able, in a multi-faceted territory, to efficiently mobilize technological innovations so as to anticipate, understand, openly discuss, act and serve many actors with a wide range of profiles” (p. 708). The definition expresses general mission and goals of the smart city and is emphasized importance of the technology on its way of being formed. Washburn et al. (2010) stated the smart city as “a city that uses information and communication technologies to make the critical infrastructure components and services of a city (administration, education, healthcare, public safety, real estate, transportation and utilities) more aware, interactive and efficient” (p. 2). Washburn et al. has been emphasized on that services which are the backbone of city life have been the higher quality with the help of smart city. Batty et al. (2012) defined the smart city as “synthesis of hard infrastructure (or physical capital) with the availability and quality of knowledge communication and social infrastructure” (p. 486). There are many definitions about smart city like these ones. The common point between the definitions is that internet and communication technologies are fundamental criteria for being operated smart services in the city. Also, the frameworks and infrastructures related to this technology should be established very well around whole urban areas.

In addition to, experts have been addressed the unignorable importance of the smart city, because the term of smart means the facilitation of urban life through the integration of technologic developments with real life. The smart city’s system is formed by the conglomeration of mutually complementary sub-systems. Each of them takes on particular tasks for the Improvement of urbanization. Cities, specially nowadays by the more engagement of diverse technologies on people's life, may be resembled a complicated chain structure which has lots of different constructive elements to carry out its base functions. The Figure 2.1 demonstrates this complicated and interconnected system structure.

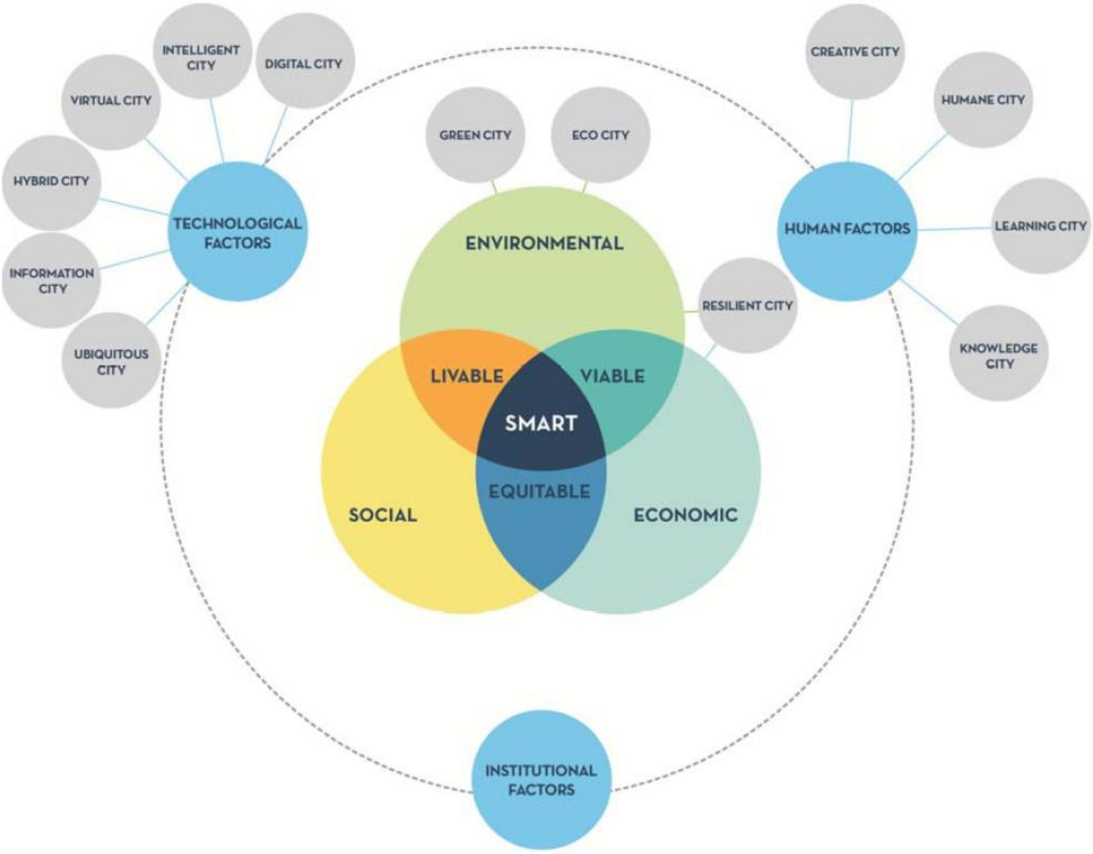

Figure 2.1 : The smart city model based on other smart city definitions (European Investment Bank Institute, 2015).

On the other hand, the smart city means flexible city as well because not only stakeholders of the city play an important role in administration process, but also the well adaptation of people to the implementation phase of smart cities is quite important at least as far as the first one. Locals can contribute to the city management via their feedbacks through smart applications. So, it will bring about a synthesis composed by users who direct the course of development and stakeholders who have the mission to improve it in the light of incoming feedbacks.

2.1 Why A City Must Be Smart?

Being crowded of the world's cities is triggered numerous problems that have negative impacts on human life. Not only human life, but also this circumstance has serious impacts on natural life cycle. The crowded human population means the increase of waste materials, the critical fluctuation of natural environment sustainability, the big danger for ecology, more emitting of greenhouse gases from human-made structures and accordingly the inevitable case called the climate change, melting of glaciers and because of that, going up the sea level all around the world. Such horrific scenarios are being shown in many science-fiction movies, however; according to scientists today, these kinds of situations are not that far for real life as well.

Besides, the rapid population growth decreases the quality of citizen's life in terms of social and economic perspective. The intense and jammed life conditions make people to live more depressively. It falls down the energy of people and productivity in return that. Moreover, the city that has over population becomes ponderous through losing its flexibility. Therefore, a ponderous city loses the competitive power and the capability of adopting novel techniques and innovative methods in the light of the technologic developments.

The city administrators can not hinder the increase of population and problems rising because of that, but can manage them logically without harming the natural tissue of the city. Thanks to improvements that will be done to make the city smart, the city life will have the harmony and strong relationship between the city managers and the citizens.

Furthermore, one of the main principles of being a smart city is to advocate the natural environment. A city should not be disconnected from the nature. Green tissue is the natural ventilation system which protect the city to be exposed to high-level air pollution. It has been mentioned about the smart city as the sustainable city, the green city, the eco-city or the low carbon city in the literature (Fu and Zhang, 2017).

With the modernization of the world and substantially shifting the population from rural to urban regions, the cities have become the new control center of countries. Today, modern cities constitutes the fundamental economic resource of countries in 21th century. When taking into consideration this remarkable reality, the management of modern cities regarding to basic rules of the smart city concept and also the transformation of these cities as far as possible into the smart form which will make easy the life for citizens, besides remove the burden on citizens resulting from the complicated urban environment come up as the most important priorities for the policy makers and the other officials who are responsible for the city management. In this regard, the internet and communication technology (ICT) is the core element (Dobriloviç, 2018). The internet and communication technologies that connect different apparatuses that assist to make the city smart have the great importance toward the achievement of smart solutions. The smart solutions are going to be the leverage in order that cities have the identification of "smart city".

2.2 Which Aspects Make A City Smart?

According to definitions about what the smart city is in the literature, the most common point is that it is the city which makes preparation and planning in the direction of the future, analyzes the usable raw material associated with any service area in needs of it and produces new solutions by using the technology for performing necessary duties in the direction of a better urbanization.

To apply an appropriate smart model, it is needed to disclose aspects that will make the city smart. There are different approaches about what the smart city characteristics are. The most preferred methodology which was submitted by the European Union (EU) is Smart Cities Wheel (SCW) that has been proposed by Cohen in 2012. According to Cohen's methodology, the smart city model is composed of six core constituents, as it is seen in the Figure 2.2.

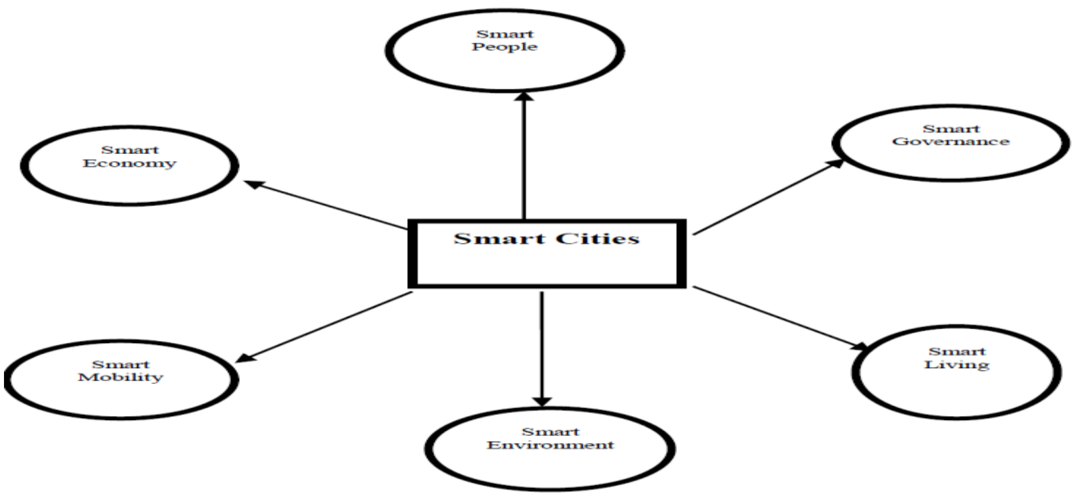

Figure 2.2 : Smart cities characteristics (Kumar and Jailia, 2018).

According to Caragliu et al. (2009), “a city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and high quality of life, with a wise management of natural resources, through participatory governance” (p. 50). Smart city characteristics (the six indicators) is based on the definition above. These six indicators must be elaborated to develop the best smart city model. Each indicator must be reciprocally scrutinized by researchers and stakeholders. The key factors of each indicator must be determined and tested in suitable testbeds. The Table 2.1 points out the fundamental smart city characteristics.

Smart economy consists of e-business, productivity growth by using ICT, advanced manufacturing and providing systems, smart clustering and the laboratories serving with business ecosystems. Smart economy is targeted to constitute the network of organizations which contains customers, distributors, suppliers, government agencies, competitors working in a collaborative approach.

The purpose of smart people is to create a complementary society model adopting the creativity and innovation by being improved ICT use and production skills of people. The smart city management agencies can carry out the city’s services better through the feedbacks of community, playing an active role in management of the city and sharing their experiences about different smart applications.

Table 2.1 : Smart cities characteristics (Kumar and Jailia, 2018).

Smart Economy	Innovation of Spririt Productivity Cooperation Between Private and Public Sector Entrepreneurship Economic Images Economic Trades
Smart People	People with Professional Techniques Flexibility Qualification Level Affection of Lifelong Learning Intelligent Governance
Smart Living	Facilities in Education Health Condition Social Cohesion Medical Service

Table 2.1 (Continue) : Smart cities characteristics (Kumar and Jailia, 2018)

Smart Governance	24/7 Emergency System Digital Infrastructure Monitoring in Urban Services for Public and Social
Smart Mobility	Travelling Options Resources for ICT Infrastructure Safety in Transport Accessibility
Smart Environment	Management of Sustainable Resources Environment Protection Air Pollution Consumption in Energy

In smart living, it is aimed to make the citizen's life more comfortable and to prepare more healthy and safe living space for them in the city by being benefitted from ICT opportunities.

Smart governance is predicated the governance constitution which has the transparency of the public administration, the participative decision-making mechanism and the communication based on ICT between the stakeholders at different scales. Moreover, the sharing of data generated by public in accordance with the open data policies for all stakeholders without any charge and restriction is so important for both the transparency of the public administration and providing services and products which have high quality.

Smart mobility means transportation systems integrated with ICT in general. The most important priority in this context is to conserve the environment and to procure complementary transport solutions for disabled people. Furthermore, generating and sharing of real-time traffic data with passengers, drivers and operators are another critical matter associated with this aspect.

Smart environment is covered improvements about the renewable energy, smart networks, micro networks, smart meters, advanced air pollution monitoring systems, green buildings, eco-friendly city planning, smart street lights with energy conservation, solid waste management, smart water management and drainage systems.

3. SMART CITY IT ARCHITECTURE MODELS

Smart city models are comprehensive systems that have a lot of different service capabilities regarding the enhancement of city performance to offer a better life for citizens. A smart model that has been formed by combining with different tools, algorithms, applications and sub-systems that are in capable of the data storage, the information retrieval, networking, communication as a homogenous synthesis must have a definite organization and working mechanism. This case has a great importance in handling with the problems which cities encounter due to the rapid urbanization and the acute population growth. To conceive a consistent and functional smart model, one of the first steps that has to be taken is the determination of system architecture. The system architecture deployment can be stated as the set-up of ICT that contains all devices for the execution of public services and the seamless connectivity between them in the expected way. ICT infrastructure is enabled to improve the quality of life, efficiency of urban services, operations and competitiveness through making sure that the needs of present and future generations converge on a common point (Booch, 2010). The true architecture model is enabled diverse essential features such as flexibility, operability, innovativeness, easy-understandability, consistency, business plan and more to the smart model. There are different proposals associated with the smart city architectures in the literature.

3.1 Service-Oriented Architecture

According to the statement of Bawary and Shamsi (2015), “a service-oriented architecture (SOA)-based model, is used to transform data and perform analysis” (p. 247). This architecture model is adopted to meet some certain requirements of urban areas based on the service platform offered by agencies. The origin of service-oriented architecture is expressed as the Integrated Factory Information Network (INFINET) that was proposed in the early 1980. The INFINET was emerged as a solution to describe an architecture that had the ability permitting monolithic automation islands which could be divided into smaller, discrete, remotely accessible functions. It contains basically three layers called as application layer, support layer and service layer. The service layer has an infrastructure, that has been formed by software and hardware components, playing a key role for the city services. The Figure 3.1 represents INFINET Platform.

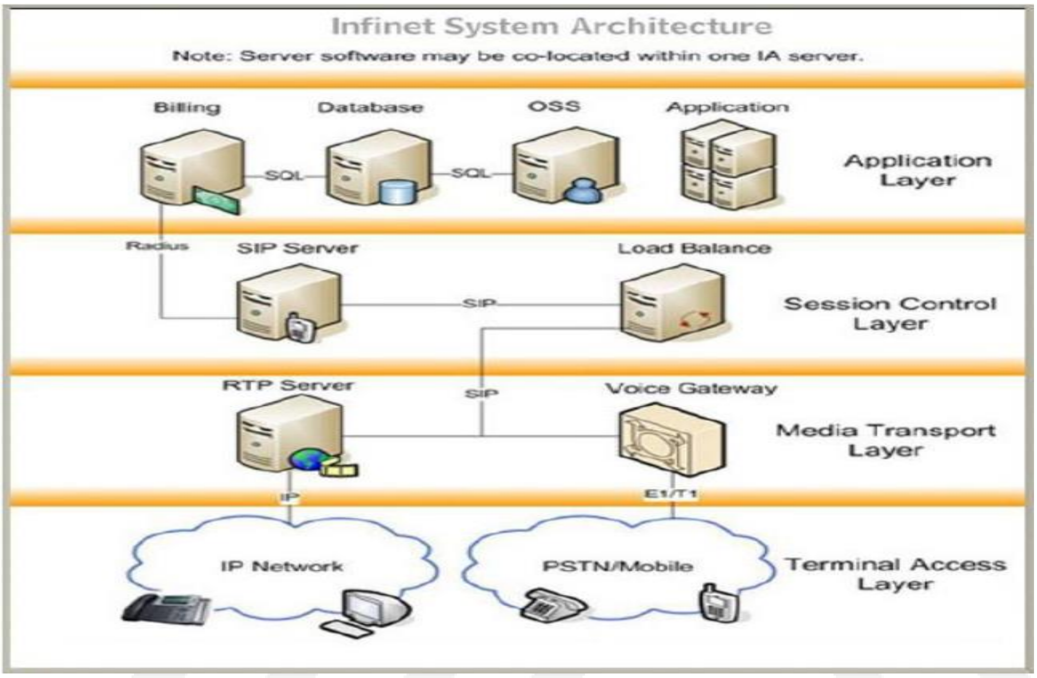

Figure 3.1 : INFINET platform (Concept USA, 2007).

There is a high similarity between the modern INFINET and SOA. Typical approach to SOA is that it promotes the interconnectivity between city services. In this regard, it is thought that SOA may be an efficient solution way to eliminate problems about the service organization and benefitting effectively from urban services.

On the other hand, service-oriented system provides a standard framework in which city services are developed, implemented and managed in order to increase the agility of the IT processes for rapid business change outcomes (Hashemi et al., 2013). By a better understanding of the geographic sciences and value of the geospatial data in urban planning to promote cities have been main contributors to which service-oriented architecture has become more important in the science environment. The Figure 3.2 presents the service-oriented architecture framework levels.

There are various service-oriented architecture models proposed. One of the mentioned models has been presented by Rolim et al. in 2014 with the name of

UrboSenti. It is a seminal approach to ubiquitous service-oriented architecture urban sensing that includes data collection services and assistance in sensing application development. UrboSent may be taken into consideration as different from other urban sensing models by the aspect what it may use diverse data detected from multi-sources and incorporates social and traditional sensing (Elhoseny et al., 2016).

Figure 3.2 : Service-oriented architecture framework levels (Falconer and Mitchell, 2012).

In addition, there is another service-oriented architecture platform that has been developed related to a visualization of 3D city model by Prandi et al. in 2014. The model has advantageous situation in order that 3D models have high importance for urban spatial data infrastructures. The Figure 3.3 on the following page indicates the developed SOA conceptual schema for 3D visualization in smart city platform.

The advantages of the model are that being scalable, interoperable and provisional for several service-oriented functionalities. Furthermore, the model can be generated improvement outcomes. It has been accepted that the model was adaptable to possible changes in the future. However, the limited accessibility to semantics of the city model and the magnitude of interactive capacities of city management functions are emerged as remarkable negative sides of the model.

The definite goals of service-oriented architecture are to upgrade IT coordinated with business, improvement of the interaction between organizations, flexibility of IT to respond to on-going changes in business, standardization and integration of platforms and IT substructures, flexibility of software components and improvement the level of reuse (Hashemi et al., 2013).

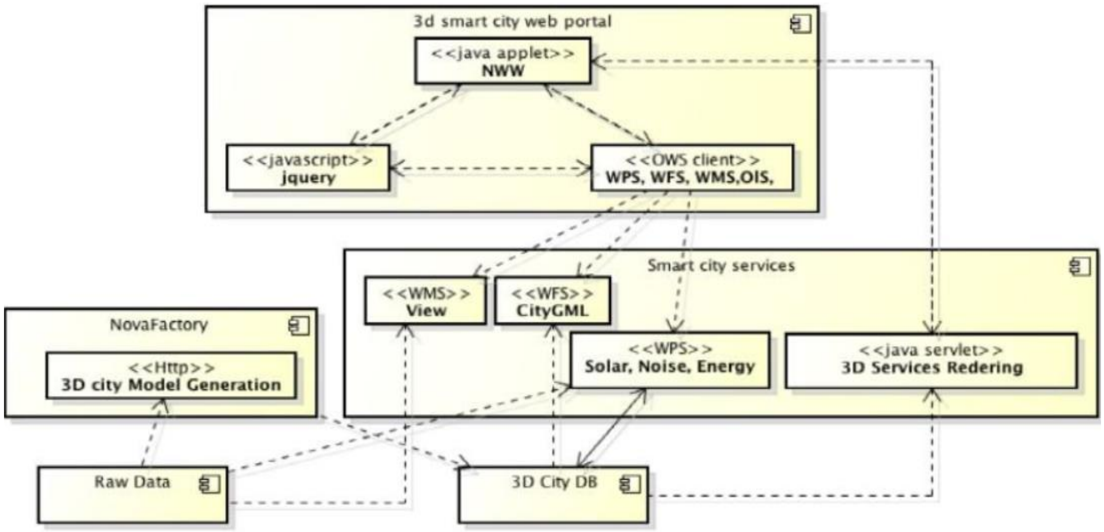

Figure 3.3 : SOA in the smart city platform for 3D visualization (Prandi et al., 2014).

According to the idea of Elhoseny et al (2016), “the ideal SOA framework should support the capabilities that are needed to integrate and to effectively manage the city’s resources and is easily modifiable in light of the changing urban landscapes along with the rapid evolution of technology” (p. 80). The framework must have IT flexibility to meet altering needs of the city and to overcome ongoing business challenges at the same time. The SOA framework should be respectively consisted of five layers to solve problems corresponding the system organization and continuous changes because of the rapid urban growth; user-oriented services layer, application-oriented layer, security service layer, data services layer and information infrastructure layer for urban systems (Elhoseny et al., 2016).

By the proposed SOA framework is aimed to succeed the creation of a basis for the management of city infrastructure components by extending the interoperability between system units via exploiting GIS platform. Other targets expected with the framework are the continuous monitoring of urban systems in which are utility, irrigation, communications and sewage networks. The achievement of targets will provide a broad city representation that covers all needs of city management agencies to be able to make better decisions for city evaluation. The Figure 3.4 exhibits layers of the proposed SOA framework for smart city concept.

Data layer is responsible for data storage, data management, data quality, data movements and the allowance of building reusable data services that can contribute to the orchestration of business processes. Stored data is distributed to certain communication channels that are controlled by human actors. The communication in integration layer designed as an Enterprise Service Bus is performed via machine-to-machine communication (M2M). Despite systems have particular assignments associated with different areas, they are constituted a network that all units connected with each other. Management of business processes, protocols and programming logic are performed in application layer which acts as a business process registry. Finally, presentation layer is assigned to host human task mediations by working as a business service registry on condition that interactions between services are identified.

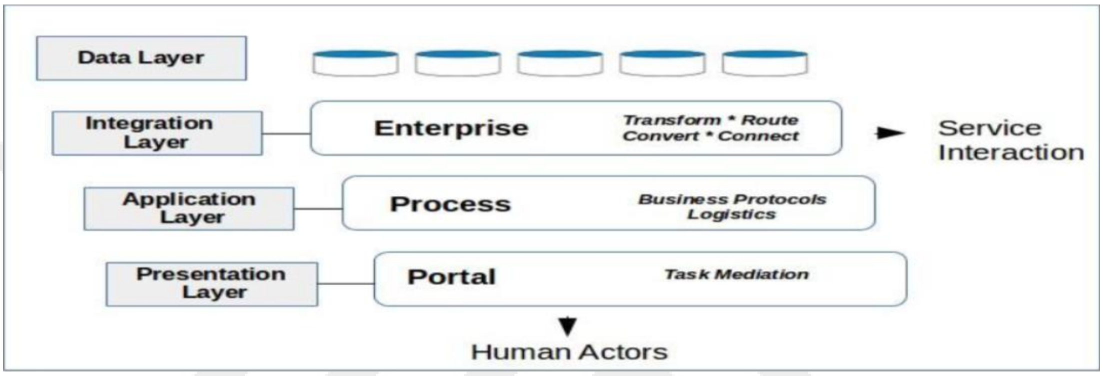

Figure 3.4 : The proposed SOA framework for the smart city concept (Elhoseny et al., 2016).

The implementation stage of proposed framework has been aimed the development of a suitable size for smart city projects by using a bottom-up approach (Elhoseny et. al, 2016). The Figure 3.5 depicts the bottom-up approach for smart city framework.

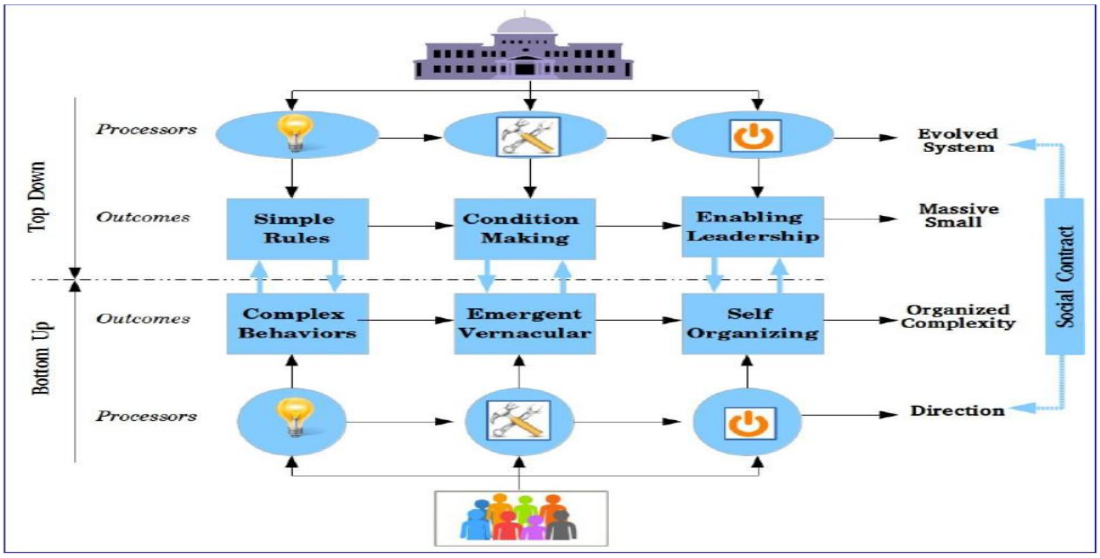

Figure 3.5 : The bottom-up Smart city framework (Elhoseny et al., 2016).

3.2 Named Data Networking Architecture (NDN)

Piro et al. (2014) has been expressed that “it is based on a data-centric approach: all contents are identified by a unique name, allowing users to retrieve information without having any awareness about the physical location of servers (e.g., IP address)” (p. 12). One of NDN’s targets is receiver-driven communications on the ground of the exchange of content chunks, name based routing and self-certifying packets (Piro et al., 2014).

A named data networking system can be set up in two ways in which are adoption of a clean-state approach or consideration of an overlay layer. The building way in the first case is that whole system must be created again from the origin phase. It must be given an attention on connecting the NDN architecture straightly to the lower technologic layer. The second building way is to consider a feasible solution that enables to quickly design, experiment and deploy the addressed architecture type on top of the existing internet structure. The architecture has to be consisted of two layers, that are strategy layer and security layer, in order to actualize the conditions of protocol suite. Strategy layer is in charge of disseminating messages via the network. As for, security layer is handled all security aspects.

The driver that is efficient upon NDN communications is consumer of data. Interests and data are two kinds of messages that are exchanged. When a user demands a content about an interest, the system is directed the user toward the nodes which have the information needed. The nodes are activated to reply with data packets.

Identification of each content is determined with a unique content name. NDN architecture is described by a hierarchical structure for names. System has a name tree that serves in the direction of this. There are several components creating the hierarchical name structure. Each of them has been made by a number of arbitrary octets. This provides to be defined sub-trees in the name space by name prefixes. On the other hand, an interest packet can reveal the entire name of content or its prefix. Therefore, it is taken place an access to the whole collection of elements under that prefix (Piro et al., 2014). An example of name tree structure can be seen in figure 3.6 on the next page. Routing and distributed caching mechanisms are other two new aspects that constitute the behavior character of NDN architecture. Strategy layer is performed routing operations only for interest packet.

NDN nodes must have three structures to perform effectively main functions of NDN system (Piro et al., 2014). These are the content store, the forwarding information base and the pending interest table. The content store is a memory cache method working in accordance with different replacement policies such as Least Recently Used, Least Frequently Used or Random. This is applicable where some received contents can be stored. The forwarding information base is ensured being able to be forwarded of interest packets to many potential required data sources. The pending interest table is supplied to be kept track of interest packets that previously forwarded upstream to content sources. This keeps safe the information about arrival faces. Besides, it enables proper deliver of backward data packets to the right requesters. The Figure 3.7 on the top of page 18 displays the NDN functionalities.

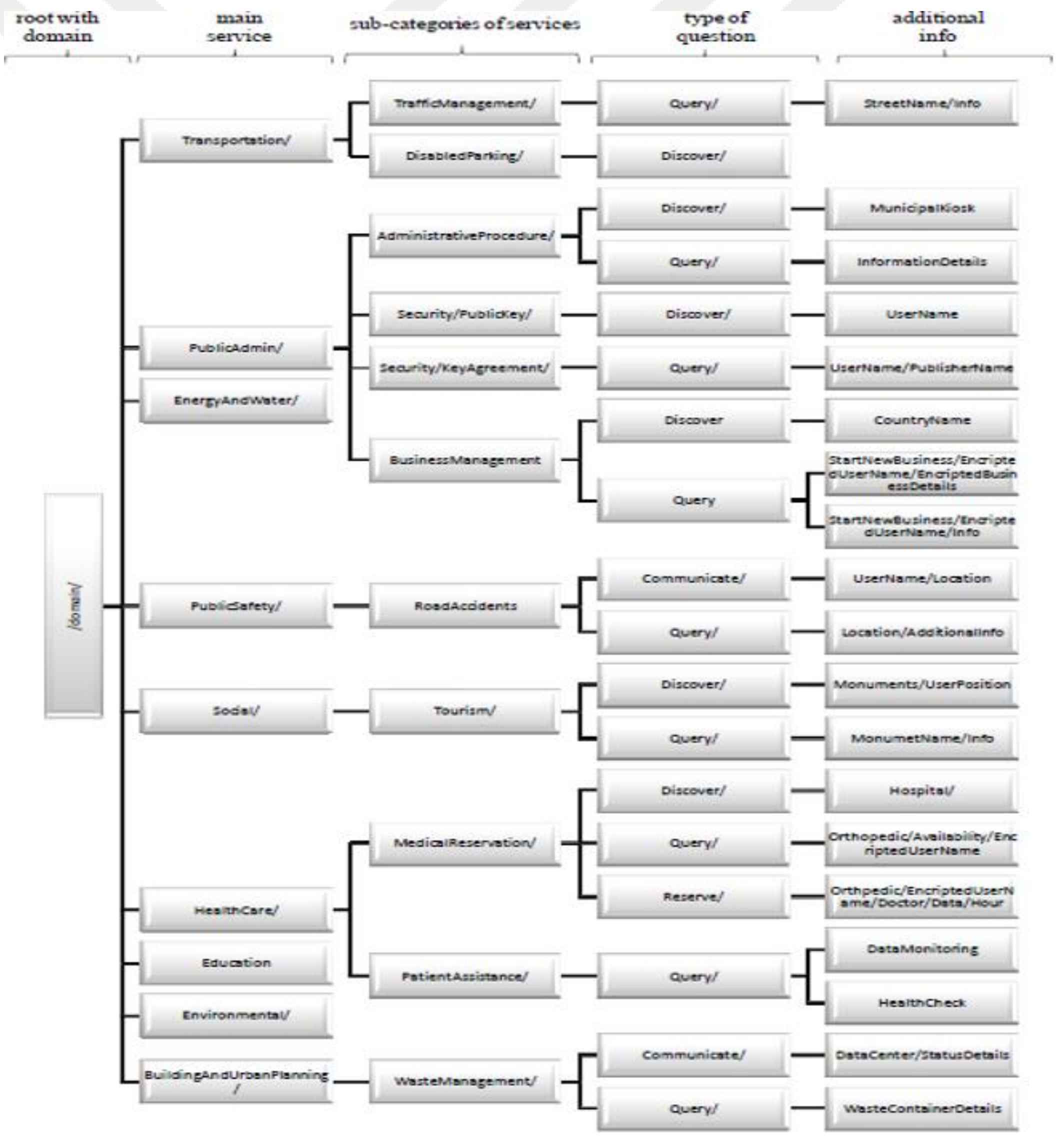

Figure 3.6 : The example of name tree structure (Piro et al., 2014).

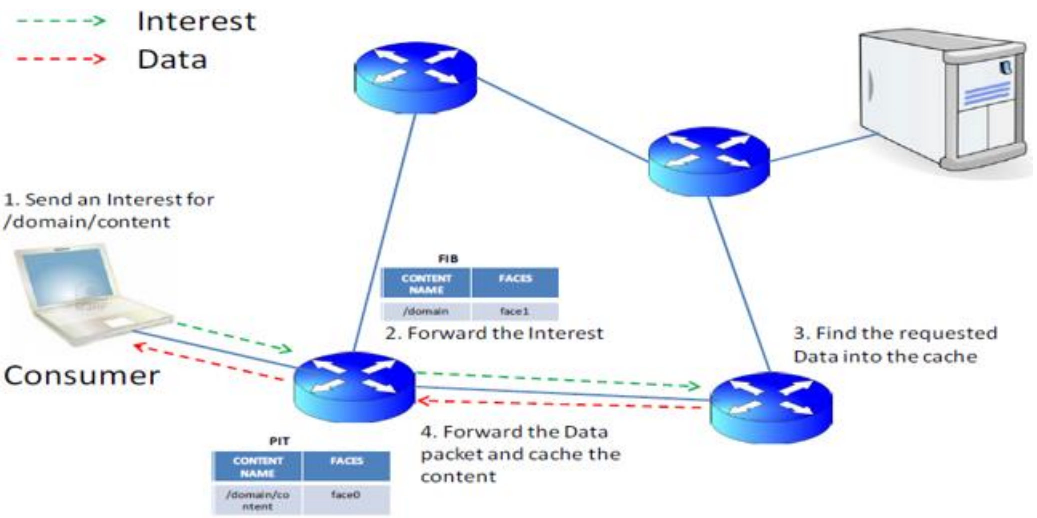

Figure 3.7 : The demonstration of NDN functionalities (Piro et al., 2014).

Depending the study on the establishment of NDN architecture for smart city by Piro et al. (2014), "the service platform proposed in this work is built on two level: the service layer and the technology layer, both interacting through NDN interface" (p. 15). The Figure 3.8 briefly shows NDN-oriented service platform.

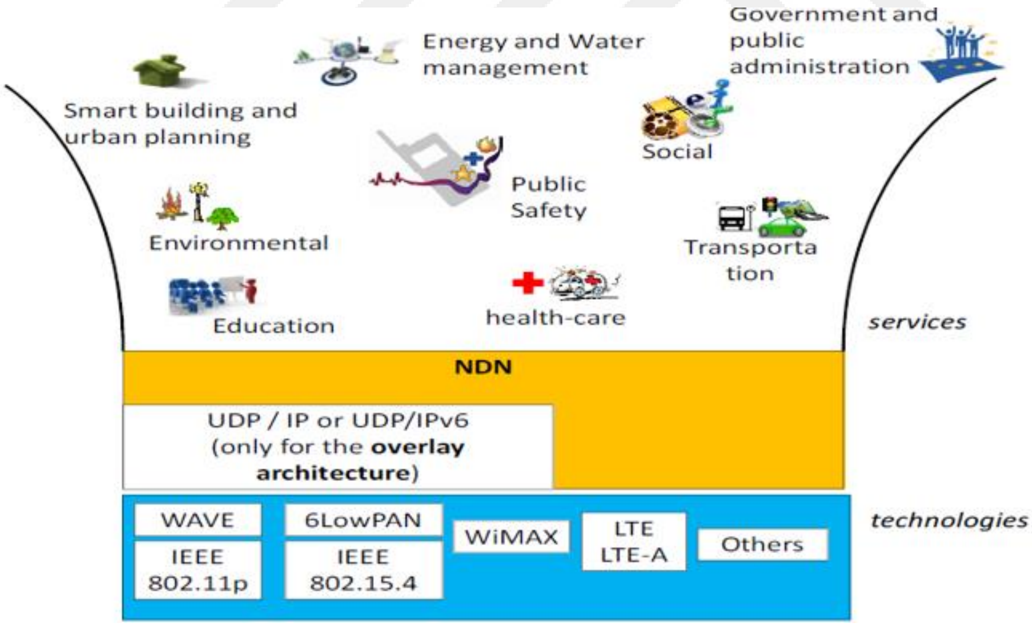

Figure 3.8 : The NDN-oriented service platform (Piro et al., 2014).

A user may benefit from the given service platform in a ubiquitous manner via a device that makes a connection with the world by using specific wireless technology. It has been also considered the software which can be adaptable with devices produced for users and can be properly developed on the basis of emerged new cases related to city.

Satisfying all expected tasks for each service execution phase is known as the most important goal of the software introduced. The user may reach to the service list by utilizing the graphical NDN interface in order to select one according to what he/she is interested to.

3.3 Zone-Level Architecture

Zone level architecture is offered four layers for the smart city establishment. The fundamental layer is ICT infrastructure that assures the connectivity between various smart devices through a high-speed wire or a wireless technology. Besides, it is consisted of high-end data centers, sensors, actuators, physical space enrichment with smart devices and more (Bawany and Shamsi, 2015). The second one is e-governance layer. It is provided the enhancement of strategic connections between diverse departments of public sector organizations. Formulating of policies, regulations and legislations for a better governance performance and in this way, offering useful, potential opportunities for citizens are important works which are executed within the scope of the layer. Third layer is smart services regulated in accordance with rules specified in e-governance layer, and utilized ICT infrastructure as a technologic base. The top layer is composed of stakeholders that have different sensitive roles in performing smart functions. The Figure 3.9 exhibits the summary of aforementioned terms.

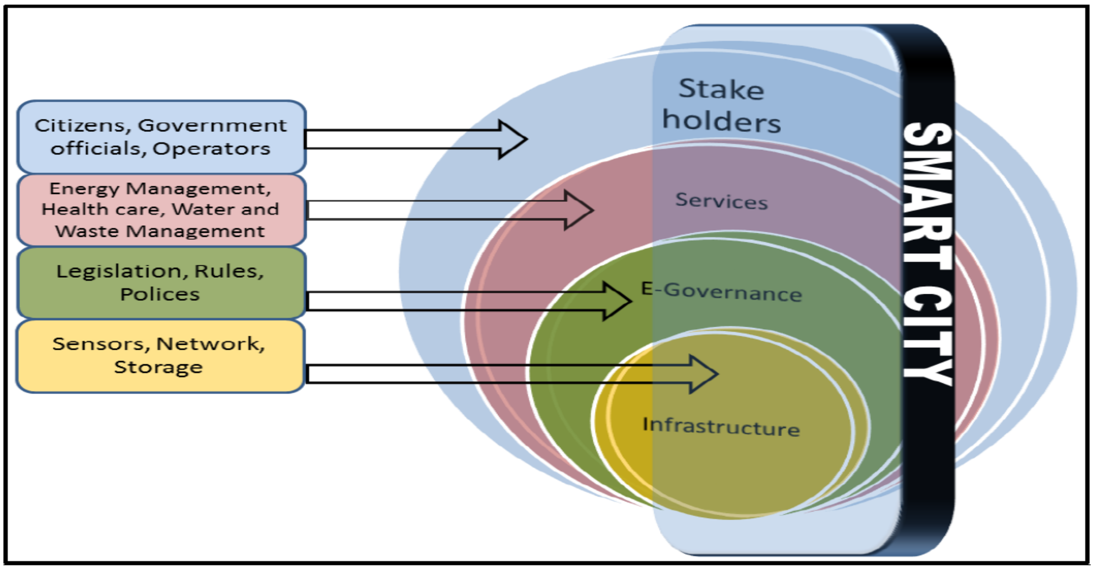

Figure 3.9 : The smart city layers of zone-level architecture (Bawany and Shamsi, 2015).

Zone level architecture model is concentrated on seamless information sharing to ensure both across departments and between data services and other interested parties through open data model.

On the other hand, it is aimed according to the proposed architecture model to manage city activities with the help of a system composed of different sub-systems. These autonomous sub-systems are units of Central Data Management System (CDMS) which has wholly a compact structure integrated and interconnected with all sub-systems. CDMS supplying cross domain services to citizens is allowed to each sub-system to share their data on itself. All the information sending from sub-systems are integrated in CDMS. CDMS can be processed this information and data at its disposal for the progression on the way of making a better decision in real-time. The Figure 3.10 shows the overview of relevant architecture.

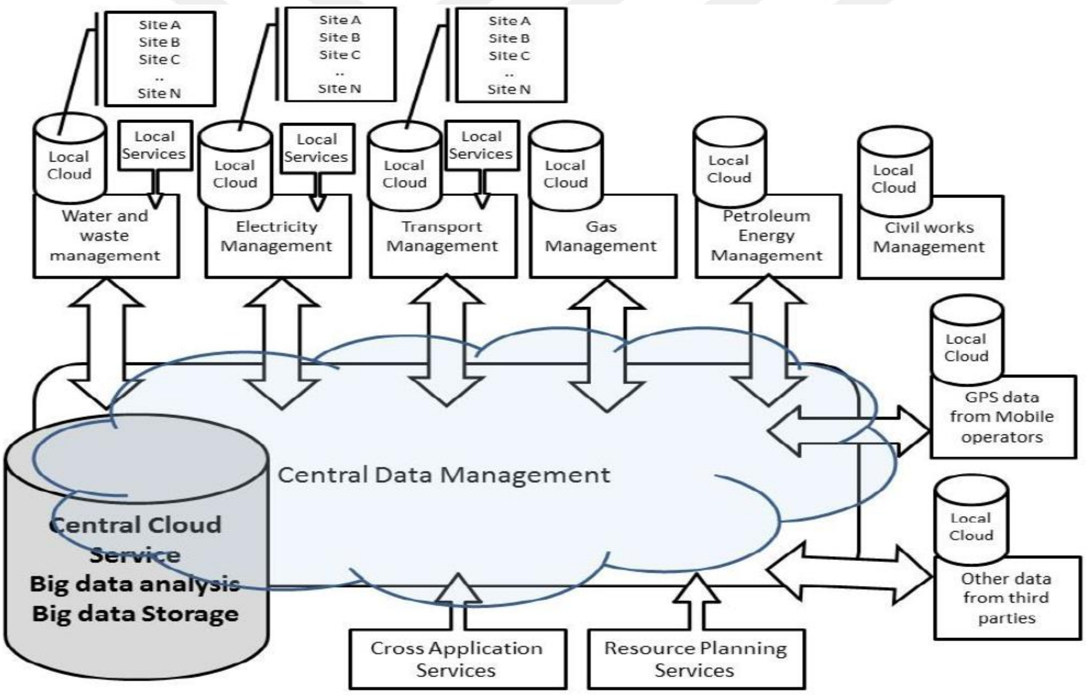

Figure 3.10 : Holistic view of zone-level architecture model (Bawany and Shamsi, 2015).

Each sub-system is gathered data from different zones of the city. Each zone is responsible for own data center cloud at site level. Sub-systems have connections with different sites throughout the city and the data pertained to these sites is stored in local clouds. The dividing into zones of the city is facilitated the administration cycle and the process of making a better decision about requirements of urban areas. This may lead to proper emergency action at zonal level, for example, in a disaster scenario.

Each autonomous system in utility zonal sites is contained a local data center, wireless sensor and network infrastructure, technology and facility-related components. Zonal site is represented an environment that is capable of processing, networking, storage, management of data within a zone. There are some connections between these zonal sites thanks to web services for providing cross zone services to citizens. The operation schema of zone-based architecture has been represented in the Figure 3.11.

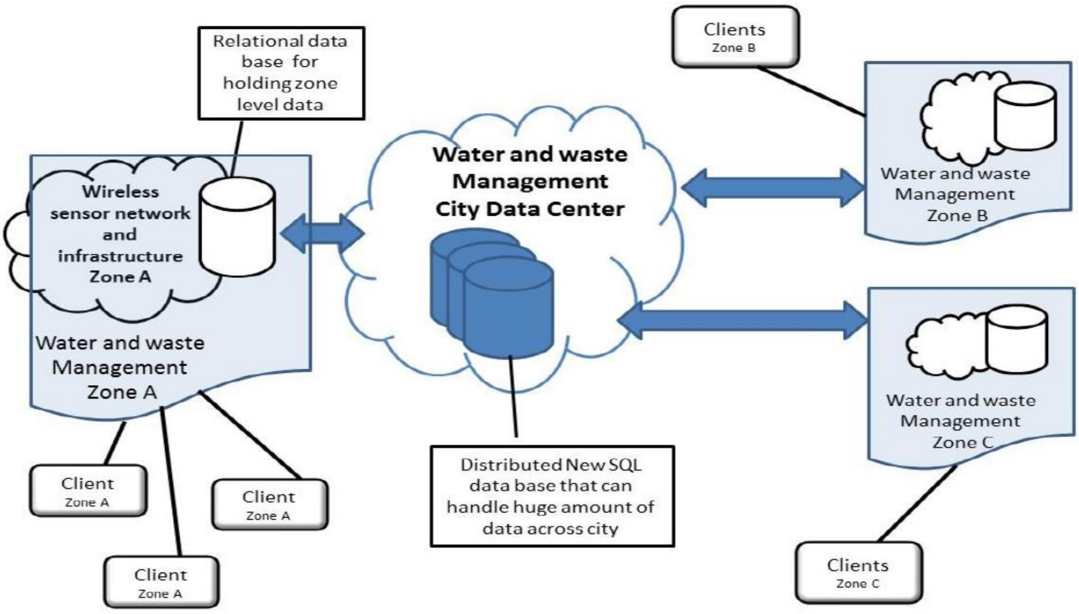

Figure 3.11 : The zone-based view of the proposed architecture (Bawany and Shamsi, 2015).

3.4 Conceptual Enterprise Architecture

The architecture type has been proposed in the light of an important questionnaire that includes different basic domains related to smart cities in 2014. The questions are based on architectural relative questions, data sources, smart city management-organization-funding, smart city management-critical issues-milestones, smart city management-project mission and objectives (Kakarontzas et al., 2014). The aim of questionnaire conducted is to determine primary drivers of smart city systems and general patterns of smart city architectures. Interoperability, usability, availability, recoverability, confidentiality and authentication-authorization has been determined as core drivers of smart systems (Kakarontzas et al., 2014). The proposed architectural model does not comprise a detailed approach that captures all specific functions concerning with different cases, but it presents a general approach that can be a guideline for forward-looking studies and applications. It has been benefitted from the Pattern-Driven Architectural Partitioning (PDAP) put forward by Harrison and Avgeriou in 2007. The Figure 3.12 indicates the conceptual representation of the Pattern-Driven Architectural Partitioning.

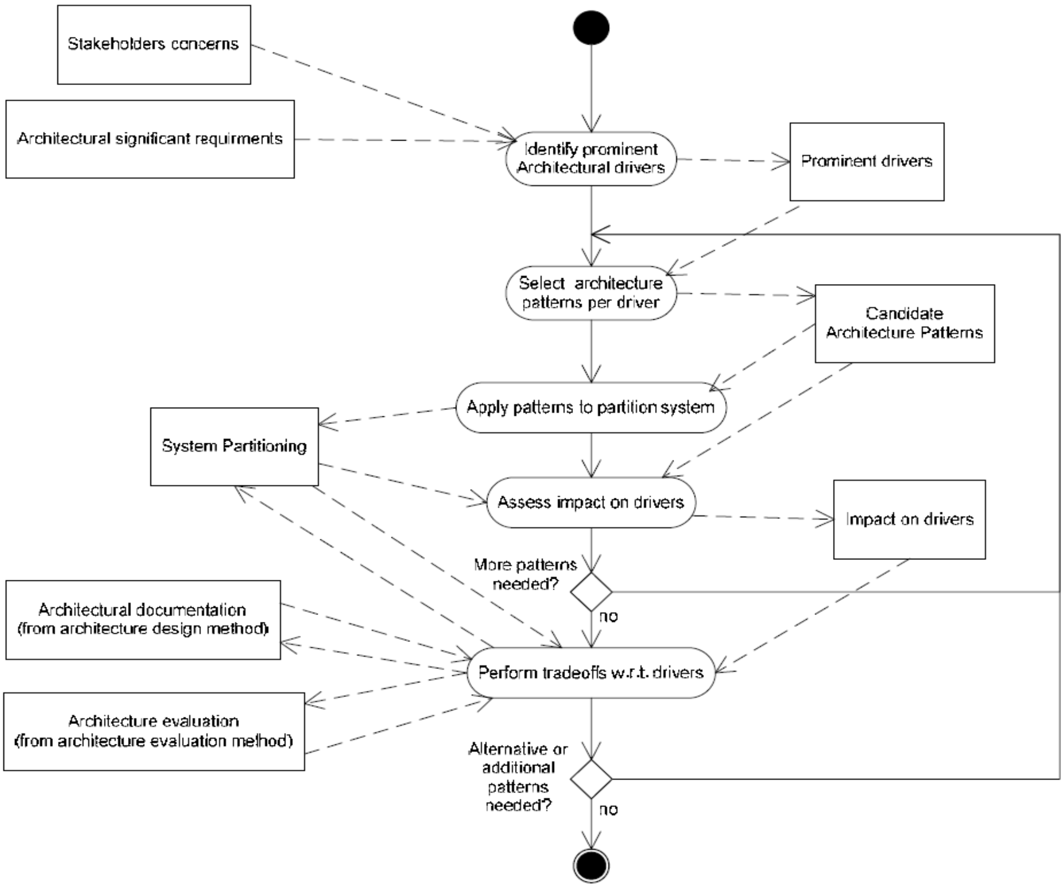

Figure 3.12 : The pattern-driven architectural partitioning (Harrison and Avgerious, 2007).

The proposed architecture has applications hosted in host organizations and separate integration server to be used in the municipality infrastructure or in any main organization that plays a key role in smart projects.

When it comes to the implementation of abovementioned main drivers of smart systems in the proposed architecture, interoperability is supported by being provided a Web Service interface in the business logic layer. This layer runs in the application server. Usability is applied by being allowed for an access from available various channels consisting of browsers and mobile devices. Besides; authentication, authorization and confidentiality are accomplished with the aid of application's and web server's mechanisms provided. Availability and recoverability are upgraded via the smart city integration host that benefits from the messaging technique to collect data from different applications. As a conclusion, maintainability for a single application is implemented by means of layered architectural style. This architectural style has a great advantage in this aspect (Kakanrontzas et al., 2014). The conceptual enterprise architecture framework has been depicted in the Figure 3.13.

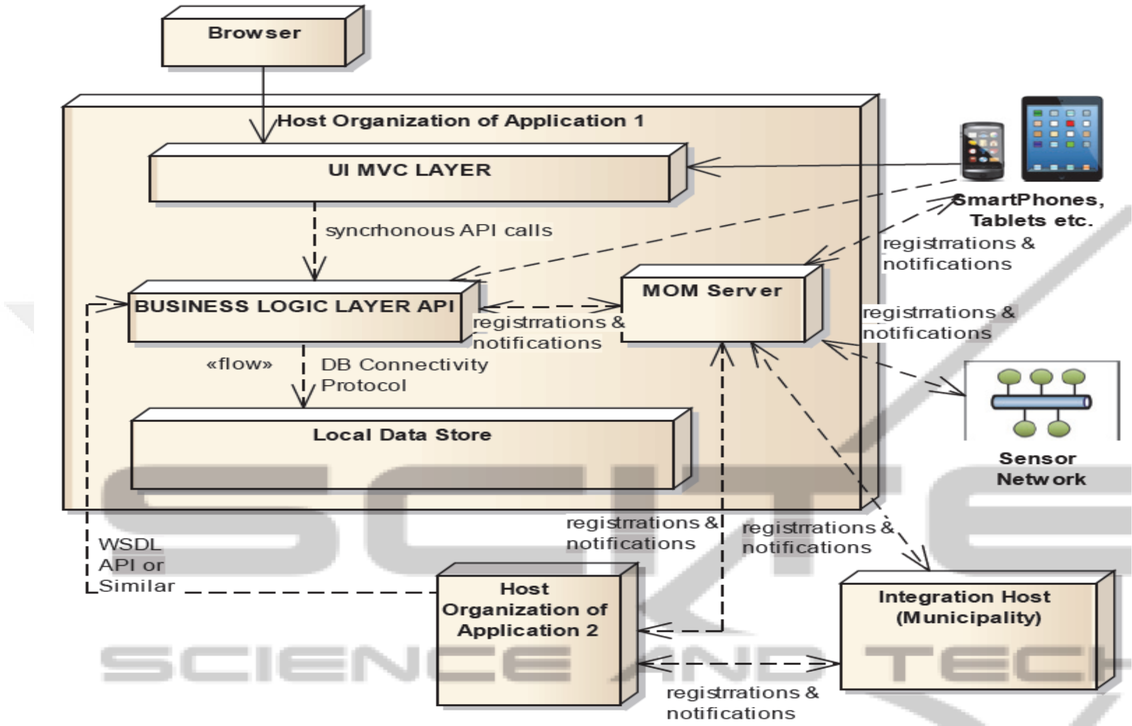

Figure 3.13 : The conceptual enterprise architecture framework (Kakarontzas et al., 2014).

3.5 Hybrid Cloud Architecture Model

Hybrid cloud architecture has been designed for emergency case management in urban sites. As considering the one of state-of-art products in IT environment, this architecture type is aimed the best localization by using deployed connected devices like sensors and other kinds of devices across urban areas and the quickest interference for evacuation to decrease loss of life as much as possible. The important matter is the rapid detection of crisis event site, because a crisis event may simultaneously take place in several territories of the city, otherwise two or more crisis events may take place in a particular territory. However, the interconnected structure of classical smart systems may cause single or multiple failure(s) owing to the impact of disaster over deployed smart systems. To cope with this critical issue, the computing infrastructure related to designed architecture must has supportive functions for service continuity during the crisis management, consisting of the store, retrieve and run-time processing of radio maps required by the positioning framework. Moreover, it must be flexible and elastic structure to execute emergency operations needed and also must ensure the fast recovery against drawbacks that may occur in mobile sensing devices or command/control nodes in crisis event site (Palmieri et al., 2016). The Figure 3.14 demonstrates the layered hybrid cloud architecture.

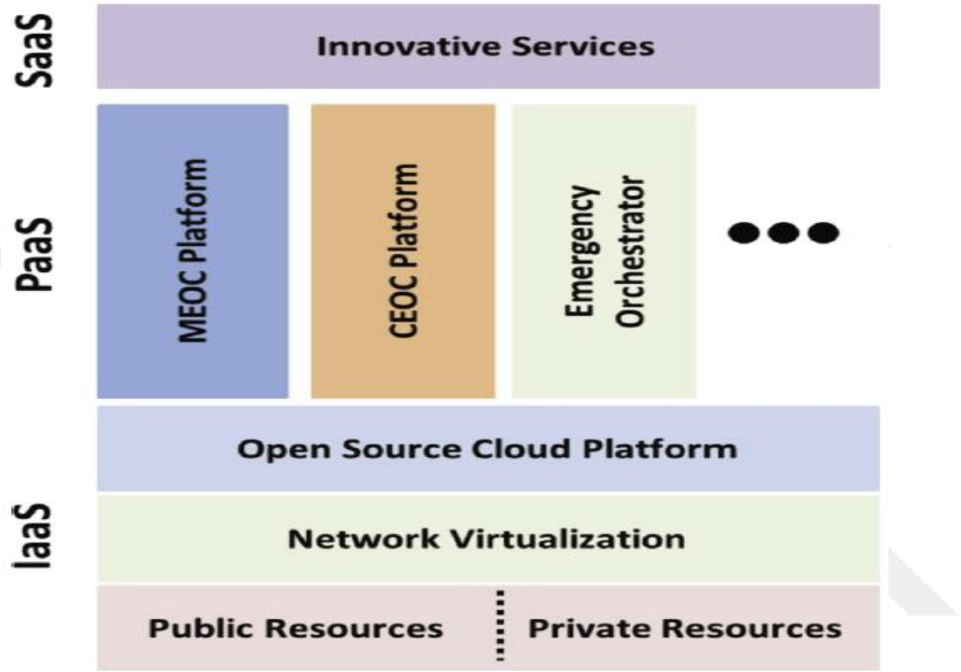

Figure 3.14 : The layered hybrid cloud architecture (Palmieri et al., 2016).

The proposed architecture has been modelled on the basis of layered framework offered by NIST and by being used standard nomenclature (Palmieri at al., 2016). It comprises of three service layers following as IaaS (Infrastructure as a Service), PaaS (Platform as a Service) and SaaS (Software as a Service). Each of them has special goals.

The lowest layer combines private/public computing and storage resources. It is accountable for the harmonization of coexistence of hybrid resources in a secure and transparent environment. This case is provided via LAN extensions compatible with both private and public transport networks. The middle layer assures all special run-time operations for emergency/crisis events. It is formed by a group of various environments to manage legacy run-time frameworks. There are MEOC and CEOC platforms in this layer. MEOC platform is the system dynamically installed over mobile nodes allowing adequate storage and processing resources. Additionally, CEOC platform is the system allowing to manage databases, large storage and high-level analytics facilities and also other segments of the system working within a centralized manner. Besides, there is an Emergency Orchestrator that is main control center allowing all configurations and monitoring transactions related to entire crisis management system. Ultimately, the highest layer supplies the legacy software that is necessary to setup MEOC and CEOC services.

3.6 Fog Supported Smart City Network Architecture (FOCAN)

As it is known, the smart city paradigm is a holistic system comprising of heterogeneous technologic components to be enabled well-distributed service alongside the urban environment. One of those technologic components is Fog Computing (FC). It is targeted to substantially diminish the latency and energy consumption of Internet of Everything (IoE) apparatuses operating different applications. The primary matter which comes FC paradigm into prominence in the smart city coverage is its spreading of communication and computing resources via wired or wireless access networks to supply resource augmentation for wired or wireless devices which have constraints in terms of resource and energy. Processing and storage of big data originated from IoE are principal problems that can be come across in smart city studies. Even though the cloud computing seems as a permanent solution regarding these bottlenecks, some inherit problems such as the delay and latency occurred because of the transferring of a massive amount of data between smart sub-systems are resulted in serious borders against achieving high quality smart services. In this direction, the fundamental element of FC, is called Fog Node (FN), eases the performing of IoT applications. Fog Node can be simply considered as an interface layer between end users/end devices and long-distance cloud data centers so as to procure mobility support, locational awareness, geo-distribution and low latency needs for IoT applications (Naranjo et al., 2019).

FOCAN is a multi-tier architecture type utilized the capabilities of Fog Node. It minimizes energy consumption and delays by abstaining from transferring huge amount of data or using data resources that are too far from the Fog Code by being selected the closest one to the end-users. According to this architecture type, it has been developed a Fog Code supported resource allocation including device-to-device,

device-to-FN and FN-to-FN components. The most remarkable aspect of this architecture framework is the utilization of resources closer to the end users. The technique used by FOCAN to provide low-latency and high-quality computing services is so vital since, elimination of these adverse factors is added extra quality to urban life and besides is provided the enhancement in effectiveness of smart services. FOCAN is formed by two tiers which are called as the IoE tier and the FN tier (Naranjo et al., 2019). The IoE tier gives the opportunity to end users that can apply any application anytime, anywhere out of limitations. The clustering based on device locations is an essential need to preserve basic IoE function. The service of the IoE applications is able to be utilized with tolerable latency and throughput provided the IoE makes a dynamic connection between heterogeneous hardware and software services whereby using of the IoE tier. When it comes to the objective of FN tier, each FN is acted as a small-sized virtualized networked data center which allows the installation of Fog services in accordance with different types of hardware with fixed hardware resources that are able to be connected by various network technologies, configured, combined and abstracted in the way of operating as a single logical entity. The FN tier is structurally consisted of a local database which can store applications not actively used in its memory. In addition, this layer benefits from several retrieval policies for accessing the data in its coverage to reduce processing time of IoT applications. Finally, it can be also specified that the FN tier has been devised as being capable of implementing social IoT applications. This means that FN can optimize IoE deployment, bandwidth, reliability, security in IoE networks and improving latency. The Figure 3.15 represents the deployment of Fog supported smart city architecture.

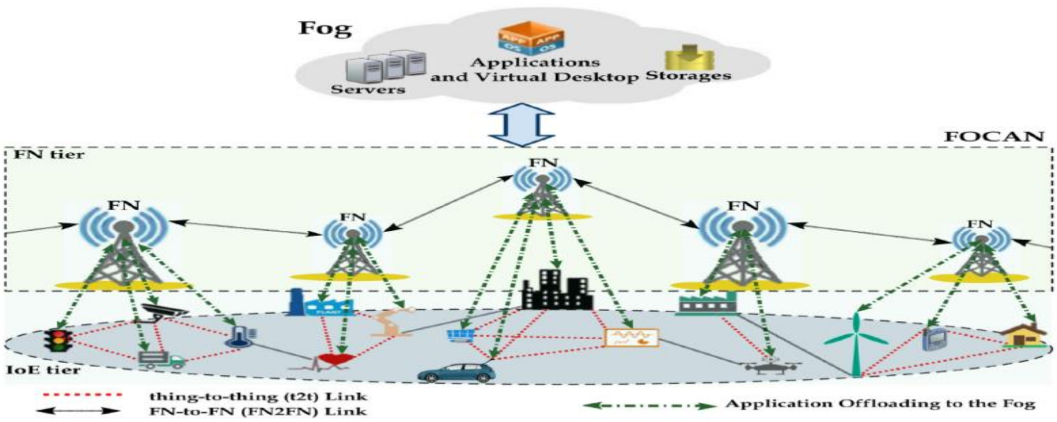

Figure 3.15 : The deployment of Fog supported smart city architecture (Naranjo et al., 2019).

3.7 Data Driven Reference Architecture

This architecture type has been proposed by being basically taken into account the multiple view modelling offered by Kruchten in 1995. The multiple view modelling is a software architecture model comprised of five main views that are milestones for this approach. These are the logical view, the process view, the physical view, the development view and selected scenarios as the fifth view. The logical view represents the object model of the design under the condition that the selected design method is object-oriented design method. The process view covers concurrency and synchronization features of the design. The physical view means the mapping of the software upon the hardware. This view shows distributed aspect of the software. The development view defines the static organization of the software in its development environment. The architecture utilized for making a decision is taken shape around abovementioned four key view. In following, the blueprint demonstrated in the light of four views is illustrated, as the fifth view, to create a scenario or a use case. The schema of multiple view modelling is illustrated in the Figure 3.16.

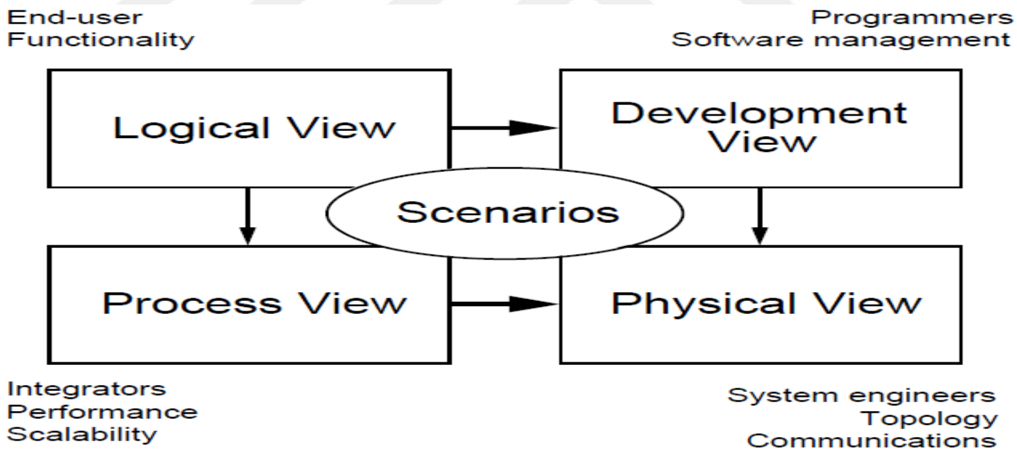

Figure 3.16 : The 4+1 multiple view modelling schema (Kruchten, 1995).

Data driven reference architecture is formed by nine software-defined views and modelling elements. Each element is referred an iterative initiative of smart city model building. The software-defined views contain capability view, participation view, place view, service view, data view, application view, infrastructure view, business process view and finally analytics view. As a first one, capability view expresses the abstraction that represents all capabilities assured by the modelled smart city system. Participation view indicates the stakeholder group that has objectives in building and recovering of smart systems. Citizens, policy makers or businesses can take part in this group. Place view includes place models, buildings, hospitals, municipalities and etc. Service view is used to model specific services with details in the smart city coverage. Data view is focused to model any type of data required for smart city applications. Application view can be designed various beneficial apps such as individual applications, system components, enterprise systems or any computation unit offered effectiveness needed by smart services. Infrastructure view investigates basic physical components that underpin the building of smart city environment. Additionally, business process view is scrutinized the modelling of which corresponding independent business flows need to be orchestrated as a whole, in accordance with the create of a consistent smart city environment. Ultimately, analytics view is associated with the analytics modelling that has influential role over decision-making phase to make better and forward-looking plans regarding smart city phenomena. The Figure 3.17 shows multiple view structure of data driven reference architecture.

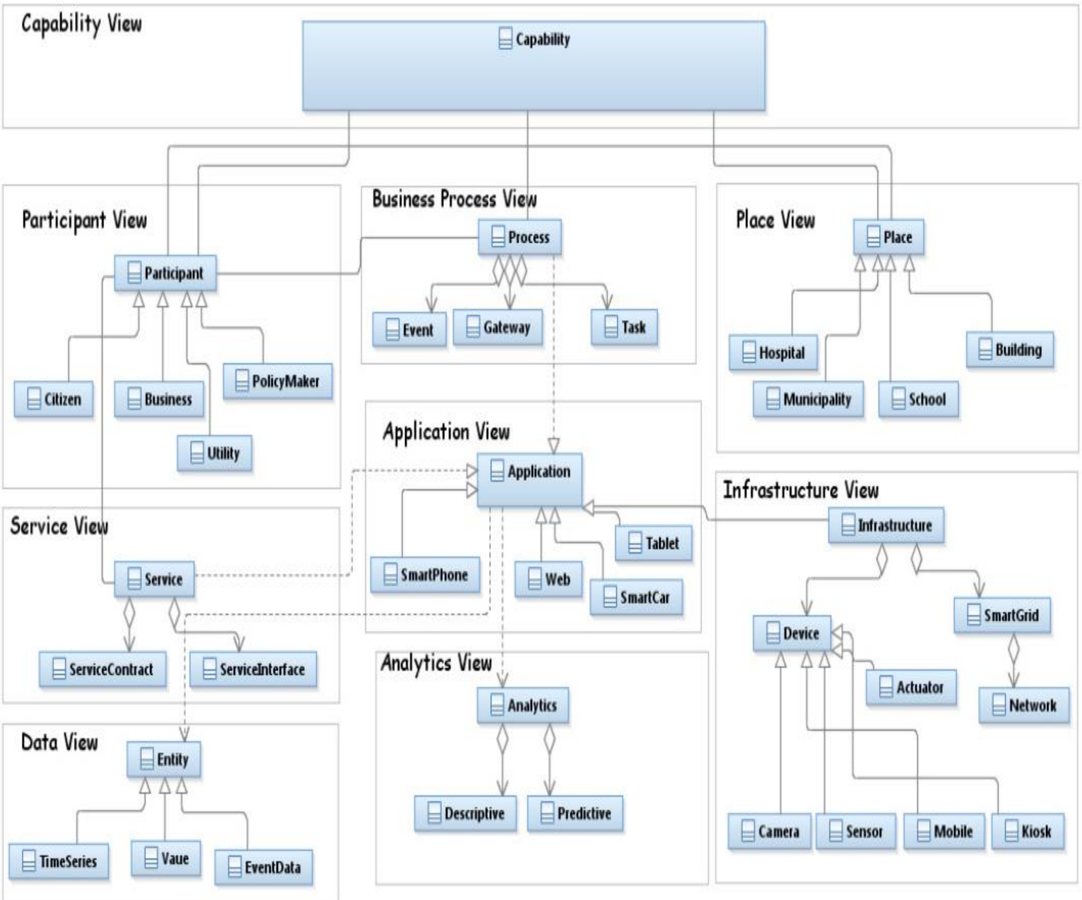

Figure 3.17 : The multiple view structure of data driven reference architecture (Matar and Davies, 2017).

3.8 Distributed Blockchain Based Vehicular Network Architecture

As it is known, transportation is one of important issues of smart city concept. The increase of vehicle number and demanding conditions resulting from extreme traffic congestion in urban areas has been turned into the compulsory matter needed to be solved in terms of smart services. In this regard, there are several network models and computing techniques proposed to facilitate transport cases for drivers. One of them is ad hoc network for vehicles. It is a core network technology to offer comfort and security to drivers in crowded vehicle environment. Distributed blockchain based vehicular network (Block-VN) architecture combines ad hoc network and blockchain technology that is broadly known as really important disruptive technology has been invented in recent years. It has great potential to enable rapid development and trigger a new revolution in smart transportation projects engaged in smart city concept. Blockchain is capable of building an intelligent, distributed, autonomous and secure transport system. It is procured the effectiveness in crowdsourcing technology and also a better exploitation from infrastructures and resources of intelligent transport systems. The advantages of blockchain technique can be respectively specified; transparency, no risk of fraud, low or no exchange cost, transactions almost instantaneous, network security, financial data assurance and financial access (Sharma et al., 2017).

- All exchanges of blockchain network can be clearly seemed as total, verifiable and without obfuscation in blockchain environment and this means transparency.
- Any sending or deleting transaction in blockchain cannot be cancelled by the corresponding actor. Thus, the risk of fraud is entirely terminated.
- The blockchain network organization is sponsored by the procedure of the treasury. Because of this reason, the system can be required low or no exchange fee. Furthermore, it is not demanded any cost for access.
- Exchanges in blockchain system is quickly registered. The processes of affirmation and compensations based on exchanges can be performed in the time interval up to 60 minutes.
- Blockchain network system is used specific security techniques against cyberattacks. These are cryptographic and decentralized blockchain conventions. They are also limited the vulnerability of the blockchain network owing to downtime and piracy.

- Transactions in blockchain network can be executed by abstaining from the disclosure them to beneficiary sensitive users and restricting the representation of financial data to restrain using of this data with the purpose of piracy.
- Blockchain network presents incentive storage and payment services for customers who demand to get traditional financial services.

Block-VN can be evaluated as a secure and reliable architecture so as to build intelligent transport system thanks to an operation style in distributed attitude. The Figure 3.18 illustrates the operation schema of Block-VN architecture.

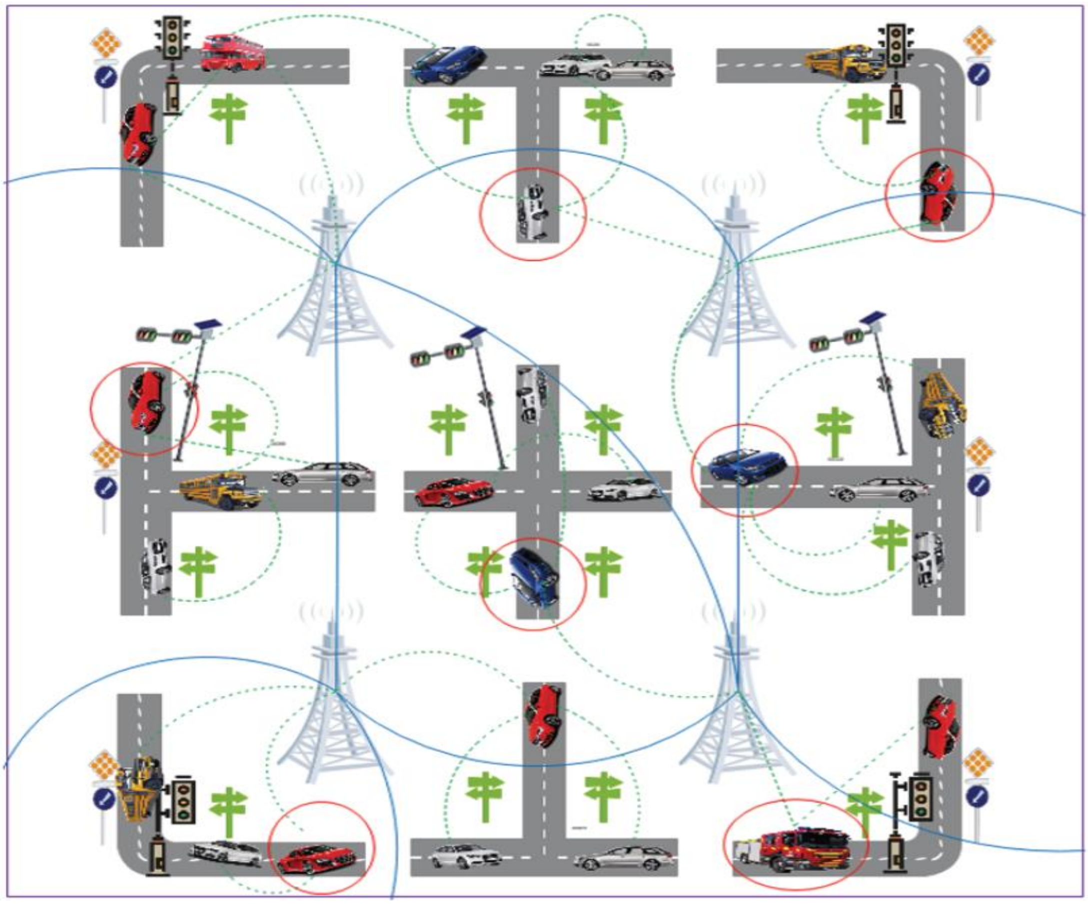

Figure 3.18 : The Block-VN architecture operation schema (Sharma et al., 2017).

In this model, the controller nodes are in connection with each other in a distributed way to supply necessary services on large scale. The vehicle nodes that are in red circles refers minor nodes which organize request/response requests. Other all vehicle nodes show ordinary nodes. An ordinary node is able to deliver a service request message both to minor nodes and controller codes. The using of minor and controller nodes in distributed way allows to effortlessly accomplish the scalability and high availability of the vehicle network. In addition, it must be also considered that Block-VN is a contributor system in improving vehicle network architecture by means of consumer-to-machine and machine-to-machine trusted intermediary free services and so, with the aid of distributed, secure and shared records of all services, inventories and assets.

In the working mechanism of Block-VN model; when a new issued vehicle is registered, the department of motor vehicles conveys all details to the revocation authority. This unit has an authority to determine which vehicle is convenient to be minor node out of controller nodes. The revocation authority allows to deliver all information about minor and ordinary nodes to the distributed blockchain vehicle network. Whole controller nodes consist of a hash, a timestamp, a nonce and a Merkle root to withhold the entire information needed to operate the necessary services. Controller nodes are worked at independent levels to compute and process the data and to transmit it to other nodes in a distributed way. All communications within the scope of Block-VN system are administrated by being used the public private key encryption technique to enable the security of private client data (Sharma et al., 2017). It is available to see the structure of Block-VN model architecture in the sense of the deployment of nodes infrastructure in the Figure 3.19.

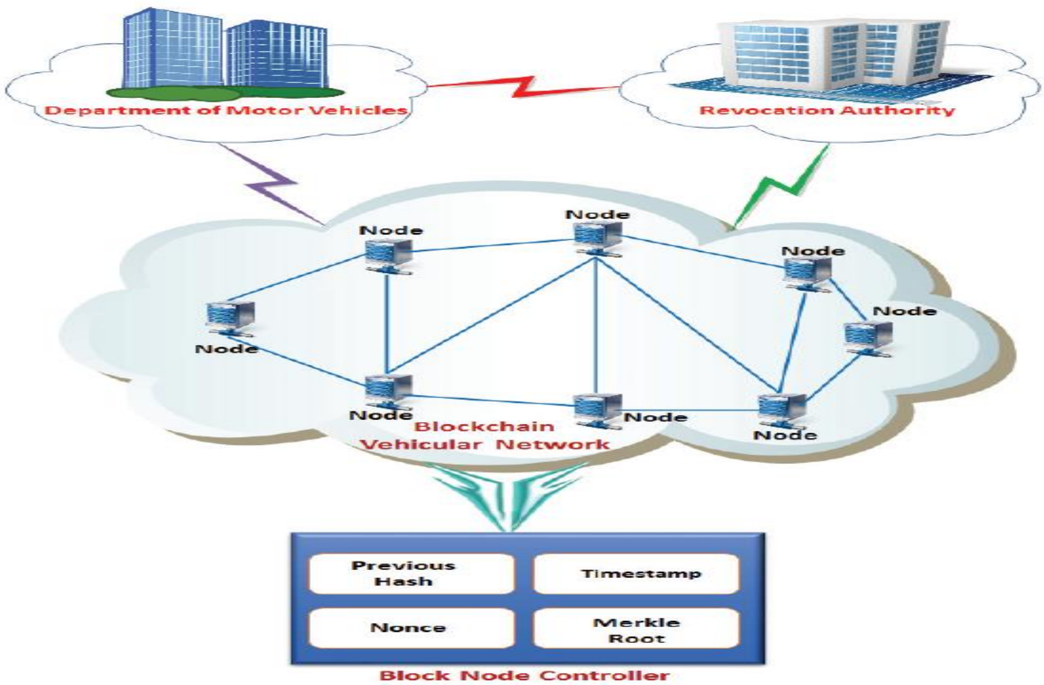

Figure 3.19 : The deployment of nodes infrastructure in Block-VN model (Sharma et al., 2017).

3.9 Blockchain Based Hybrid Network Architecture

It has been addressed about the blockchain technology in previous chapter. This novel architecture type is utilized the merits of blockchain technique as well. As it is widely known, smart city is the concept based on autonomous and distributed infrastructure across huge urban areas that comprises of processing and control systems, intelligent information driven the course of urban events, heterogeneous network infrastructures and ubiquitous sensing mechanism consisted of scores of data sources. According to the structure of smart city concept addressed, there are several bottlenecks resulting from continued growth of data volume and high number of interconnected IoT devices. Up-to-date issues come across in smart city network architectures can be expressed as high latency, bandwidth problems, security- privacy and finally scalability. The corresponding architecture has been developed with the purpose of designing an efficient, scalable and secure distributed architecture by converging storage and computational resources with endpoints (Sharma and Park, 2018). It is consolidated by advantageous of Software Defined Networking (SDN) and blockchain technology mainstream emerged in recent years. It is exhibited the characteristics of both centralized and distributed network architectures. The overview of blockchain based hybrid network architecture has been presented in the Figure 3.20.

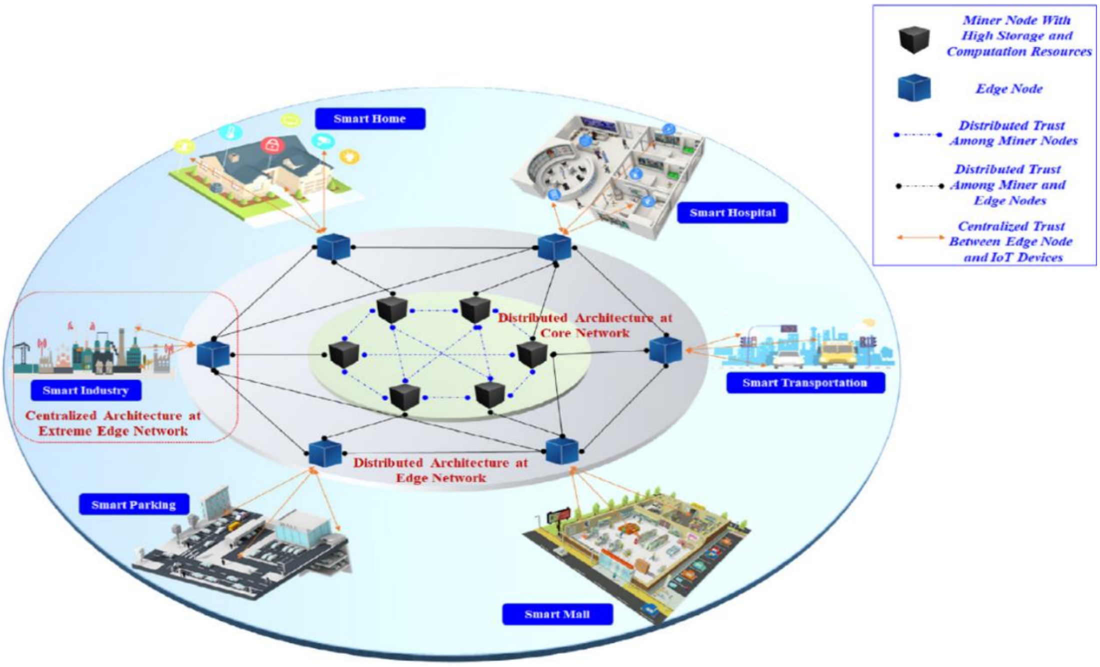

Figure 3.20 : The overview of blockchain based hybrid network architecture (Sharma and Park, 2018).

SDN can be defined as a network management technique ensuring dynamic and programmatically effective network configuration so as to enhance network performance and monitoring thanks to using more cloud computing technology than traditional network management techniques (Url-1).

Blockchain based hybrid network architecture is formed by the core network and the edge network, which benefit from blockchain technique. The core network includes minor nodes that have high computation and storage resources. Contrary to the core network, the edge network has the edge nodes which have limited storage and computation power. Minor nodes in the core network are accountable for creating blocks and proof-of-work. All of them are supported by SDN controller in order to accomplish high security and agility, to diminish hardware management cost and to offer an ease of installation in the smart city network infrastructure. On the other hand, each edge node works in centralized service manner for specific public infrastructure to assure essential services and efficient localizations. Access policies and the credentials related to its locally entities in databases are stored in edge nodes. Moreover, they are contributed to the achievement of low latency and reduced network bandwidth. The distributed nature of this architecture is allowed that the system becomes more durable and to decrease the impact of attacks even if the working mechanism of edge node is impaired. This means that the adverse impact on network system is restrained into a local area so as to prevent a large-scaled system crippling.

When it comes to the workflow of this architecture model, edge nodes are applied real-time processing with low latency and network bandwidth usages. Additionally, they preprocess the raw data supplied by end devices with the intent of filtering data to extract meaningful information. If it is necessary, after the preprocessing, the encrypted data is swiftly transferred to the core network of smart city by edge nodes. The minor nodes in the core network are capable of making advanced analysis using pre-processed data in the direction of making a decision, generating blocks, validating and verifying PoW that is core component for blockchains and cryptocurrencies. These two techniques offer large public distributed ledgers with their resolving abilities the difficulty of quantifying and managing intricate mathematical computations in a correct manner. The integrity of data in the core network is catered by being used of digital signature and stored hashes in blockchain. The hash is a function converting an input in the forms of letter or number into an encrypted output in fixed length (Url-2).

It is the backbone of blockchain management in cryptocurrency. These hashes in blockchain are stable for procuring the integrity of data. The Figure 3.21 displays the workflow of blockchain based hybrid network architecture.

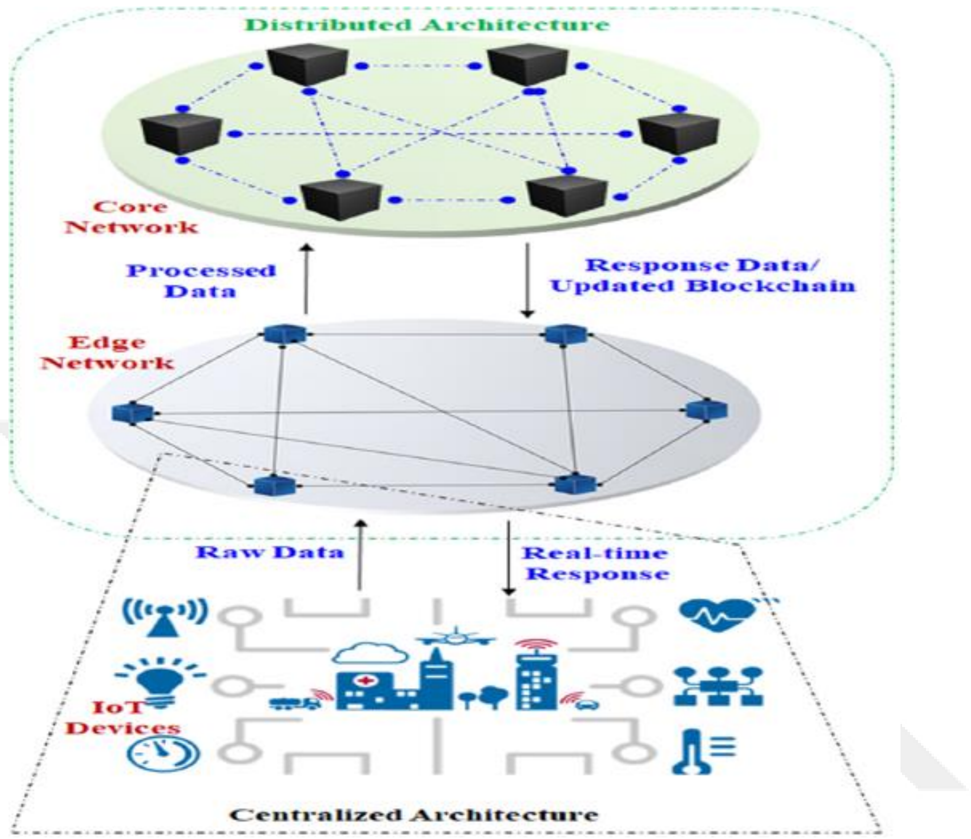

Figure 3.21 : The workflow of blockchain based hybrid network architecture (Sharma and Park, 2018).

3.10 Generic Multi-Tier ICT Architecture

The generic multi-tier ICT architecture model has been envisaged by being taken into consideration the categorization of smart city components following as soft infrastructure (knowledge, people, communities), hard infrastructure (waste, energy, water), ICT-based innovative solutions (both hardware and software solutions), other innovative solutions beyond the ICT (smart materials, recycling system, open spaces, organizational innovations in government etc.) and natural environment (rivers, lakes, ground, forests, flora, mountains etc.). Furthermore, United Nations Habitat (UN-Habitat) key-performance indicators (KPIs) have been taken into account as other main drivers for the architecture designation. These indicators are the information and communication technology, environmental sustainability, productivity, quality of life, equity-social inclusion and hard infrastructure (ITU-T Focus Group on Smart

Sustainable Cities, 2014). The schema of corresponding indicators has been demonstrated in the Figure 3.22.

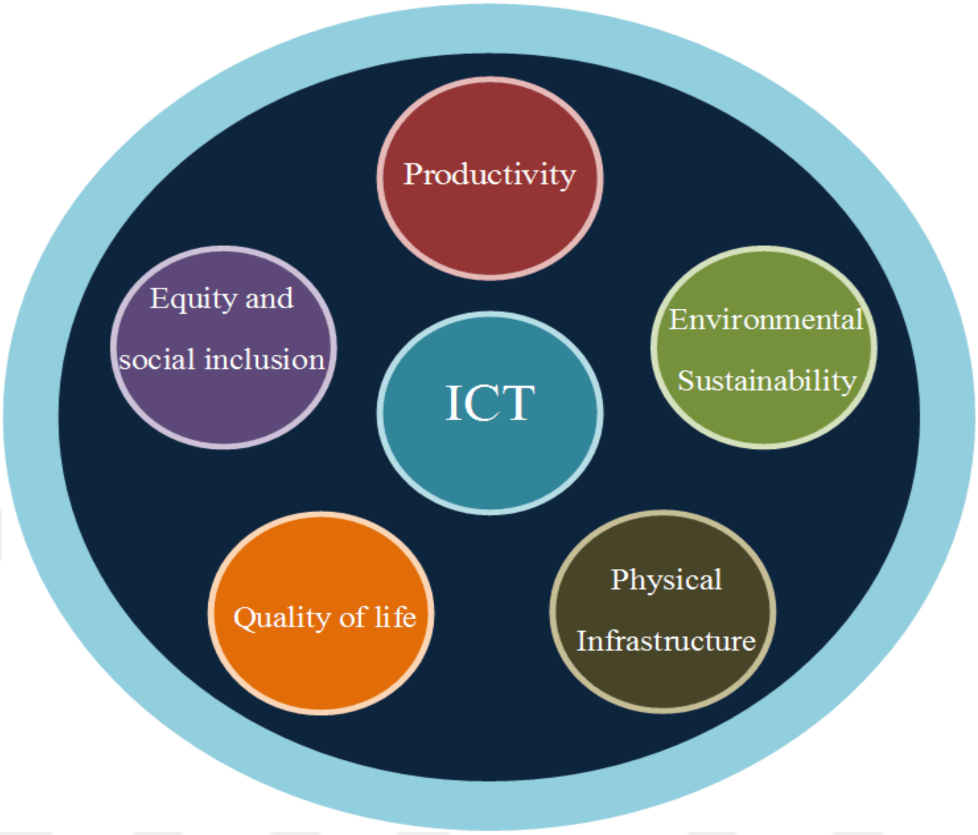

Figure 3.22 : Dimensions of UN-Habitat Key-Performance Indicators for Smart Cities (ITU-T Focus Group on Smart Sustainable Cities, 2014).

Each key-performance indicator includes various important sub-dimensions which are cornerstones for the realization of smart city phenomena. The sub-dimensions can be categorized according to the coverage of UN-Habitat KPIs as follows (ITU-T Focus Group on Smart Sustainable Cities, 2014):

1. Information and Communication Technology
    - Network and access
    - Service and information platforms
    - Information security and privacy
    - Electromagnetic field
2. Environmental Sustainability
    - Air quality
    - CO_2 emissions
    - Energy

- Indoor pollution
- Water, soil and noise

3. Productivity
   - Capital investment
   - Employment
   - Inflation
   - Trade
   - Savings
   - Export-import
   - Household income-consumption
   - Innovation
   - Knowledge economy
4. Quality of Life
   - Education
   - Health
   - Safety-security public place
   - Convenience and comfort
5. Equity and Social Inclusion
   - Inequity of income-consumption
   - Social and gender inequity of access to services and infrastructure
   - Openness and public participation
   - Governance
6. Physical Infrastructure
   - Infrastructure/connection to services-piped water
   - Infrastructure/connection to services-sewage
   - Infrastructure/connection to services-electricity
   - Infrastructure/connection to services-waste management
   - Infrastructure/connection to services-knowledge infrastructure
   - Infrastructure/connection to services-health infrastructure
   - Infrastructure/connection to services-transport
   - Infrastructure/connection to services-road infrastructure
   - Housing-building materials

- Housing-living space
- Building

The overview of generic multi-tier ICT architecture that has been designed in the light of abovementioned international urban KPIs and its sub-dimensions has been demonstrated in the Figure 3.23.

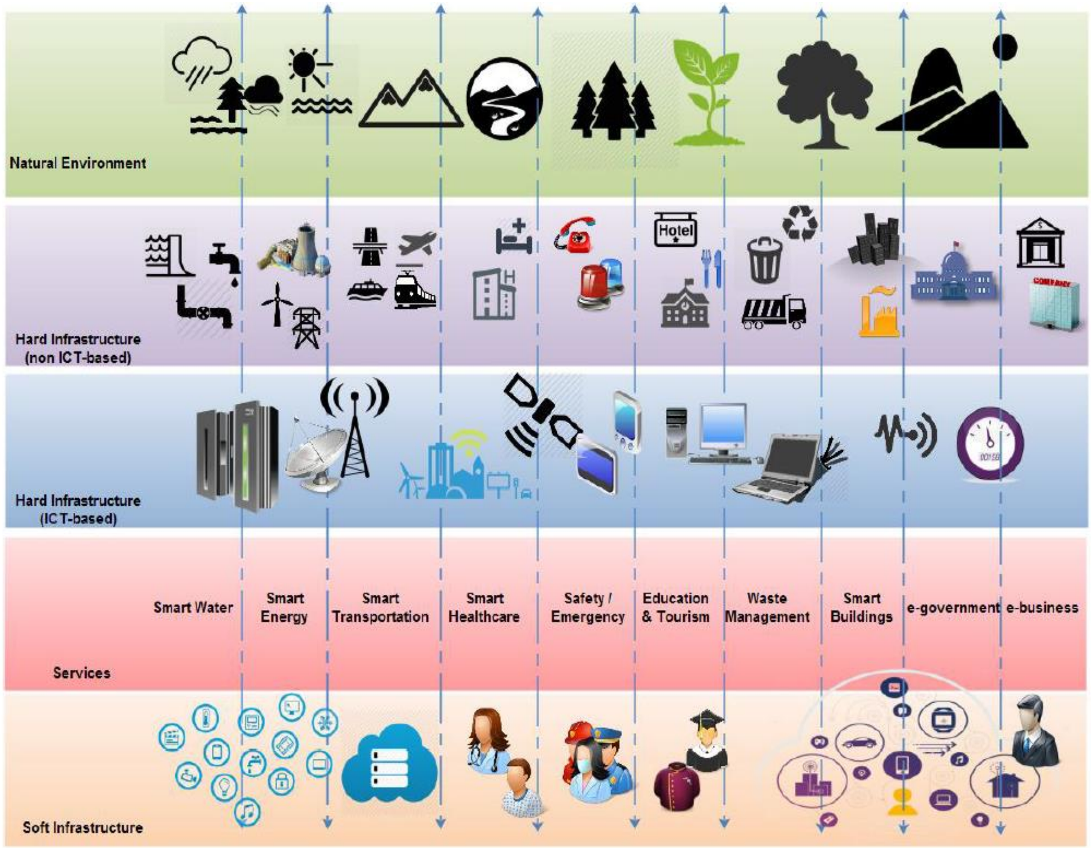

Figure 3.23 : The overview of generic multi-tier ICT architecture (Anthopoulos, 2015).

The generic multi-tier ICT architecture consists of five layers. The first one, which is the top level in architectural structure, is natural environment. It encompasses all the natural features inside borders of the urban area. The second one is hard infrastructure (non-ICT based) that includes all necessary urban features that are man-made (buildings, bridges, roads, energy-water-waste utilities etc.). The third layer is ICT based hard infrastructure covers smart hardware systems provided sustainable smart city services (supercomputers, datacenters, servers, networks, sensors, IoT etc.). The next layer is services categorized by six dimensions of smart city concept and orchestrated in accordance with international urban KPIs. As a final, the bottom layer is soft infrastructure that spans over individuals and groups sharing the urban environment together by exploiting sustainable smart city services.

3.11 The Layered Architecture For Smart Cities

The layered architecture composes of four layers from the bottom to the top following as: sensing layer, transmission layer, data management layer and application layer. All layers have been designed according to sensitive data protection rules by being paid attention to the degree of their need. The Figure 3.24 displays a general composition of the layered architecture model.

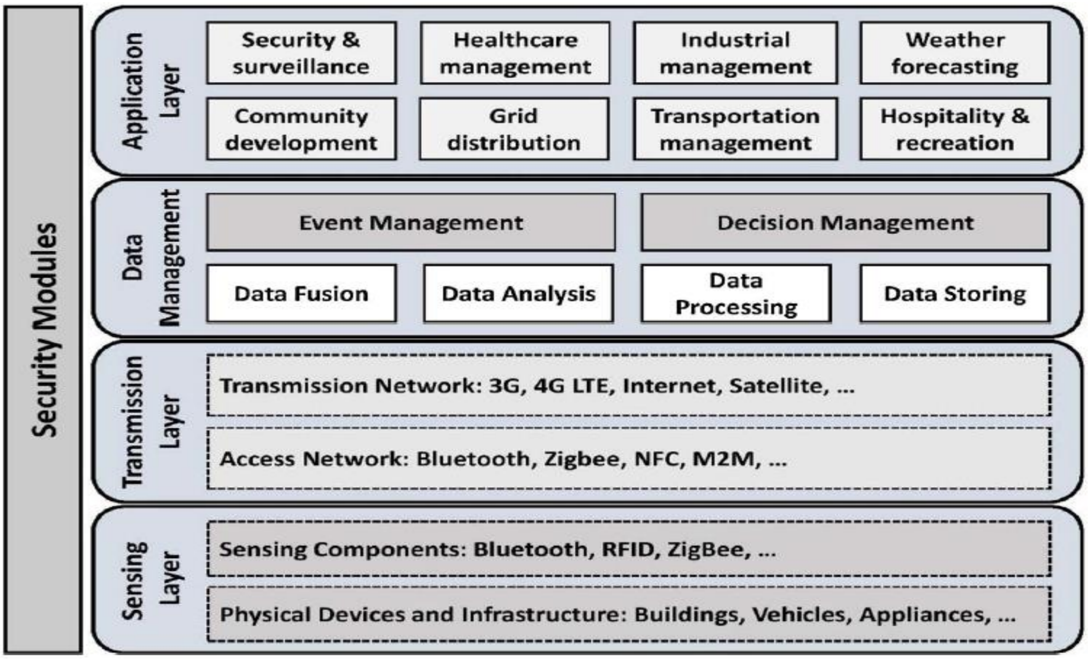

Figure 3.24 : The composition of layered architecture for smart cities (Silva et al., 2018).

The main objective of sensing layer is data collection from various physical devices. This layer includes smart devices, WSN and other kind of data capturing devices. It has been built in the way of which it is capable of gathering all data produced in different formats by smart devices. The sensing layer is utilized from different techniques for more efficient data capturing in different contexts. Some data parameters which are sensible for the sensing layer are temperature, pressure, light and humidity. In this respects, multiple sensing equipments such as ZigBee, RFID sensors and Bluetooth, actuators, cameras and GPS terminals are used to perform sensing transactions with high efficiency. Besides, enlarged network capacity is catered not only improved performance for ubiquitous accessibility and smartness, but also extended data collecting abilities. In fact, the evolution of city intelligence is relied on the coverage of sensing network (Kim et al., 2012). Also, the operating of sensing layer with various data sources and infrastructures is made compulsory that there must be numerous interconnected devices performing in smart city platform.

The second layer toward the top is transmission layer. The fact that makes this layer important is its interconnective function among data sources and management stations. Transmission layer is comprised of diverse types of wired, wireless and satellite technologies. It can split into two groups as access transmission and network transmission by being taken into consideration its coverage aspect. Access network technologies that procure short-range coverage to an extent are Bluetooth, ZigBee, NFC, M2M, RFID and Z-wave. In other respects, transmission network technologies offering broader coverage can be expressed as 3G, 4G, LTE (Long-Term Evolution), 5G and LP-WAN (Low Power Wide Area Network) (Silva et al., 2018). On the other hand, transmission layer may be evaluated as an intersection point of various communication networks. Hence, the myriad devices connected to a single network fulfils the routing by means of unique addressability.

As the third main part of layered architecture, data management layer can be taken into account as the brain of entire system. This layer has vital objectives for performing sustainability parameters of system such as data manipulating, organizing, storing, analyzing and decision-making duties. This layer is directly influential over the performance of smart city operations. The fundamental objective of data management layer is to maintain vitality of data that encompasses specific tasks of data cleaning, evolution, association and maintenance. Likewise, data management layer can be divided into data fusion, data analysis, data processing, data storage and event-decision management (Silva et al., 2018). Data fusion is the combination of data obtained from heterogeneous sources to strengthen accuracy and to improve decision-making mechanism by being avoided to be dependent to only few of data sources. Improvement of data analytics is significant in terms of efficiency, real-time data analysis and processing of data in smart city platforms. Data storing is also an ignorable function because data analysis and processing themselves are not enough for the enhancement of city performance from the point of city intelligence. Besides, intelligent operations are based on event-decision management. This part of data management layer provides to generate reasonable forward-looking decisions and precise predictions in the light of data attained from innumerous sensing devices scattered across the city. It is the crucial fact that performing continuous operations of any smart city is associated with correct decisions. Out of aforementioned tasks of data management layer, sending of produced decisions to application layer to execute them accordingly is the last mission.

The top and final layer is application layer working as a bridge between urban citizens and data management layer. It is the face of smart platform interacting with citizens. That's why it is straightforwardly affected the viewpoint and satisfaction of users about performance of smart services. The application layer has remarkable components which are active on multiple domains. The most important application layer services are community development, smart transportation, grid distribution, weather forecasting and more like these ones (Silva et al., 2018). Application layer is the basic contributor for the increase of city performance by using processed and stored data. Using of shared information between smart application services is the most dominant factor for evolution of smart cities. Since isolated applications are deprived of the support of data sources in multiple domains and the principle of interoperability. Application layer is performed in accordance with receiving decisions from data management layer and is accountable for implementing them.

4. TECHNOLOGIC FUNDAMENTALS OF SMART CITIES

The concept of smart city is spanned two essential mainstream approaches as the technology and ICT oriented-approach and the people oriented-approach. Developed and being developed strategies over the smart city concept are being concentrated on the advancement of hard infrastructures and technologic aspects organizing different city services (transportation, energy use, communication, water and waste management, etc.). And also, strategies are scrutinized soft infrastructures and social skills of smart city model that is assured an interaction between people and city management agencies. In addition; participation, safety, equity, utilizing of human capital in the direction of contribution to the city intelligence and so forth are other fundamental characteristics within the scope of the smart city's technology trend (Angelidou, 2014). The first approach can be examined as monitoring all critical infrastructures of a city, using integrated data obtained from different sources so as to reach better results about city management, optimizing city resources for sustainable development and maximizing city services for a better urban life. Other unignorable matters, that will be able to be addressed in the parallel of the first approach, can be expressed as extending the effort in creating a collaborative synergy between city agencies, supporting innovative business models covering public and private sectors, and planning better policies regarding city administration.

In the second approach, human is the basis element for smart city phenomena. To design a holistic structure like a smart city model including scores of constituents to execute various duties, a versatile standpoint is required to evaluate all factors which have an impact on the system creation. In the light of this case, the balance between the technology and people who will use the technology is a noteworthy cornerstone. Because the accomplishment of city managers and produced services is associated with satisfying participation of citizens and their constructive feedbacks about service performances. The quick detection of deficiencies in service performances and improvement of them are going to provide an orchestrated urban environment in terms of basic indicators of smart city (governance, people, environment, economy, living and mobility) (Kitchin, 2014).

4.1 ICT Infrastructure

ICT infrastructure forms the necessary application site to develop urban management system. It is a base framework for transactions which need to be performed for the establishment of smart city environment. Bibri and Krogstie (2017) stated about ICT concept that;

> The concept of ICT refers to set of urban infrastructures, architectures, applications, systems and data analytics capabilities – i.e. constellation of hardware and software instruments across several scales connected through wireless, mobile and ad hoc networks which provide continuous data regarding the physical, spatiotemporal, infrastructural, operational, functional and socio-economic forms of the city (Bibri and Krogstie, 2017, p. 10).

As understood from the statement of Bibri and Krogstie about ICT system, it is a sophisticated technologic world that organizes urban operations such as sensing, collection, storage, coordination, integration, analysis, data processing, modelling, manipulation, management, exchange and share of data for particular urbanization purposes.

Besides, ICT infrastructure technically comprises of hardware and software component in itself. Hardware components are covered sensor systems (RFID, GPS, infrared sensors, smart devices) that ensure to gather data across the city about various areas such as traffic, air pollution, energy, waste etc.; smartphones, computers and terminals, wireless communication networks, database systems, telecommunication systems, internet infrastructure, cloud computing infrastructure and middleware architectures. On the other hand, software components can be stated as all sorts of software supporting digital functions of hardware system, big data analytics techniques; for example, data mining, machine learning, natural language processing and statistical analysis; modeling and simulation methods, database integration and management methods, visualization methods, real-time operation methods, decision support systems, communication-networking protocols and enterprise integration methods (Bibri and Krogstie, 2017). ICT infrastructure has a major role in cases of smart city building, especially deployment of smart apparatuses for efficient smart service performance, and the development of city intelligence. The Figure 4.1 shows the components of the ICT system.

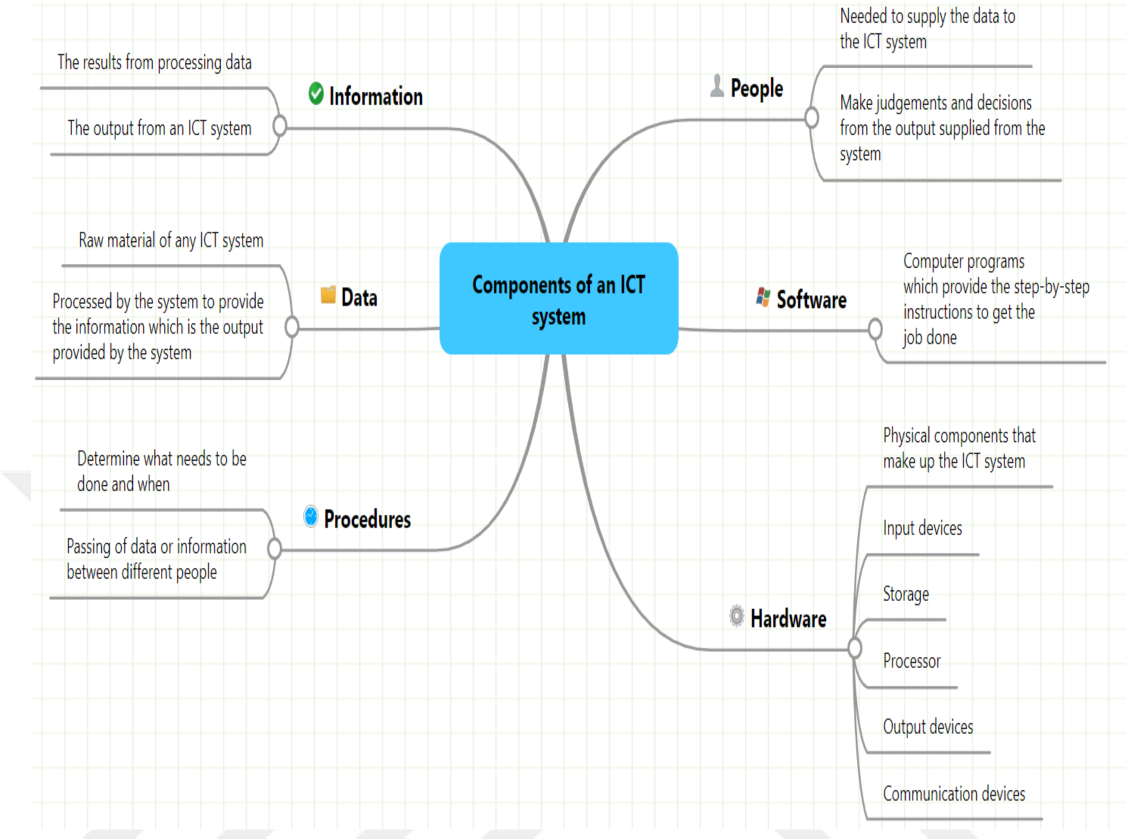

Figure 4.1 : The components of the ICT system (Url-3).

Hardware part is concerned with how data can be obtained in range of different formats and devices such as keyboards, pointing devices, cards, document readers, sensors, data logging, speech input and video input. Moreover, the being produced way of outputs via broad range of devices and formats is another subject that comes out within the scope of this part.

When it comes to storage devices, it is underscored the feature descriptions of internal memories consisting of the difference between ROM and RAM, the identification of appropriate uses in accordance with various types of internal memory, the definition of how data can be stored in external memory with the help of both optical and magnetic technologies and the identification of appropriate using ways for different external memory types.

Processor components are related to the consideration of the need for primary CPU components that are control unit, arithmetic and logic unit and memory.

The determination of favorable sides of networking about stand-alone computers, the identification the crucial features of LAN and WAN, common network topologies (ring, star, bus and bus-star composites), making brainstorming to make a better decision about suitable uses for diverse network topologies and the description of the function of a certain set of communication resources such as modem, router, fibre optic cable, gateway, proxy server etc. are significant examination subjects corresponding to communication devices.

Software part is spanned over the determination of operating system's characteristic aspects like single user, multi-tasking, multi-user and multi-programming systems; the determination of features associated with batch processing and real-time transaction processing, the description of generic software's features (word processing, spreadsheet, database management, desktop publishing, presentation, web authoring, communication packages and graphics), the scrutinization of more special features (commonly used for different tasks) regarding generic software (querying, wizards, object linking and embedding) and compare package use types as a solution for data processing problems.

Data part is included the evaluation on the difference between data validation and data verification, the determination of data validation and verification techniques, the identification of data transcription errors and different forms of data representations.

People part is shaped around smart city services. Also, ICT is put forth the condition that citizens should take part in the decision-making phase for the service improvement. User comments can be contributed to the innovation of new smart systems and recovery processes about deficiencies. Outputs of ICT must be conveyed to people for which they can comfortably live as far as possible by being dramatically diminished time consumption, energy and resource waste.

Information is a result of the raw material processing done in order to make analysis, interpretation about different urban cases and to improve effective solutions for problems encountered.

Procedures are mostly concentrated on the steps that need to take in the direction of data sharing between stakeholders and people.

4.2 Internet of Things (IoT)

The term of Internet of Things was firstly put forward by the employees of MIT Auto ID Center in 1999 and some studies about it were carried out in labs by using RFID (Radio Frequency Identification) technology. However, the term of IoT was officially announced by the report of ITU (International Telecommunication Union) in 2005. Internet of things is the technology which provides that different devices using in casual life can generate data and transmit it to other devices and systems. In the light of other definitions in the literature about what IoT is, it can be described as a system that ensure to utilize more efficiently the services of a certain place such as safety, healthcare or transportation via using of information technologies (Belissent, 2010). On the other hand, IoT is defined in different way like that the capability of an object to make connection in any place at any time (ITU, 2005). As figured out from descriptions about IoT, this technology is used in many domains such as transport, military, agriculture, health, etc. Using areas of this system are being increased day by day and also, there are various technologies being used for the organization of IoT infrastructure. Especially, the technologies being used in communication domain have great importance for IoT. The architectural structure of IoT is differently orchestrated according to the aspects of preferred technologies.

In addition to the devices, which are deployed in particular areas, of communication through wire or wireless technologies, IoT can have the advanced features by being used additional functional services. IoT is one of the most significant elements that makes human life smarter and more controllable.

Some kind of technologies benefitting from the communication domain within the scope of IoT are Bluetooth, ZigBee, 6LoWPAN and Wi-fi. As taking into consideration the working structures and methods of addressed technologies, it is demonstrated that there are different aspects (Söğüt and Erdem, 2017).

IoT is assured lots of innovation to facilitate the urban life. Basic example is smart housewares. Thanks to smart air conditioning systems, the heat arrangement in the house can be managed through a remote control as people are not at home or getting closer to the home. Smart detectors which attain information about weather, humidity or traffic can report to people about possible negative cases in the city. Smart products that are able to monitor the movements of babies or elder people may be assisted people in some critical situations. According to the estimation about IoT by Gartner Inc., it was specified that active smart city market would be reached up to 9.7 billion in 2020. It is foreseen that people will be able to conserve more energy, time and financial resources with the help of the innovations presented by IoT-oriented smart city projects and these projects are going to be indispensable for citizens (Url-4).

The IoT is split into three parts as follows:

1. RFID technology
2. Machine-to-machine communication
3. Near field communication

RFID technology has been developed to use in wars in the midst of 20. century. It is evaluated as an important wireless communication technology. RFID is comprised of main three components as the reader, the tag and the antenna. The reader is a tool that acquires information of the object thanks to tags deployed on the object in numerical code format by using radio waves. Tags are the components that store information. When it comes to the antenna, it is provided the communication between tags and reader and this process is called as "coupling". RFID technology is applicable in many areas such as supply chains, health, library, animal husbandry, security, education (Maraşlı and Çıbuk, 2015). The Figure 4.2 demonstrates the working mechanism of RFID technology.

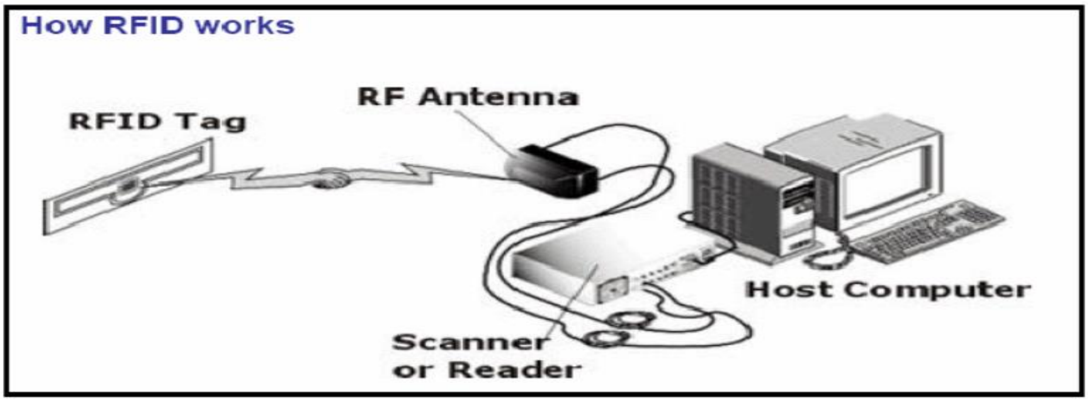

Figure 4.2 : The RFID working mechanism (Johansson, 2004).

Machine-to-machine (M2M) communication is a data communication type that contains one or more entities that do not absolutely need human interaction or intervention in the process of communication. Machine-to-machine communication is also called as "Machine Type Communication". It can be carried out over mobile networks such as GSM-GPRS, CDMA EVDO networks. Mobile networks in machine-to-machine communication is only served as a transport network.

The application areas of machine-to-machine communication is very large. These can be addressed as security (surveillances, alarm systems, car/driver security, access control), tracking-tracing (fleet management, order management, asset tracking, navigation, traffic information, road tolling, traffic optimization/steering), payment (vending machines, point of sales, gaming machines), health (monitoring vital signs, supporting the aged or handicapped, remote diagnostics, Web Access Telemedicine points), remote maintenance control (sensors, lighting, pumps, valves, vehicle diagnostics, vending machine control, elevator control), metering (power, water, gas, grid control, heating, industrial metering), manufacturing (production chain monitoring and automation), facility management (home/building/campus automation).

Architecture of M2M communication is consisted of M2M device, M2M area network, M2M gateway, M2M communication networks and M2M applications. M2M devices are able to response the coming request from the data within the device and to transmit autonomously data to target according to the process demand. Communications devices and sensors are defined as endpoints for M2M applications. In general, devices can be directly connected to the operating system network or they can be made interconnection via WPAN technologies such as Bluetooth or Zig Bee. M2M area network is ensured the communication between M2M devices and M2M gateway. The Table 4.1 is pointed different technologies about M2M area network.

Table 4.1 : Technologies of M2M area network (Chen et al., 2012).

Standard	**Area**	**Rate** (Mbit/s)	**Energy-constrained**	**Typical applications**
SRD	Personal area	<0.02	No	Wireless audio, RFID
UWB	Personal area	>100	No	Video, files sharing
Zigbee	Personal area	<0.25	Yes	Sensors, monitoring
Bluetooth	Personal area	3.00 (V2.0)	Yes	Music sharing
PLC	Local area	>4.5	No	Smart power grid
M-BUS	Local area	<0.0096	No	Consumption meters
Wi-Fi	Local area	108 (802.11g+)	No	Water metering
Femtocell	Local area	>7.2	No	Cellular phones

M2M gateway is the instrument that provides interconnection of M2M devices to the communication network and working of them in inter-connected state. M2M communication network is spanned the communication between M2M gateway and M2M applications. M2M applications have the middleware layer in which data is transmitted via diverse application services. It is managed through the specific business-processing engine. In the Figure 4.3, it is available to see domains of machine-to-machine architecture.

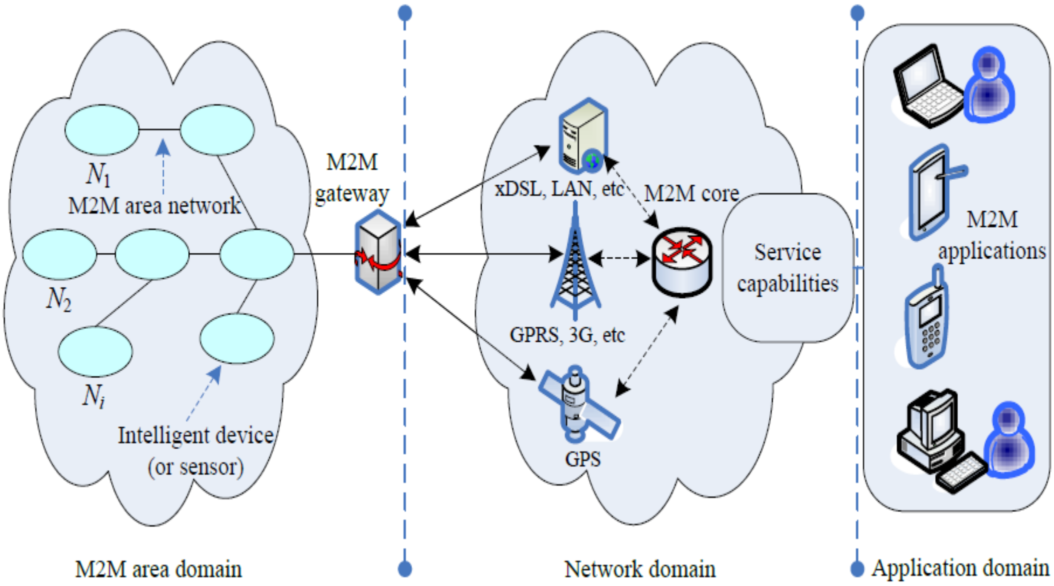

Figure 4.3 : Machine-to-machine architecture domains (Chen et al., 2012).

NFC (Near Communication Field) is one of the most popular communication technologies over the world nowadays. Especially, it has begun to be more noteworthy along with common use of mobile phones by people. To perform this technology, two devices that are compatible with NFC are required in very short distance (less than 4 cm). NFC is operated at 13.56 MHz. Its maximum information transmittance rate is 424 Kbits per second (Rahul et al., 2015). First device in communication is called the initiator that is an active device and starting of communication is in charge of it. As for second device is called the target and its mission in communication is to reply the initiator's requests. Target device does not have to be necessarily active. The NFC technology is worked by way of magnetic field induction and, is used an unlicensed radio frequency band. Furthermore, it is contained embedded energy source component. As for the target device can be RFID card, tag or NFC device that is able to response requests of the initiator (Strömmer et al., 2006). The Figure 4.4 is depicted

NFC technology interaction between two devices complied with NFC which are in suitable closeness to each other.

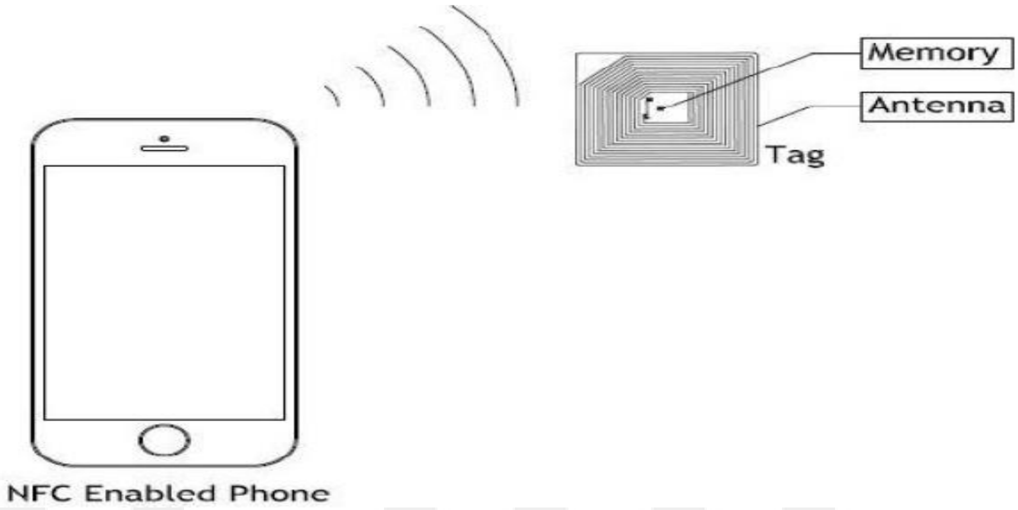

Figure 4.4 : NFC technology interaction (Rahul et al., 2015).

Other the most preferred communication technologies within the scope of IoT can be specified as Zigbee, Bluetooth, 6LoWPAN, Wi-fi and cellular.

First of all, Zigbee is a wireless communication technology that has low power consumption aspect and is based on IEEE 802.15.4 standard. It is named by being inspired from sophisticated ways in zigzag shape as bees draw in the air during their flight. Zigbee devices are carried out the energy conservation in sleep mode. Zigbee structure comprised of four layers is also complied with different structures such as star, point-to-point and tree network structure (Kılıç et al., 2013).

As the second one, Bluetooth is a wireless communication technology standardized as 802.15.1 by IEEE. It is adopted the short-range communication as the operation basis, aimed low cost and low power consumption. There are two ways used for data transmittance. This technology based on radio frequency is evaluated as point-to-point transmittance interface.

The third one is 6LoWPAN. It is IPv6 network technology worked in accordance with IEEE 802.15.4 standard. It covers four functions which are packet sending, packet receiving, packet encapsulating and packet compressing. It is shown as a preferable technology owing to its features of low power consumption and the capability of working with micro-devices.

The another one is Wi-fi technology. It can be expressed as the most known communication technology when compared to others. It can be almost used in all smart devices, computers and mobile systems. Even though its coverage area is broader than others, including or excluding of a new device to/from network is more difficult and this case is influenced all system. It has broad infrastructure system and this is allowed to large scale data transfer. However, it is not so preferable in IoT structure compared to other communication technologies because of its high energy consumption (Söğüt and Erdem, 2017).

When it comes to the last one, cellular is being exploited from GSM (Global System for Mobile Communications) and GPRS (General Package Radio Service) to provide long range communication in IoT. This technology is being used in remotely monitoring, inspecting and processing automatically of many applications. It is being particularly preferred because of being low-cost systems. Data transfer speed of this technology is differed in 2G, 3G and 4G options. In general, SIM cards which have long-lived, are durable and used as embedded are being preferred for these systems.

ZigBee technology is more developed than others in terms of battery life and network size. In comparison of data-network width, Wi-Fi technology has the best degree whereas cellular technology has the worst performance. According to coverage areas, the biggest coverage area is pertained to cellular technology. As examining the frequency results; ZigBee, Wi-Fi and Bluetooth technologies seem in the similarity compared to each other. Bluetooth can be preferred because of its cost and easy-using. Wi-Fi is drawn the attention in terms of speed and flexibility. Cellular is exhibited the best performance in accessibility and quality. Finally, ZigBee can be chosen by being taken into consideration cost, durability and battery life. The Table 4.2 is revealed the comparison of ZigBee, Cellular, Wi-Fi and Bluetooth in terms of main technical aspects.

Table 4.2 : Comparison of ZigBee, Cellular, Wi-Fi and Bluetooth (Söğüt and Erdem, 2017).

Feature	ZigBee	Gsm/Gprs	Wifi	Bluetooth
Focus Area	Tracking and Control	Broad Area Sound and Data	Web, E-post, Image	Instead of Cable
System Resource	4-32 Kb	16 Mb +	1 Mb +	250 Kb +

Table 4.2 (Continue) : Comparison of ZigBee, Cellular, Wi-Fi and Bluetooth (Söğüt and Erdem, 2017).

Battery Life (day)	100-1000 +	1-7	0,5-5	1-7
Network Size (number)	Unlimited	1	32	7
Data-Network Width (kb/s)	100-1000 +	64-128 +	11000 +	720
Coverage Area (meter)	1-100 +	1000 +	1-100 +	1-10 +
Frequency	2,4 Ghz	900/1800/1900/2100 Mhz	2,4-5 Ghz	2,4 Ghz
Data Transfer	250 Kbps	3-10 Mbps (4G), 600 Kbps - 10 Mbps (3G)	Max 60 Mbps	1 Mbps
Success Areas	Durability, Cost, Energy Consumption	Accessibility, Quality	Speed, Flexibility	Cost, Easy Using

4.3 Cloud Computing

Cloud computing is another remarkable technologic constituent for the systems like smart city models which operates by using big data. Particularly, cloud computing has been come into prominence as a basic notion by means of the increase of the requirement connected with high amount of data processing, much more participation of big data in modern life to organize mutually public and service behaviors, the innovation of technologic products working on the basis of big data and the seeking of more practical and low-cost data storage solutions. All these reasons aforementioned have been triggered that cloud computing was essential element in recent years.

There are various definitions pertaining to what cloud computing is technically. According to Mell and Grance (2011), "cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort and or service provider interaction" (p. 2). The specified configurable computing resources may be explained as networks, servers, storage, application and services. In other words, cloud computing has been defined as "a new style of computing in which dynamically scalable and often virtualized resources are provided as a service over the Internet" (Furht and Escalante, 2010, p. 3). Cloud computing is evaluated as a new and significant trend of technology that is going to manipulate the course of IT processes and IT market. Users may have an opportunity by using many devices such as laptops, PDAs (Personal Digital Assistant), PCs, smartphones in order to access data storage, different application-development platforms or programs through the Internet and special cloud computing services allowing to the accessibility. Noteworthy advantages of this technology are cost saving, high availability and easy scalability. Easy scalability means the capability that be able to readily arrange the data capacity and the computing transaction volume in order to satisfy expected demands.

The definition of cloud computing can be defined in other way like that "a large-scale distributed computing paradigm that is driven by economies of scale, in which a pool of abstracted, virtualized, dynamically-scalable, managed computing power, storage, platforms and services are delivered on demand to external customers over the Internet" (Foster et al., 2008, p. 1). Cloud computing technology promises a broad range of opportunities for users including programming environments, computing cycles, storage space and software applications. Furthermore, there are some other supplementary functionalities to make easier processes depending on information systems for customers. These are less investment, scale and manageability.

According to Mell and Grance (2011), there are five essential characteristic features of cloud computing in which are on-demand self-service, broad network access, resource pooling, rapid elasticity and measured service. On-demand self-service is that users can unilaterally satisfy their needs on computing service without any human interaction or other middle-tier.

Broad network access provisions high available accessibility for customers over the network thanks to the using of different platforms such as mobile phones, tablets, laptops and workstations.

When it comes to the resource pooling, cloud system is comprised of a wide range of data resources in association with distinctive domains. Physical and virtual resources in the cloud system are precisely organized by being used multi-tenant model so as to rapidly respond multiple users' requests. The implemented principle in the working mechanism of resource pooling can be called as the sense of location independence and this means that a customer has not an active control over the exact location of resource provider but, the location may be determined thanks to the system for the customer at a higher level of abstraction such as country, state or datacenter. Example resources are storage, processing, memory and network bandwidth.

The rapid elasticity is expressed that cloud technology capabilities are assured and released in an elastic manner by being swiftly scaled outward and inward commensurate with demand. The available capabilities are often presented as unlimited to customers in order to they can utilize it in any quantity at any time (Mell and Grance, 2011).

The measured service is controlled and optimized resource use by taking support from the metering capability at some level of abstraction as considering the service type. By the condition of what ensuring the transparency for both the customer and the provider, resource usage in cloud system is monitored, controlled and reported. Computing paradigm which composes of six phases is depicted in the Figure 4.5 below.

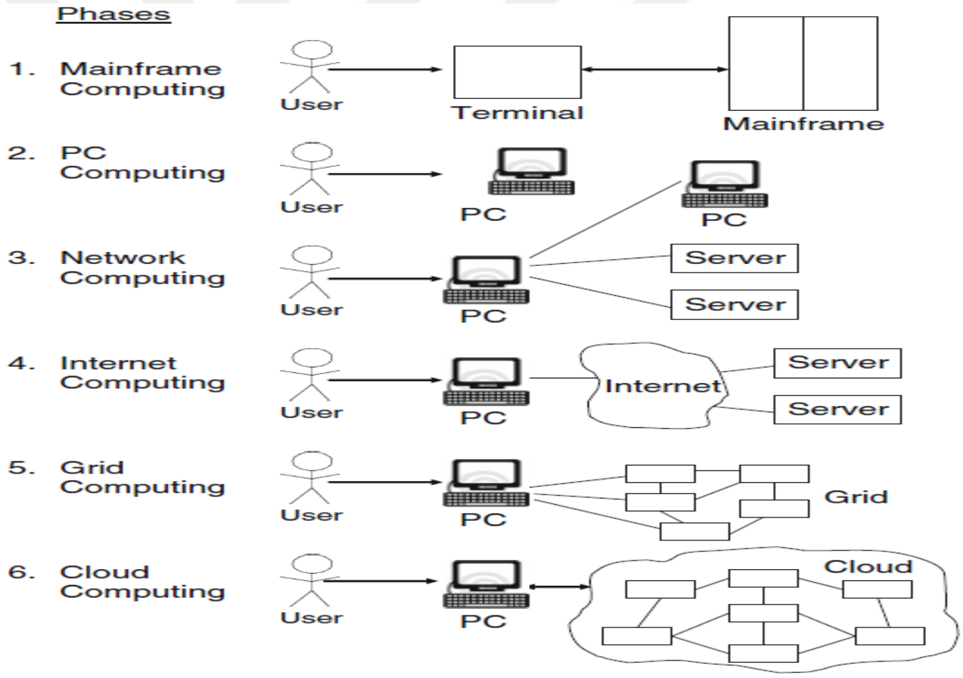

Figure 4.5 : Cloud computing phases (Voas and Zang, 2009).

In the phase one, powerful mainframes are shared between a lot of users using dummy terminal. In the second phase, it is depicted being met the requirements depending on the majority of users by the stand-alone PCs. The third phase is demonstrated the connection between PCs, servers and laptops by means of local networks for supplying and promoting the performance. The fourth phase is specified the merge of local networks for the purpose of the creation a global network in similar to Internet so as to exploit remote applications and resources. The phase five is emphasized on the grid computing that procures a shared computing power and a storage through a distributed computing system. Finally, it may be underscored that cloud computing supplies more shared resources in a scalable and simple manner with the help of the Internet. As scrutinizing the aforementioned six phases of cloud computing paradigm based on general standpoint, it seems that there is a strong similarity between the cloud computing and the original mainframe computing model. Nonetheless, two paradigms have several definite distinctions. Computing power of mainframe model is finite, whereas cloud computing model has infinite computing power and capacity. Besides, dummy terminal of mainframe computing is behaved as a user interface, whereas powerful PCs working on cloud computing may promise the local computing power and the cashing support (Furht and Escalante, 2010).

On the other hand, cloud computing is a collection made by different layers of which have significant tasks. These layers are Software-as-a- Service (SaaS), Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), the data Storage-as-a-Service (dSaaS) and virtualization process. The first layer is an enabler that allows users to remotely operate the applications by means of the cloud. IaaS is represented the computing resources as a service. This layer has virtualized the computers that enables processing power and bandwidths separated for storage and Internet access. PaaS looking like IaaS contains the operating systems and required services for certain implementations. PaaS can be also expressed as a special version of IaaS, with custom software package for the applications offered. The dSaaS layer is provided the storage area used by customers including bandwidth requirements. Virtualization is presented the visual representation of data framework in virtual environment for users and other agents. There is another important advantage of cloud computing, like that it can be virtualized the resources and shared them between various implementations to provide that users can be benefitted from the server well. In addition, the virtualization technologies consist of virtual machine techniques such as virtual networks, VMware and Xen or VPN. The Figure 4.6 indicates the relevant layers of cloud computing technology.

Moreover, there are four deployment models of the cloud computing technology called as public cloud, private cloud, hybrid cloud and community cloud. As the first one, public cloud, in other words external cloud, has a cloud computing dynamically provided over the Internet through Web services or Web applications from an off-site third-party provider (Furht and Escalante, 2010). The cloud infrastructure is supplied in order that public can be utilized it as an open source for the particular aims. Business, academic or government organizations may manage, operate or own it.

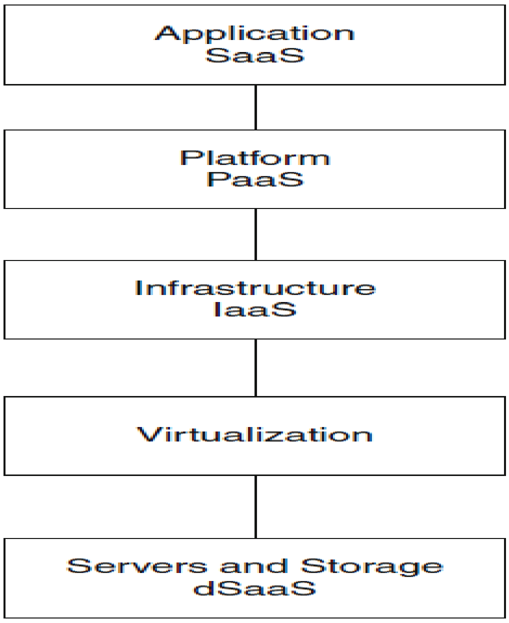

Figure 4.6 : The layers of cloud computing (Furht and Escalante, 2010).

As the second one; private cloud, in other words internal cloud, is simply referred a cloud computing type on private networks. It has been innovated for special usage of one customer with high protective restrictions against outer interactions, full control mechanism over the data and well-quality of service. Private clouds can be established and administrated by an IT organization of a company or by a cloud provider.

As the third one, the hybrid cloud is highlighted the combination process as it is understood out of the term “hybrid”. It is combined public and private cloud models. According to Furht’s view (2010), “hybrid clouds introduce the complexity of determining how to distribute applications across both a public and private clouds” (p. 7).

The last deployment model of cloud computing is the community cloud. It is delivered for special use by exclusive community of customers from institutions that have common interests such as security requirements, policy, mission or compliance considerations. The community cloud may be administrated, operated or owned by one or more of institutions in the community. The schematic representation of public, private and hybrid cloud computing types is available to see in the Figure 4.7.

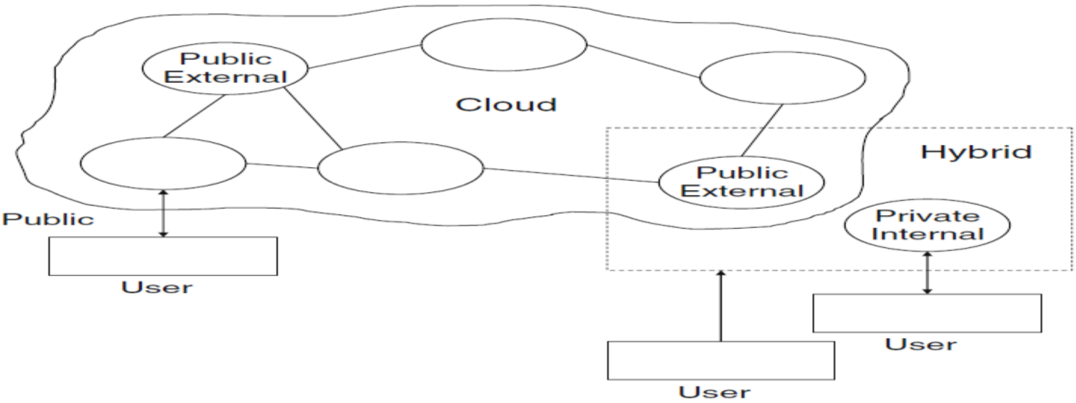

Figure 4.7 : Types of cloud computing (Furht, 2010).

There are some key attributes need to be known about cloud computing for a better understanding of cloud computing phenomena. These are the infrastructure systems, the application software, the application development and deployment software, the system and application management software and finally IP networks. Firstly, infrastructure systems are covered servers, storage and networks built in the form of scalable structure towards user's demand. Secondly, the application software is pertaining to Web-based user interface, Web services APIs and a bountiful diversity of configurations. Then, the application development and deployment software have the duty to supports the development and integration of cloud application software. As the third one, the system and application management software is supported rapid self-service provisioning and configuration and also usage monitoring. To conclude, IP networks are established a connection among the end-users and the cloud-infrastructure components.

4.4 Big-Open-Urban Data

Data is the basic element for the information systems. All processes and studies about information systems are carried out by means of different kinds of data. This situation is caused the increasing value of data in many domains associated with cities. The development of cities is regarded the correct processing of data attained from various sources such as traffic sensors, GPS devices, pollution detectors etc. Management of this big data is a crucial work in making reasonable interpretations about possible issues of the city or in making better decisions about futuristic city planning. In other words, big data management is the fundamental factor to succeed desired intelligent city projects.

In general, the characterization analysis of big data is composed of three main factors which are volume, variety and velocity (Laney, 2001). Data volume is specified the considerable amount of data supply. Data variety reveals sophisticated data structure resulting from multiple data sources. Data velocity means the speed of new data is acquired (Helfert and Ge, 2016).

"Data lies at the heart of smart city concept. This is because city governments and businesses require data and information to be able to provide appropriate and timely services and products to their citizens and customers" (Sexton et al., 2017, p. 12). To better understand the importance of data for city development, the Figure 4.8 is offered the summary which indicates the insights about supportive data requirement for cities.

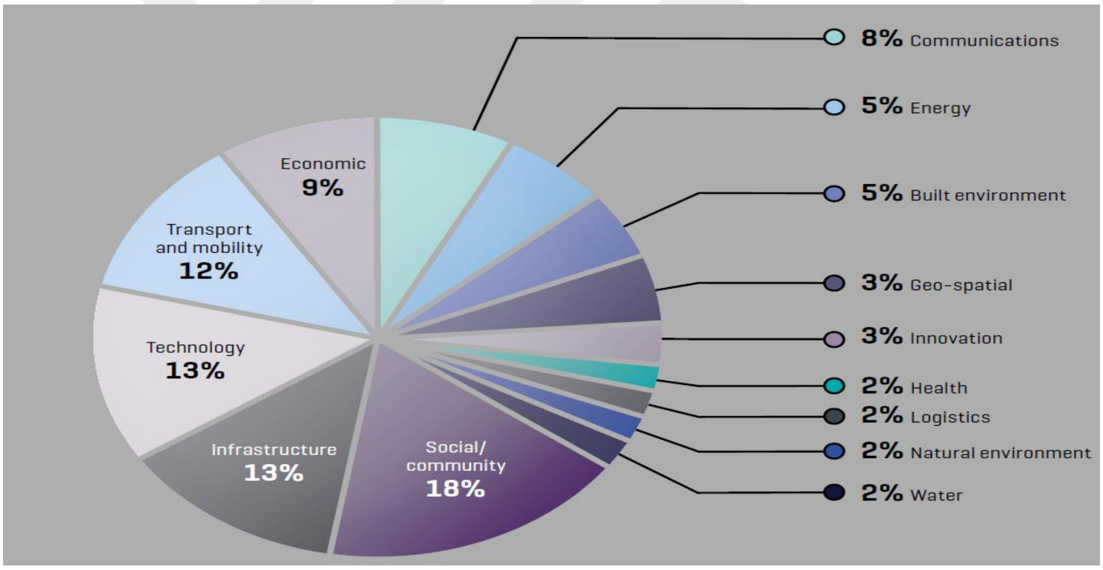

Figure 4.8 : Required data in the support of urban projects (Sexton et al., 2017).

When it comes to what the big data is in technical perspective, it is referred to "the data that can no longer be captured, stored, managed and analyzed using conventional methods" (Sexton et al., 2017, p. 13). Big data has been classified under "Eight Great Technologies" paradigm by UK Government (Sexton et al., 2017). This is also proofed how important the big data is for current technologic systems and models.

In addition, UK Government has defined the big data as "both large volumes of data with high level of complexity and the analytical methods aimed applied to them which required more advanced techniques and technologies in order to derive meaningful information and insights in real-time (Sexton et al., 2017, p. 13)" The definition indicates the growing potential of big data and big data analytics in terms of emerging new meanings, insights and values by being combined different datasets. Big data analytics is emphasized the data using for decision purposes. Any organization can apply a convenient big data analytics method such as data mining to determine the possible opportunities for high performance. Big data analytics as a concept is definitely significant for the invention of successful smart city models. Another definition of it is that "big data is a term that describes large volumes of high velocity, complex and variable data that required advanced techniques and technologies to enable the capture, storage, distribution, management and analysis of the information" (TechAmerica Foundation's Federal Big Data Commission, 2012). In the light of this definition, the Figure 4.9 is indicated the extracting insights related to big data process.

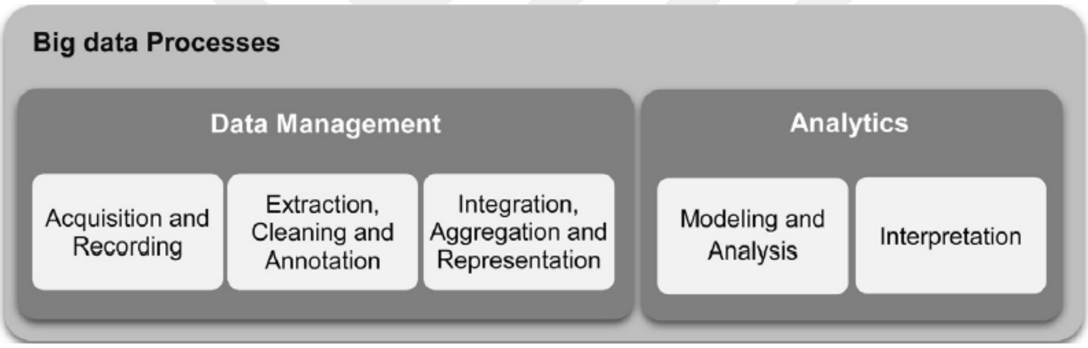

Figure 4.9 : Big data process (Gandomi and Haider, 2015).

In other respects, big data can be characterized in a different way by means of five features (Gandomi & Haider, 2015). These are followed;

1. Large volume or magnitude of data.
2. Wide variety or structural heterogeneity of datasets.
3. High velocity and rate at which data are generated.
4. Very variable and variation in the data flow rates.
5. High degree of veracity or reliability inherent in data sources.

Value and complexity can add to these characteristic features. Value can be expressed as relatively low information value related to data volume. Complexity is the consequence of obtaining data in various formats via different sources.

Likewise, big data analytics have several characteristic features such as advanced data storage requirements, data management, analysis and visualization technologies. These features are not provided by using traditional business methods (Janssen et al., 2015). The subject of big data analytics is not simple as it is supposed. Because, aim of this process is to make the complicated high amount of data more understandable, to disclose hidden correlations between local data units within the big data, to determine unseen patterns, market trends and useful business information so as to increase organization performance and service utility. In a nutshell, big data analytics is done to turn big datasets that can be structured, semi-structured or unstructured into a considerable data form that allows to make better decisions about business course and to make qualified interpretations on possible negative or positive cases associated with the business environment thanks to several certain big data visualization techniques that visually highlight the unknown sides of big data such as visualization algorithms, tables, charts etc (Marjani et al., 2017). Even though it seems that there are some beneficial big data analytics tools and methods, they are insufficient to totally meet the requirements of the business community (data miners, big data and metadata analyzers and scientists). The majority of them use the complicated trial-and-error method to handle the big data problems and the big data heterogeneity. One of the existing big data analytics systems is the Exploratory Data Analysis Environment. It is knowns as a big data visual analytic system that is used for the analysis of complex earth system simulations that have a massive amount of data (Marjani et al., 2017). Moreover, there are other big data analytics systems such as real-time analytics, off-line analytics, memory-level analytics, BI analytics and massive analytics.

In the real-time analytics, the important matter is the constant data change in a short period. It is focused on the data group collected from different sensors across the urban areas. It needs the rapid analyze techniques to filter high amount of data obtained from sensors for the extracting of useful data. For a better understanding the working mechanism of real-time analytics, there are two architecture types offered and these are respectively parallel processing clusters using traditional relational databases and memory-based computing platforms (Pfaffl, 2001).

The Off-line analytics works in the opposite way of real-time analytics working phenomena. Quick response is not necessary for this type (Chen and Zhang, 2014). It can be showed as an example of the advantages about off-line analytics that, numerous

Internet enterprises is being chosen the off-line analytics architecture to diminish the cost of data format transformations. Also, it is enabled an efficient data acquisition. This feature can be accepted as another advantage of it.

The memory level analytics is operated if the amount of data is less than the memory of a cluster (Chen and Zhang, 2014). As being considered the current technology in storage domain, the memory of clusters has been achieved terabyte level. Because of this fact, several internal database technologies are required for improved analytical efficiency. The memory level analytics is evaluated as a convenient form for the real-time analytics.

The BI analytics is discussed when the size of data is larger than the memory stage. However, the data must be imported to the BI analysis environment. The BI analytics is adopted the terabyte-level data in recent years. In other respects, the BI analytics discovers the strategic business opportunities within sophisticated and enormous datasets and allows to make readily interpretations regarding data volumes. The improvement of these features for the acquisition of more efficient analytics ways will be ensured a more guaranteed place for enterprises in competitive market and long-term stability.

As the last one, the massive analytics is performed when the amount of data is bigger than the whole capacity of BI analytics product and traditional databases. This analytics type is benefitted from the Hadoop distributed file system with the purpose of data storage and reduce for data analysis. It is yielded the acquisition of meaningful value out of big data for the increase of competitiveness in the market and to create the business foundation. Furthermore, it is enabled productive services and improved making-decision ability about any business domain to remove possible risks by offering accurate data (Marjani et al., 2017). The Table 4.3 reveals the comparison of different types of big data analytics.

Table 4.3 : The comparison of big data analytics (Marjani et al., 2017).

Analytic Types/Level	Specified Use	Existing Architectures/Tools	Advantages/Category
Real time[33]	To analyze the large amounts of data generated by the sensors	+Greenplum +HANA	+Parallel processing clusters using traditional databases memory based computing platforms

Table 4.3 (Continue) : The comparison of big data analytics (Marjani et al., 2017).

Offline [36]	To use for the Applications where there is no high requirements on response time	+Scribe + Kafka +Timetunnel +Chukwa	+Efficient Data acquisition +Reduce the cost of data format conversion
Memory level [41]	To use where the total data volume is smaller than the maximum Memory of the cluster	+MongoDB	+Real time
Business intelligence level [43]	To use when the data scale surpasses the memory level	+Data analysis plans.	+Both offline and Online
Massive level [44]	To use when data scale is totally surpassed the capacity of business intelligence products and traditional databases	+MapReduce	+Mostly belong to Offline

On the other hand, it needs to be addressed about the close relationship between big data analytics and IoT. Because using of IoT to connect with different systems to each other is resulted in the massive data conglomeration required to be analyzed for reaching a meaningful conclusion related to the city intelligence. In this regard, it may be said that the deployment of IoT associated with many urban domains has been pioneered in that big data analytics attract the attention of the smart business environment. And this is also shown that both of them are dependent with each other from the point of the development. The determination of big data context according to the degree of their meaningfulness and extracting the suitable data in accordance with the making-decision process about likely business initiatives toward the future is obliged the consideration of big data analytics and IoT as a whole. It is possible to see the depicted relationship among big data analytics and IoT in the Figure 4.10 on the following page.

In addition, there are four big data analytics methods on the basis of data miming. But firstly, data mining can be described as one of the most important and preferred big data analytics method to extract required data that helps finding hidden information, making reasonable decisions, identifying recent trends and making realistic and consistent predictions related to the futuristic business cases. Data mining has a crucial role for analyzing, besides, the majority of developed analysis techniques has been created by being utilized data mining algorithms. Data mining has also a big importance in sorting the IoT datasets produced by myriad devices.

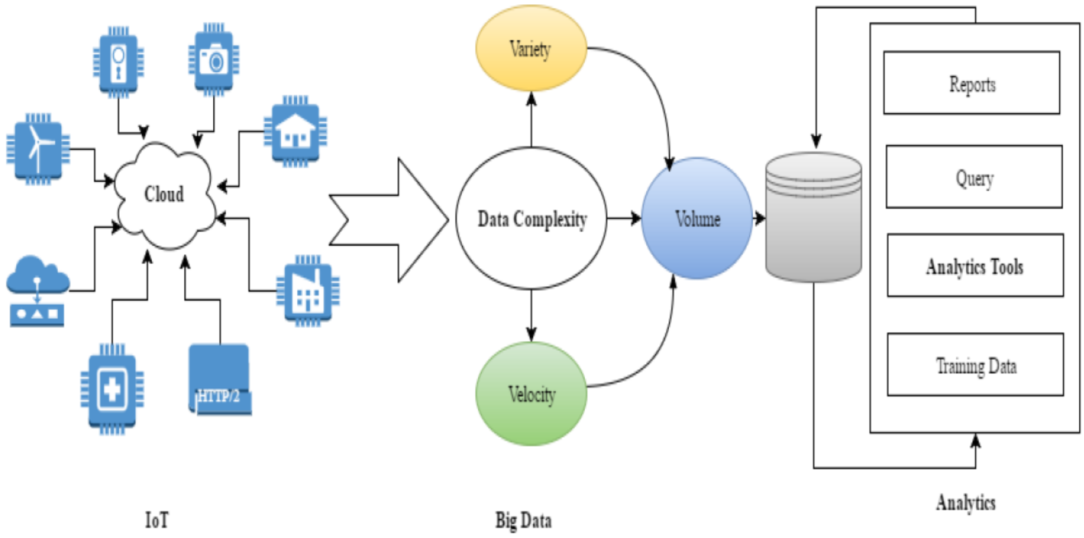

Figure 4.10 : The relationship between big data analytics and IoT (Marjani et al., 2017).

The aforementioned big data analytics methods based on data mining are classification, clustering, association rule mining and prediction. All methods have data mining functions. Classification can be explained as a supervised learning approach which uses prior knowledge as training data to categorize data objects into different groups (Estivill and Castro, 2002). A predefined group is associated to an object, and hence the task of predicting of a group for an object is accomplished. Additionally, introducing the necessary information within big datasets is another remarkable duty of it. As an example, Bayesian networks that are effective in analyzing complex-structured datasets compared to other traditional methods can be showed for classification methods. Additionally, the SVM (Support Vector Machine) is further example evaluated in classification methods. The strong sides of it are analyzing data patterns and creating groups in an effective manner. The SVM is exploited the statistical learning theory in order to analyze data patterns and create groups. In general, applications of the SVM classification method are consisted of pattern matching, text classification, health diagnostics and commerce. In similar way, the KNN (k-nearest neighbor) is an efficient classification method in unraveling hidden patterns from big datasets and detecting of anomalies. Briefly, classification is a widespread data mining technique used for big data analytics.

Clustering is further important data mining technique. It is operated according to the unsupervised learning approach and is generated the object groups through considering their distinctive meaningful features. Being large number of objects in groups is facilitated the data manipulation. There are two common methods used as hierarchical and partitioning clustering. The first one is combined the small data object clusters to produce a hierarchical tree and the agglomerative clusters. Contrary to the first one, the second one uses the approach dividing the main cluster in which all data objects are into smaller appropriate clusters (Berkhin, 2006).

Furthermore, the association rule mining is another significant data mining technique in terms of identifying the interesting relationships between different objects, events or other kind of entities to make an analysis of consumer buying behavior, market trends and product demand estimations. This technique is given close attention to specifying and creating rules depending on the frequency of occurrences for numeric and non-numeric data. In this respect, there are two valid data processing types performing within the scope of association rule mining called as the sequential data processing that uses priori-based algorithms and the temporal sequence analysis that uses custom algorithms for event patterns analysis in continuous data (Marjani et al., 2017).

Lastly, the predictive analysis technique performs with historical data so as to specify the results about data with regards to trends or behaviors. The SVM and the fuzzy logic algorithms are delivered the service to determine correlations among dependent and independent variables and also to attain regression curves for predictions, for instance the natural disasters. Besides, the predictive analysis is utilized in the direction of implementing social media trends analysis and customer buying predictions analysis. The Figure 4.11 enables the representation associated with the overview of big data analytics methods.

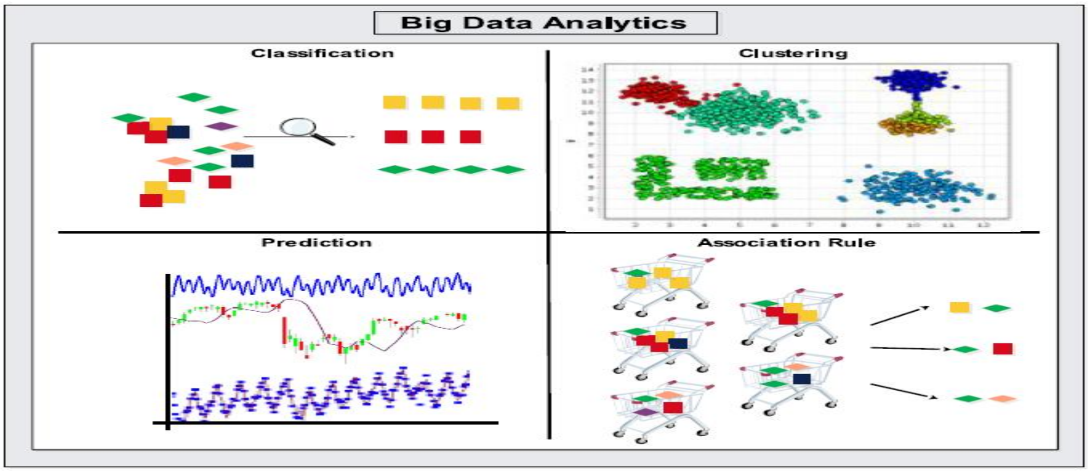

Figure 4.11 : The overview of big data analytics methods (Marjani et al., 2017).

Open data is another significant matter. Open data is able to a gateway between government agencies, different organizations in public or private sector and contributors which are academicians, researchers or special experts so as to develop new ideas, analysis patterns and trends, to make a decision and to solve the problems related to the concept of smart city. Open data can be defined as “data that anyone access, use or share” (Open Data Institute, 2016). According to the explanations of UK Government, a data type should have the addressed properties below to be able to be evaluated as the open data:

1. It must be accessible (normally through Internet).
2. It must be without limitations associated with user identity or intent.
3. It has no cost that is more than the cost of reproduction.
4. It must be digital and machine-readable format.
5. It must be free of restriction on use or redistribution (Sexton et al., 2017).

Also, the advantages of open data for service improvement are a better planning and predictive analysis, improved citizen engagement, more efficient construction and a better asset management in a city and as a final, the disclosing of hidden and important correlations between data (OECD, 2016). The Figure 4.12 underscores noteworthy overlapping domains of big and open data.

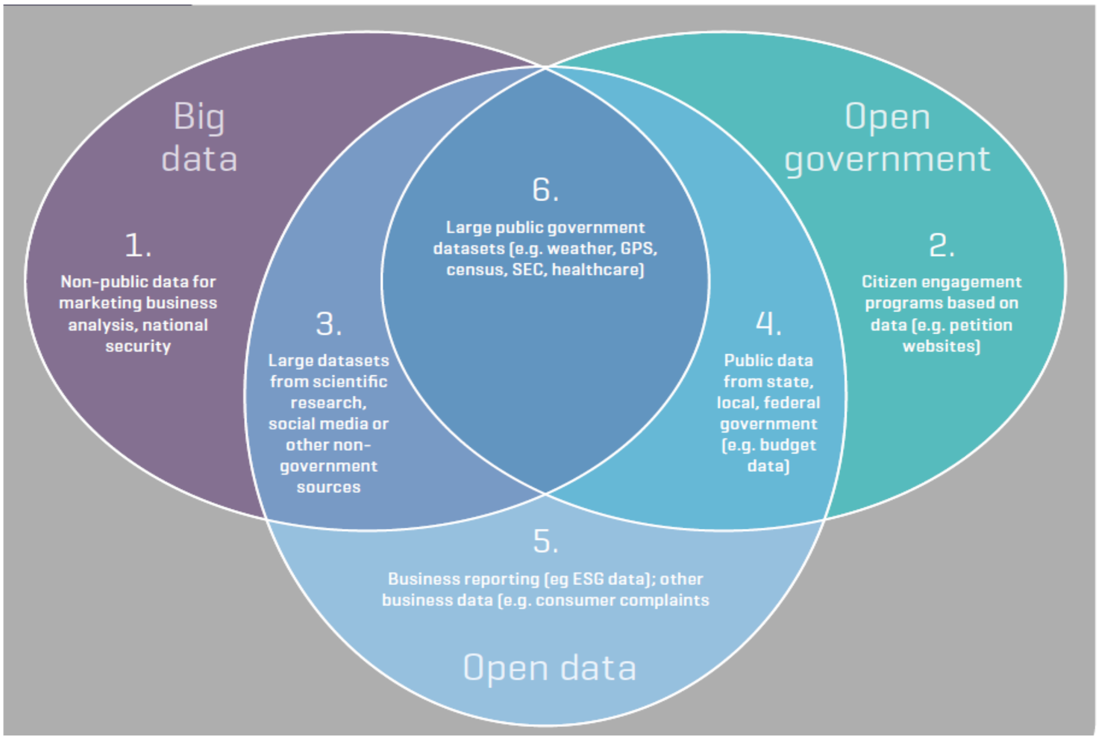

Figure 4.12 : Overlapping domains of big and open data (Gurin, 2015).

Open data can be often used as urban data to develop the city intelligence and the smart city services. For this purpose, many cities are being created their own open data hubs or urban data platforms. Urban data platform means that a logical architecture or design that contains data flows across the city systems in a holistic structure and benefits from the modern technologies such as sensors, mobile devices, cloud services, social media or analytics (EIP SCC, 2015). The Table 4.4 indicates the overview of applied urban data platform types across the world cities.

Table 4.4 : The overview of urban data platform types in the world (Barns, 2018).

Data Repositories	Data Showcase	CityScores	Data Marketplaces
Open Data Portals • Provide access to government data often in machine readable formats • Data not usually listed according to policy or performance target • Created by city governments	City Dashboards • Promote access to data visualisations aligned to urban policy priorities • Underlying data not always available or machine-readable • Created by city governments or through partnerships with educational institutions	Score Cards • Integrate a range of dataset to support peformance monitoring against set targets • Underlying data not usually available • Created by city governments	Datastores • Provide access to data in machine readable formats • Data access and reuse by external parties promoted and encouraged (incl sales) • Performance monitoring one among a number of data uses • Created by city governments or private sector
Objective • Data services innovation • Transparency	Obective • Data visibility • Transparency	Obective • Performance Monitoring	Obective • Data services innovation
Examples • New York Citizen Dashboard • Socrata Dashboards • CKAN Dashboards	Examples • Dublin Dashboard • London Dashboard • Sydney Dashboard	Examples • Boston CityScore • GSC Dashboard	Examples • London Datastore • City Data Exchange (Copenhagen)

Additionally, Dublin dashboard can be given as an example for applicable urban data platforms in real life in the Figure 4.13.

Figure 4.13 : Dublin Dashboard as an active urban data platform (Url-5).

The increase in using open data for the smart city models has been provided the forming of new business models. In this regard, it can be addressed four types of open data re-users. These are enablers, enrichers, developers and aggregators. Enablers refer the organizations, particularly in public sector, which provide open data. Enrichers mean bigger organizations that use open data to enrich existing products and services. In addition, developers describe the organizations responsible for designing, creating and selling the smart applications. Ultimately, aggregators refer to the organizations that gather and aggregate open data.

Urban data is other important matter for smart cities. It may be in open data format and generally, it has high amount of data volume due to many data sources are used to collect urban data. Urban data is big data at the same time. It is a cornerstone for the detection of main city problems and preparing of solution plans once. Urban data is also contributed to be enhanced city ecosystem which comprises of three environments called as the first-dimensional space, the second-dimensional space and the third-dimensional space. The first-dimensional space refers to the physical space composed of merely physical environment with all its resources in natural state. The second-dimensional space means human society space taken shape by cultural norms and social contact between urban residents. Lately, the third-dimensional space specifies a cyber space that contains computers, internet access and data flowing via addressed systems to digital domains (Pan et al., 2016).

In other respects, technical definition of urban data;

> Urban data is that which is held by any organization – government, public sector, private sector or not for profit – which is providing a service or utility, or is occupying part of the city in a way that can be said to have a bearing on local populations and functioning of that place. It can be static, near-real-time or in the future, real-time, descriptive or operational (EIP-SCC Urban Platform Management Network, 2016, p. 6).

In general meaning, urban data can be investigated under three primary categories;

1. Flows of resources, people, information and products beyond the cities, measured by using sensor or other advanced technologic devices.
2. States of urban spaces and environments which is measurable such as density of population or detectable environmental factors by means of sensors, satellite images or incessant observation.

3. Activities of people, devices and machines, transaction measurement, communication patterns measurement and also consumption measurement (OECD, 2016).

On the other hand, urban data can be mapped according to “5 Pools of Urban Data”. Respectively, the corresponding pools are firewalled, open data, social, sensor/IoT and commercial (EIP-SCC Urban Platform Management Network, 2016). The largest proportion of urban data is in firewalled pool.

Open data is an important trend owing to offering publicity associated with any city domain but, it has not the adequate growth speed relevant to urban data.

Social pool refers to produced social media data via different ways. It is scrutinized the instantaneous circumstances of cities with personal or collective shares about the life. The negative side is to be unstructured but still, it is an important pace from the point of feeling cities pulse in social perspective.

According to the estimation about using sensors and IoT, 50 billion devices will be connected with each other in urban areas by 2050. These networks play a key role in effective operating the city services and other systems.

When it comes to commercial pool, “with the trend to externalize city services, commissioned city service providers, utilities and the broader business community now hold a major portion of commercial data that can play an increasingly important role in delivering policy outcomes” (EIP-SCC Urban Platform Management Network, 2016, p. 12). The Figure 4.14 depicts the aforementioned five pools about urban data.

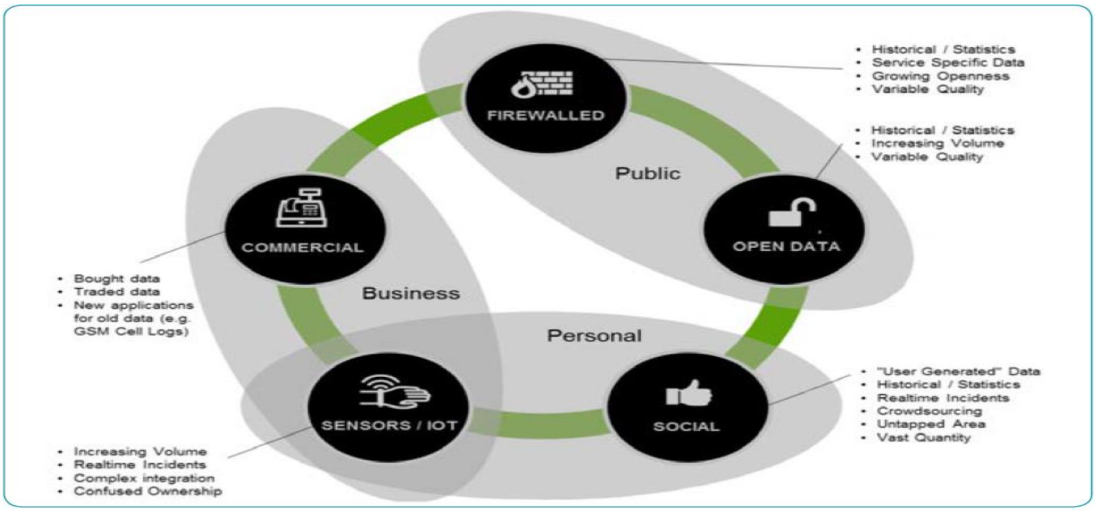

Figure 4.14 : 5 pools of urban data (EIP-SCC Urban Platform Management Network, 2016).

4.4.1 Challenges for open, big and urban data in smart cities

Even though data is a fundamental element for the generation of smart cities, there are several complicated challenges standing against the expectations.

4.4.1.1 Interoperability and common standards

Smart city models are contained different systems at different scales. Each system has unique data format and to needs different standards for effective operation. However, a smart city model should be evaluated as a whole and accordingly, diversity in data formats and standards must be eliminated so as to produce a holistic structure in which all units can be suitably work together. Some data standards generated for the smart city projects seems vital due to this problem. These standards also aim to dispose unintended data duplications that are the important reasons of complication in smart city environment.

The main international bodies working to solve this problem are ISO (International Organization for Standards), CEN/CENELEC/ETSI (the European Committee for Standardization/the European Committee for Electrotechnical Standardization/the European Telecommunication Standardization Institution), ITU (International Telecommunication Union) and IEC (International Electrotechnical Commission) (Url-6).

According to the study of BSI on acquiring standardization to the smart cities for finding the rapid solutions of possible problems, it has been proposed four key questions that will shed light on this subject as follows:

1. How will city authorities set their objectives for smart cities and measure progress?
2. How can cities create the shared understanding to deliver the vision?
3. How will the information be captured and shared between infrastructure and services?
4. What risks are there in moving to smart city services and how can these be managed (BSI-The Role of Standards in Smart Cities, 2014, p. 6)?

By the effect of these problematic questions about standardization in smart cities, the studies have been accelerated to create a common standardization platform that would set a bridge between different smart solutions and would provide the interoperability. In the light of the studies, the advisory group has been concentrated on two fundamental standards-based activities which are significant:

1. “Those that will accelerate the uptake of smart city products and services.

2. Those that will ensure that the smart city developments are built on a solid foundation" (BSI-The Role of Standardization in Smart Cities, 2014, p. 6).

In other respects, BSI is separated the standardization process into three different levels called as the strategic, the process and the technical specifications. The strategic level is offered to shape overall strategic standardization perception that will assure a guideline for the city leaderships and other bodies in the direction of the forming smarter cities. The priorities associated with how will the roadmap be determined and how will the progress of this roadmap be efficiently monitored are participated within the scope of this level. The second level focuses on the development of best practices and implementations in the direction of the guideline to manage smart city activities. The last level includes lots of technical specification that have great importance for the innovation of smart products and services reflecting overall objectives (BSI Standards Publication-PD 8100, 2015). The Figure 4.15 reveals the aforementioned smart city standardization levels.

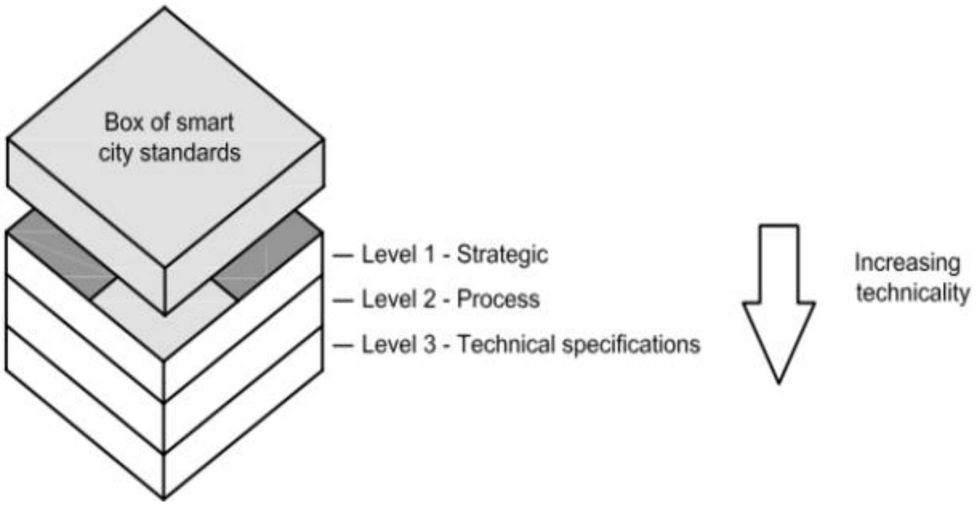

Figure 4.15 : The levels of smart city standards (BSI Standards Publication-PD 8100, 2015).

4.4.1.2 Open access to data

The transaction costs, legal and contractual issues resulting from data collection policies are constituted an ignorable barrier to access data in the sense of many organizations and users. Besides, the privacy and the confidentiality of accessed data are other problematic cases even if the organizations or a user may access to data. Commercial interests and regulations are prohibited the use of public data by private sector agencies for their own interests. On the other hands, the same legal units may be impeded that organizations in private sector use their proprietary data with the purpose of public benefit.

4.4.1.3 Security and privacy

The intensively use of technologic devices in casual life brings up some hazards threating privacy and security. The technologic gaps in connections between ICT systems, established networks or other linkages between smart services stored many personal data of users based on coding phenomena are caused to arise the cybersecurity threads and the violation of privacy. Moreover, because of the sensitive structure of technologic components used in smart cities, the natural disasters may lead to wholly or partially collapse urban infrastructures or vital systems organizing the urban life and thus, the majority of people in disaster site may suffer from.

4.4.1.4 Scarcity and fragmented structure of urban data

This problem is resulted from different survey techniques carried out by government, business and academia units and as a consequence of this case; forming of non-continuance datasets had different formats (Sexton et al., 2017).

4.4.1.5 Ongoing data regulations and data protection studies

It concerns with the illegal interference to private data. In other words, it expresses that there is no a completed deterrent legal framework for data privacy protection. This situation poses heavy risks on data ownership and privacy.

5. 3D MODELLING AND VISUALIZATION IN SMART CITIES

The concept of smart city is a multi-faceted structure combining a variety of technologies and methods to achieve the goal of sustainable urban development, the competition in difficult economic, environmental and social conditions, improving quality of urban life, alleviating the main challenges people face in urban life and also offering permanent and forward-looking solution ways to stakeholders in the direction of the reshaping of urbanization. In this context, the important information platforms such as GIS and BIM play a key role in creation of more understandable and more efficient smart city projects. According to some researchers, the possibilities arising from the integration of GIS and BIM are facilitated the process of decision-making in all stages of sustainable smart city projects. This integration has a big importance to be obtained an accurate spatial data that will be greatly affected all areas about the environmental management and the sustainable development in urban places (El-Hallaq et al., 2019). Moreover, the integration of such platforms that are influential over smart city phenomena enables to be efficiently controlled the full-cycle construction by handling graphical and non-graphical documents with the purpose of gathering information related to construction project, to be accelerated the work flow in ongoing planning thanks to data accuracy and integration ensured. Last but not least, it provides the possibility to be able to make spatial analysis about real scenarios in the real world. Data integration within this scope is allowed more green and efficient construction management, producing efficient solutions corresponding to usability problems and effective asset management with the aid of third dimension (El-Hallaq et al., 2019).

It is cleared that the majority of cities put in effort for a high-level transition and continuous development so as to adopt the salient changes in rapid economic, demographic, environmental and social domains along the world. The topic of 3D visualization has been brought up as an innovative and uttermost necessary tool whereby the needs of cities' regarding the adoption this ongoing rapid change that covers all world. The 3D city modelling presents salient and constructive techniques for the improvement of traditional building understanding and interpretation manners and relatively other environmental features. As well as, these models are consisted of GIS functions with high data representation and analysis capabilities. Besides, they are provided a better decision-making mechanism, the citizen participation. When considered the all abovementioned properties, 3D models seem as an indispensable part for the transformation of cities from a traditional form to an intelligent form via information and communication technologies. In other respects, 3D city model can be described as “a digital representation of the earth’s surface and related objects such as constructions, trees, vegetation and some man-made characteristics in urban areas” (El-Hallaq et al., 2019, p. 323). 3D modelling and visualization techniques are being used for numerous applications nowadays in order to not only present the current representation of a region, but also to exhibit the simulations corresponding to likely future scenarios. In addition, the clear presentation of new urban development projects and futuristic scenarios and besides, the leading up of the participation for urban administration may be expressed as some merits of web-based applications associated with the smart city concept.

On the other hand, the most important targets and benefits of the 3D city modelling can be specified as follows:

- Its vital role in continuity, quality control, management and service delivery.
- It allows to create innovative and sustainable 3D scenarios in the basis of current data and plans.
- It helps to depict the environmental effects and also mobility energy data through merging standard model outputs with the 3D GIS database.
- It makes easier to establish an interactive 3D portal corresponding to GIS in order to assure the citizen participation and a decision support panel commissioned for the city government. This gives way that the planners and other managers responsible for the city management use it as a key tool for analysis, interpretation and presentation regarding current state and future scenarios of the city (Schaller et al., 2015).

5.1 The Pillars of 3D Visualization in Smart Cities

The 3D visualization and the 3D city modelling are helping factors for enabling to figure out the insights about city needs, requirements of citizens and briefly the basic things to make the urban environment more livable. Therefore, the 3D modelling provides that the stakeholders commissioned for the city administration take more accurate and constructive decisions about any domains of city. To accomplish this, it must be produced some definite preliminary models helping in the creation of high-detailed 3D urban models. These will also assure the fundamental frameworks corresponding to the 3D smart city visualization.

5.1.1 Digital terrain model (DTM) – Digital surface model (DSM)

The concept of digital terrain model has been proposed by Miller and Laflamme in the late of 1950s. They have been used these models to monitor basic changes in Earth's surface. Afterward, this concept has become the most important research subject for the International Society for Photogrammetry and Remote Sensing since 1960s. The main research topic was the surface modelling and contouring via the digital elevation models from 1960s to early 1970s. In this time interval, different interpolation models have been also proposed such as HIFI (height interpolation by finite element), projective interpolation and Krigging method. All experimental studies and theoretical analysis have been become a guideline so as to generate more accurate digital terrain models (Li et al., 2005). The Figure 5.1 identifies the processing of digital terrain modelling.

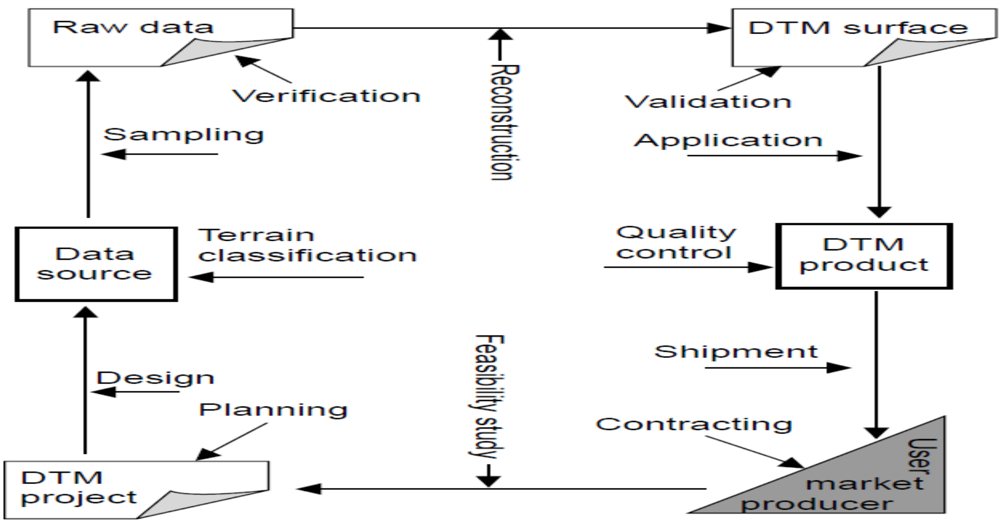

Figure 5.1 : The processing of digital terrain modelling (Li et al., 2005).

Before the terminological description of digital terrain model, the concept of model should be defined. The model can be defined as the representation of a particular matter by means of an object or a concept (Meyer, 1985). It is the form of reality scaled down and transformed into which can be comprehend by people. The most common purposes of model production are prediction and control for which the experts are able to reach necessary scientific findings corresponding to the study target. The models may be represented both the current and forward-looking situations. The concept of model is generally categorized into three groups:

1. Conceptual Model
2. Physical Model
3. Mathematical Model (Li et al., 2005).

As the first one, the conceptual model can be described as "the model borne in a person's mind about a situation or an object on his knowledge or experience" (Li et al., 2005, p. 5). Generally, this model is the first step of modelling process and it procures a guideline for physical and mathematical models. The modelling study may remain in conceptual phase by the condition of that the case is quite difficult for the representation.

The physical model is illustrated by terrain models made of plastic, rubber or clay. These sorts of models are mostly analogue. One of the most popular examples of these ones is the stereo models of terrain depending on optical or mechanical projection principles, which is extensively preferred as a fundamental study material in photogrammetry. Moreover, the physical model is commonly smaller than real object in the studies of geosciences domain.

Finally, the mathematical model can be stated as the representation of a situation, an object or a phenomenon by using mathematical terms (Li et al., 2005). The components of it are depending on mathematical concepts such as variables, constants, equations, functions etc. Also, the concept of mathematical model has been divided into two subtitles which are consecutively the quantitative models and qualitative models, according to Saaty and Alexander (1981). The first one is based on numerical systems, whereas the second is about set theory and like more this, not confinable with numbers. Furthermore; the sort of problem, which may be either deterministic or probabilistic, is determinant about the mathematical model type. In this regard, the mathematical models are allocated as functional and stochastic models (Li et al., 2005). Functional models are fitted for solution of deterministic problems, whereas stochastic models are associated with probabilistic problem solutions.

When it comes to what the digital terrain model is from the point of technical perspective. It is described as “a statistical representation of the continuous surface of the ground by a large number of selected points with known X, Y, Z coordinates in an arbitrary coordinate field” (Li et al., 2005, p. 7). In the light of DTM’s definition, it has particular properties compared to the traditional analogue representations:

1. A variety of representation forms: Diverse forms of representations can be readily generated such as vertical and cross sections or topographic maps by being benefited from the digital format.
2. No accuracy loss of data over time: Conversely the paper maps, DTM lasts for a long time without deformed in terms of the accuracy with the aid of using digital medium.
3. Greater feasibility of automation and real-time processing: Using digital format presents more flexible data integration and updating in spite of the analogue forms.
4. Easier multi-scale representation: DTM is configurable for different resolutions depending on the scale of representation (Li et al., 2005).

Additionally, the Figure 5.2 demonstrates the digital terrain modelling’s relations with other disciplines.

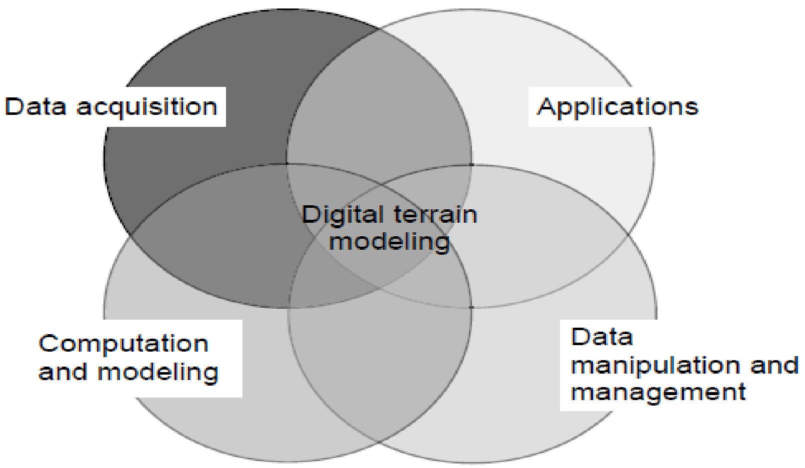

Figure 5.2 : The relations between digital terrain modelling and other disciplines (Li et al., 2005).

Digital surface model (DSM) is a kind of digital elevation model. In general meaning, whereas a digital terrain model is usually focused on bare ground of the terrain, a digital surface model additionally includes heights of vegetations (trees etc.) and of man-made features (buildings etc.). The most salient difference between the two model types is if there are any vegetations or man-made features on the terrain (Elste, 2018). The Figure 5.3 shows two aerial photographs taken in Germany for a better understanding of the difference between DTM and DSM.

Figure 5.3 : The difference between DTM (left) and DSM (right) (Elste, 2018).

After Miller and Laflamme have been offered the term “DTM” in 1958, several alternative terms have been brought up depending on it. These alternative terms can be identified as digital elevation models (DEMs), digital height models (DHMs), digital ground models (DGMs) and also digital terrain elevation models (DTEMs). The invention of these different terms is originated from the different approaches of countries to this point. DEM is a commonly used in America whereas DHM is popular in German scientific community. DGM is also opted by United Kingdom for using in this domain. Finally, DTEM is broadly used by United States Geological Survey (USGS) and Defense Mapping Agency (DMA) (Petrie and Kennie, 1987). Though all terms are accepted to have the same meaning in practice, nonetheless, there are slight differences between them. The ground is technically defined as the solid surface of the earth, a solid base or the foundation or the bottom of the sea. In other respects, the height is expressed as a term that measurement from base to top, elevation above the ground or recognized level. Subsequently, the elevation can be described as the height above the horizon or the height above a given level, particularly that is sea. Ultimately, the terrain is identified as an extent of ground, region, territory or tract of a country considered regarding its natural features (Li et al., 2005).

5.1.2 Urban (City) information model (UIM – CIM)

One of the main tasks of building up smart cities is to offer permanent solutions depending on the primary urban domains, such as transport, pollution, construction or crime etc. This is possible via some systems which play an interconnected role between different urban data sources corresponding to main urban domains. The desired model should be formed a common platform enabling the data sharing and reinforcing the relationships between the stakeholders which are influential over the city management and planning based on the interoperability. In this context, urban information models have been emerged as the expected savior for urban design. According to the study of Gil and Duarte in 2008, there are several definite requirements and challenges related to this approach proposed about urban design follows as:

- The integration of numerous stakeholder’s activities.
- The integration of analysis and evaluation in the performance depending on urban design.
- The management of a variety of outputs pertaining to different stages of urban design.
- The providing of easy access to information withheld in multi-sources and in different formats.
- The effective management of vast amount of information with good visualization for various users.

Urban information model can be considered as a system which supports to be extensively used Geographic Information System (GIS) as a fundamental tool enabling a better making-decision by means of computer technologies in urban designation (Maguire, 2003). Furthermore, one of the basic duties of urban information modelling is to build up an integrated system for e-Governance. This corresponding system composes of multi-dimensional database which is accountable for intelligent information management, spatial data for buildings and in addition to these; land, social, economic and environmental data. The system including e-GIF (Governmental Interoperability Framework) and other standards must support interoperability, integration and implementation of different datasets which are pillars of urban designing and planning. 3D spatial data is engaged into the system for 3D representation of urban places as well. For a better comprehension of the data context about UIMs, the Figure 5.4 points out the environmental data context within urban information models.

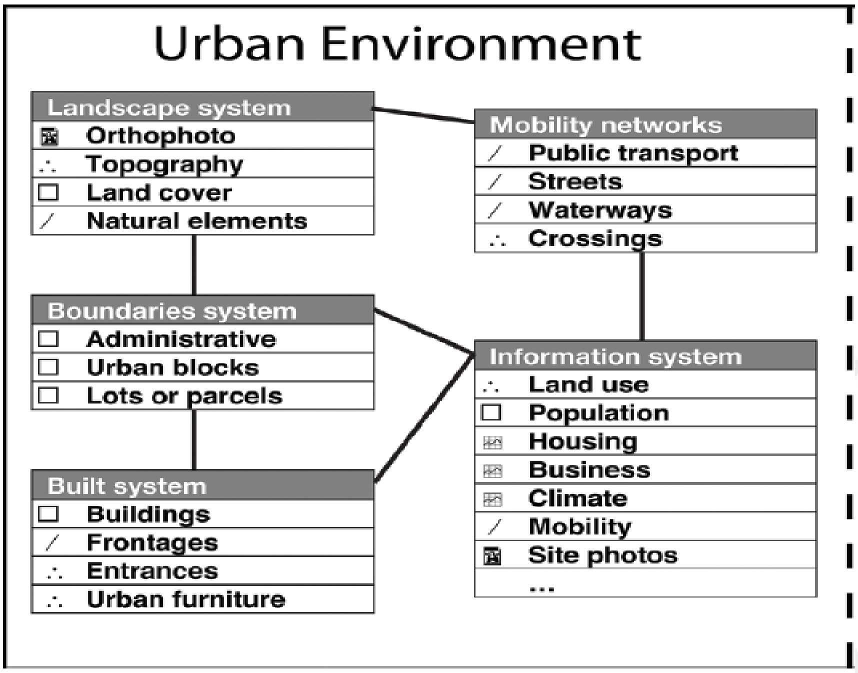

Figure 5.4 : The environmental data in urban information models (Gil et al., 2011).

Urban information models adopt an integrated and comprehensive vision enabling a guideline to be solved the urban problems and for searching the ways of triggering improvements depending on economic, social, environmental and physical aspects of urban places. In other respects, the urban information modelling is a cornerstone in coming into forefront and solving the problems which arise from being in sophisticated and multi-dimensional structure of building design and urban planning concepts. Moreover, they are targeted to make easier the integration of time, accessibility, cost, sustainability, maintainability, crime, acoustics and thermal needs with 3D building model presentations. In terms of this point, these models may be evaluated as an extended version of building information modelling by the combination of whole information required at each phases of building design phenomena as well (Kagioglou, 2003).

The 3D modelling of urban environment comprises the backbone of the visualization process which promotes the communication and the collaboration between lots of participants. The advanced visualization techniques supported by state-of-art hardware and software tools helps the creation and management of city services in an intelligent manner. Taking effective decisions in the direction of the achievement of sustainable urban goals and urban planning is strictly associated with the quality of graphical representation of urban environment. Additionally, urban information has temporal dimension. Urban planning is based on urban information. The conditions of planning can alter according to the needs of citizens or the urban vision in the course of time. At the same time, urban information which manipulate the creation of ideas about urban visions and the planning of urban design should be dealt with the information which provide the fundamentals of past and future models regarding urban design. These properties define the temporal dimension of urban information. This case is totally valid for urban information models as well, owing to the nature of urban information.

On the other hand, urban information models can be identified as nD urban information models since the factors related to time, social, environmental and economic aspects form different dimensions of an urban information model together with 3D urban model plus temporal dimension. The representation of nD urban information model is available in the Figure 5.5.

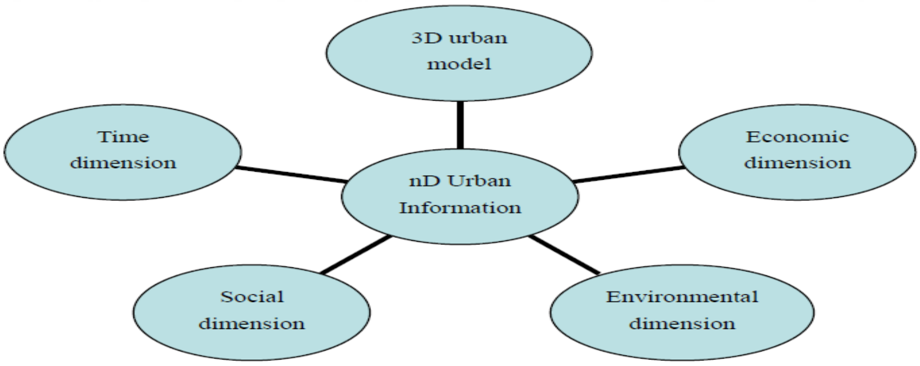

Figure 5.5 : The representation of nD urban information model (Hamilton et al., 2005).

The nD urban information models are briefly capable of which providing broad information support to a variety of urban planning application systems, implementing the interoperations among different datasets, integrating scattered data sources by using integration methodologies, meeting fundamental information requirements for urban planning, facilitating the primary transactions like data collection, access, exchange, documentation or transfer at urban scale and supplying the essential infrastructure for data integration and interoperability (Hamilton et al., 2005). The corresponding infrastructure uses various data management technologies such as databases, middleware or XML.

The final important subject about urban information models is datasets. The main dataset categories used within UIMs are topographic and thematic-spatial datasets (Hamilton et al., 2005). Topographic data primarily defines the urban environment in the sense of physical structure. Topological and geometrical information, Digital Terrain Model (DTM) or building models in CAD format are taken part in this category. In this regards, geospatial information forms the core element for urban information model, especially by the promotion of 3D detailed city models. As to what thematic data is, different themes may constitute the coverage of thematic data such as crime, population or housing etc. This kind of data can be well-structured, semi-structured or non-structured. The well-structured ones can be organized in relational databases, whereas semi-structured and non-structured ones cannot.

5.1.3 Spatial reference model (SRM)

Spatial reference model may be taken into account as the fundamental of spatial reference framework (SRF). It offers the conceptual model and the methodologies assuring the definitions, transformations or conversions, geometric properties associated with spatial reference frameworks (Url-7). In addition, spatial reference model promotes the definite specifications of the positions, distances, directions and also time corresponding to the spatial information. Afterwards, the description of algorithms to obtain precise transformation of positions, directions and distances between various spatial reference frameworks is within the scope of SRM. The conceptual coverage of SRM incorporates an integrated framework and accurate terminology for specifying spatial concepts and operations about spatial information related to positions, distances and directions. The Figure 5.6 depicts the relational structure of SRM's conceptual elements which lead to form a spatial reference framework.

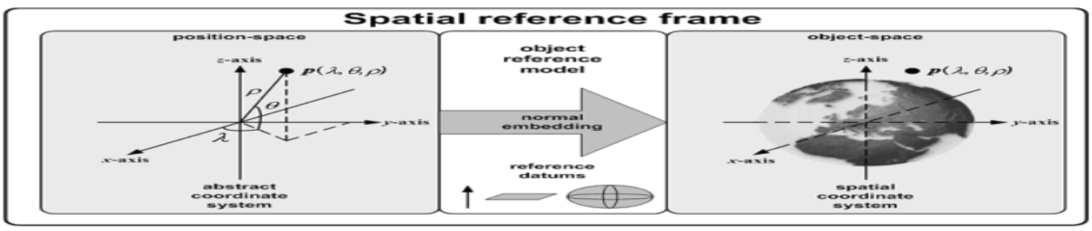

Figure 5.6 : The display of spatial reference framework (Url-7).

5.1.4 Environmental data coding specification (EDCS)

Environmental data coding specification is a mechanism depending on ISO/IEC 18025:2014 which aims to explicitly identify the objects used in the modelling of environment. In this context, there are nine collections of EDCS dictionaries based on environmental concepts to be able to create the expected environmental modelling. The Table 5.1 shows the collections of EDCS dictionaries based on environmental concepts.

Table 5.1 : The EDCS dictionary collections (Url-8).

1. Classification	Specification of the type of environmental objects.
2. Attributes	Specification of the state of environmental objects.
3. Attribute Value Characteristics	Specification of the information regarding the values of attributes.
4. Attribute Enumerates	Specification of the allowable values for the state of enumerated attribute.
5. Units	Specification of quantitative measures with respect to the state of some environmental objects.
6. Unit Scales	Allowance a broad range of numerical values to be expressed.
7. Unit Equivalence Classes	Specification of the sets of units which are reciprocally comparable.
8. Organizational Schemas	Providing better locating for classifications and attributes sharing a common context.
9. Groups	Collection of the concepts sharing a common context.

Moreover, ISO/IEC 18025:2014 has been identified some labels and codes in the dictionaries, for denoting and coding the concept needs as a standard method for concept specification. The environmental phenomena have been allocated into different categories according to the ISO/IEC 18025:2014 specifications. These categories, which are not limited to, has been displayed in the Table 5.2.

Table 5.2 : The categorization of environmental phenomena based on ISO/IEC 18025:2014 specifications (Url-8).

1. Abstract Concepts	Geodetic azimuth, absolute latitude accuracy etc.
2. Airborne Particulates and Aerosols	Cloud, dust, fog, snow etc.

Table 5.2 (Continue) : The categorization of environmental phenomena based on ISO/IEC 18025:2014 specifications (Url-8).

3. Animals	Whale pod, human, fish, civilian etc.
4.Atmosphere and Atmospheric Conditions	Air temperature, rain rate, humidity, sensible and latent heat etc.
5. Bathymetric Physiography	Continental shelf, guyot, reef etc.
6. Electromagnetic and Acoustic Phenomena	Frequency, acoustic noise, sound speed profile, polarization etc.
7. Equipment	Aircraft, spacecraft, tent, train etc.
8. Extraterrestrial Phenomena	Comet, planet, asteroid etc.
9. Hydrology	Lake, river, swamp etc.
10. Ice	Ice field, iceberg, ice shelf, glacier etc.
11. Man-made Structures and Their Interiors	Bridge, building, hallway, tower, road, room etc.
12. Ocean and Littoral Surface Phenomena	Beach profile, current, surf, wave, tide etc.
13. Ocean Floor	Rock, sand, coral etc.
14. Oceanographic Conditions	Specific gravity, salinity, luminescence etc.
15. Physiography	Island, cliff, gorge, mountain, reef etc.
16. Space	Charged particle species, magnetic field, particle density etc.
17. Surface Materials	Concrete, metal, paint, soil etc.
18. Vegetation	Forest, grass land, crop land, trees etc.

5.1.5 SC24 standards

These standards that are corresponding to some buzzing terms like augmented reality or environmental data representation are being developed to allow better 3D visualization and modelling in the smart city projects. The studies are being conducted within the body of International Standardization Organization (ISO) and created working groups which are called as International Electrotechnical Commission (IEC) and Joint Technical Committee (JTC). The Joint Technical Committees are being worked in charge of International Electrotechnical Commission. There are different working groups carrying out the corresponding studies in the direction of various specific purposes.

In general meaning, the scope of SC24 can be defined as "standardization of interfaces for information technology based on applications related to: computer graphics, image processing, environmental data representation, mixed and augmented reality, and interaction with, and visual representation of information" (Ryan and Lee, 2019, p. 3). The novel SC24 standards regarding 3D visualization in smart cities can be specified as X3D, SEDRIS and MAR (Ryan and Lee, 2019).

1. X3D (Extensible 3D) graphics consist of a coordinated set of steadily evolving ISO standards. The fundamental actor which is responsible for improvement and evolution of these standards is 3D Web Consortium. At the same time, it provides the maintenance for long-term archival stability. The developing, updating, maintaining and testing processes are executed by the members of 3D Web Consortium. The main objective of X3D standards is 3D web visualization.
2. SEDRIS is the abbreviation of Synthetic Environment Data Representation and Interchange Specification. This standard is used to create the concepts, semantics and syntax for the representation and interchange of environmental data. The specifications of SEDRIS are included topological, rule-based and other constraints enabling available information for the applications based on automatically generated behaviors during the interaction with environmental data. The scope of SEDRIS incorporates the properties follows as (Url-9):
    - Data representation model to produce environmental data
    - Specifications of data classes and data types that comprise the data representation model
    - Application program interface which promotes the storage and retrieval of environmental data utilizing data representation model

3. MAR (Mixed and Augmented Reality) is able to offer computer-generated information about real world, the development of extensions that are compatible with X3D visualization and interactivity allowing an emerging ISO reference model (Url-10).

5.2 The Importance of SDI in Modelling and Visualization of Smart Cities

There are a variety of parameters which are effective in smart city modelling and visualization processes. The smart systems composed of the combination of many tools such as sensors, computers and so forth making up the physical part of smart systems and invisible technical frameworks and also conceptual schemas underlying the proper operation of these physical devices which deliver the smart services for users are needed some certain fundamentals for meeting the organizational and individual requirements. Spatial data infrastructure is one of the most important parameters in terms of the smart city concept since SDI has a vital role in urban development. To this end, SDIs are offered a platform making easy the exchanging and sharing of spatial information between stakeholders which have an influence directly or partially on the city management. The efficient use of spatial data resources is only to be available through the promotion of spatial data infrastructures. The spatial data has a great importance owing to its crucial role in smart city modelling with desired 3D visualization. The building up of SDIs allowing to facilitate the access, reuse of spatial data, management, availability and conservation of spatial resources will eliminate the hampers standing against the achievement of sustainable and reliable smart city projects (Kumar and Jailia, 2018).

As to the technical description of SDI, it can be explained as "the technology, policies, standards and human resources necessary to acquire, process, store, distribute and improve utilization of geospatial data, services and other digital resources" (Hu and Li, 2017, p. 1). As of 1990s, the studies has been started to construct a spatial data infrastructure by governments of countries around the world in the direction of solving the problems including diverse challenges about the access to digital resources, being a large number of spatial data in dispersed manner, existing a lot of data redundancies, wasting the human and money resources in determination and maintenance of duplicated data. In this context, a national spatial data infrastructure (NSDI) introduced in U.S. has been assured a standardized access to the geographic information resources. There have been three principal missions within the body of NSDI program. These are respectively a set of data standards for formalizing data and metadata, a clearinghouse network allowing data storage and online access and finally a set of frameworks for entire country (Maguire and Longley, 2005).

The success of SDI is heavily depending on sharing data by multiple government agencies. Therefore, the bottlenecks regarding resource discovery and data redundancy can be readily handled and this enables the decrease in wasting efforts for gathering duplicated geospatial data and data redundancy. SDI allows the use of collected data at multiple times in a variety of applications toward needs. This can be demonstrated as an important advantage of SDI from the viewpoint of cost/benefit domain. Furthermore, SDI is taken into consideration as a remarkable contributor enabling the increase of transparency in government activities and enhancement of public participation. In this respect, SDI can be also defined as a mechanism playing the role as a fundamental component of open government movement and e-government system.

On the other hand, an SDI comprises of many constituents such as hardware, software, people, standards, organizations, digital geospatial resources, policies and so forth. The proper working of SDI is associated with effective communication between communities and agreements signed among organizations for better collaborative business movement.

Another important matter is SDI assessment. According to Kumar and Jalia (2018), “assessment is very crucial part of an activity to analyze the current status and performance of an activity before taking any decision” (p. 4). The assessment has been allocated into three sections following as (Kumar and Jailia, 2018):

1. Accountability Assessment (Recapitalization)
2. Development Assessment (Re-engineering)
3. Knowledge Assessment (Capacity Building)

The first assessment section is the focus of policy makers and managers for the performance indicators, performance measures and evaluation. The second one concentrates on carrying the measures out to the next level and additionally recommendations for any changes or modifications about SDI development. The final section is used to introduce new theories and implementations for the functionality improvement. The Figure 5.7 represents the flow assessment of SDI.

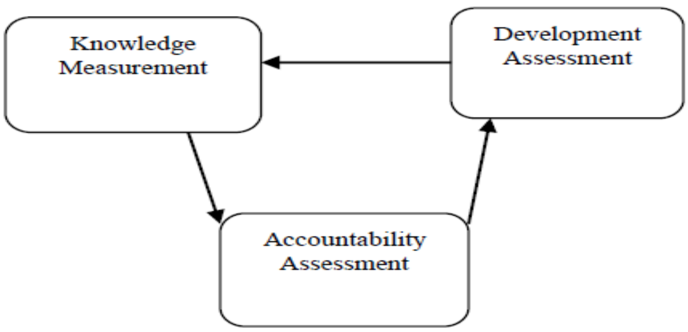

Figure 5.7 : The flow assessment of SDI (Kumar and Jailia, 2018).

At different geographic scales, there are a variety of spatial data infrastructures built up around the world. Global Earth Observation Systems of Systems can be given as an example for global scale. It consists of shared environmental data by more than 70 countries. Infrastructure for Spatial Information in Europe (INSPIRE) is an example of SDI at continental scale. It composes of the shared geospatial information between public organizations throughout Europe. Moreover, many countries such as U.S., China, Australia, Malaysia, Japan and more have their own national SDIs. Tennessee GIS portal is also an example of state level SDI. In addition, New York Open City Data portal can be shown as an example for city level SDI. Apart from aforementioned SDI types, some of them may be devoted for more specific domains such as public health, disaster response or climate change (Hu and Li, 2017).

5.3 I-SCOPE Projects

These projects target to design more understandable and effective smart city models including a pervasive service capacity and realistic representation of urban environment by being benefitted from the merits of urban information models (Amicis et al., 2012). These projects are being carried out within the body of European Union by the support of devoted investments as an economic resource. Using of urban information models within I-SCOPE projects has several important reasons follows as:

- To provide better decision-making ability on issues about city management, urban planning, energy consumption and environmental protection on the basis of urban morphology and pattern.
- To consolidate the participation of various groups across the society via services informing about the hampers at city level.
- To incorporate more citizens into the process of geo-referenced information collection around the city depending on location-based services.

According to the phenomena of I-SCOPE, it is planned to integrate the real and virtual form of city which composes of ubiquitous and pervasive services for enhanced inclusion, mobility and energy efficiency. Such a that co-existed structure comprised of real and virtual forms of city procures the fundamentals of a new articulated ecosystem in which urban life is strongly connected with urban level IT services. This means the birth of hybrid city. I-SCOPE is interested in the creation of humane cities where a user-driven approach as an open-innovation comes into forefront in tackling issues related to city from the view of the social and environmental domain. The basic factor triggering a true user-driven innovation is simply the rapid development of technology. To this end, I-SCOPE puts in effort to dramatically enlarge the user-driven innovation by paying much attention to the involvement of whom are citizens, public officers, decision-makers, administrators, high-tech entrepreneurs since the beginning of projects. The projects progressing in this way is carried out within three main research areas (Amicis et al. 2012):

1. Inclusive routing for the facilitation corresponding to personal mobility of differently-abled citizens.
2. Solar impact analysis for the promotion about energy conservation planning policies.
3. Crowdsourced environmental monitoring for being able to use citizens and IT devices as distributed active sensors providing environmental information.

Besides, I-SCOPE aims to deliver an open source toolkit based on 3D urban information models, built up according to the basics of service-oriented architecture model and based on utilize of open standards within the scope of Open Geospatial Consortium (OGC). The toolkit is capable of the 3D urban information model creation in the light of the OGC standard City GML by using raw data such as surface or terrain models. The open source toolkit enables several important services for the city management scenarios with the help of 3D urban information model. Noise mapping and simulation, energy dispersion and solar energy potential assessment, improved inclusion and personal mobility of elderly people are examples of them.

Furthermore, to give examples with the intention of introducing the enriched innovative features of I-SCOPE, some smart routing service elements can be clarified follows as:

- Automatic map-descriptions in words.
- Information corresponding to the surrounding.
- Maps including larger fonts and mouse over acoustic descriptions.
- Navigation functionalities based on landmark descriptions.
- Offering a simple button to invoke the “where I am?” function consisting of additional descriptions about targeted places surrounding to people with reduced orientation skills.

6. EVALUATION OF INTERNATIONAL SMART CITY PROJECTS

With the advancement of technology and rapid growth in population, the movement from traditional cities to smart cities has been drastically speed up. Lots of governments are dwelt upon how fast they will be able to complete the digital and innovative transformation of their cities. Despite the smart city concept is a synthesis of different characteristic aspects (smart mobility, smart economy, smart people, smart environment, smart living and smart governance), many ongoing smart projects are just focused on some particular aspects of this broad concept. In this context, there are manifold sample studies that pay attention to smart phenomena at small scale in different regions of the world.

In Oss (Netherlands), the lines of N329 highway has been drawn by a new technology which enables the storage of solar energy during day time and then, using it for the illumination of highway at night till ten hours without extra energy need. The shiny color of highway lines provides an additional alert support for drivers against traffic accidents. Hence, this technology contributes reducing the energy waste and assuring a more secure transport. The addressed smart project is come into prominence with the aspects of smart environment, smart mobility and relatively smart economy.

In San Francisco (United States), the using way of smart networks is attracted the attention as a desired model in the world. It is already known that United States is one of the best countries applying the smart network technology in the world. The employment in energy area has increased up to 130 percent in United States thanks to the technologies of smart network throughout the last ten years. In this regard, the reason of what San Francisco is indicated as a model in applying of smart network technology is the efficiently using of controllable smart street lights in terms of the time and amount of illumination. Meanwhile, the amount of electricity that San Francisco needs can be provided by renewable energy sources and this rate is almost the half of general need, is 41 percent. When this smart project is scrutinized from the point of smart city characteristics, the aspect of smart environment is highly drawn the attention owing to the contribution to energy conservation. The aspect of smart economy may be relatively considered within the scope of advantages of this smart project because of its energy productivity.

Smart Santander (Spain) project is resembled a giant lab consisting of myriad cameras, devices and sensors deployed at different points of the city, that captures data in various domains corresponding to the urban life cycle. These data domains can be expressed in wide range from traffic congestion to vehicle movements, from the rate of humidity and heat in the air to the amount of air pollution and nitric acid and so forth. All data collected are conveyed to a robotic data center and then, it is processed for analysis. All people residing in Santander are able to access whole urban information being provided by this smart system to be aware of current circumstances about the city by using a smartphone application which is freely downloadable. The essential idea on that is to allow ubiquitous access opportunities to all citizens for better service. In the light of attained data about urban environment, the city managers and other stakeholders which have important positions in the city management at different scales are able to immediately take precautions associated with the different urban situations seeming necessary and urgent (Url-11). It can be said that the coverage of Smart Santander is more comprehensive compared to the majority of other smart models. It is primarily in the relationship with smart environment, smart mobility and smart governance and partially with others in terms of smart city characteristics.

Another smart project is a smart water technology in Columbia district of United States. This technology has been enabled 7 percent profit in incomes after the involvement of smart meters into the coverage of smart services. Besides, this technology has been offered a significant reduction in costs as far as from 4.15 dollars to less than 1 dollar per meter. Whereby the automatic meter readings; the complaint calls that companies expose to, have been diminished 50 percent and also the calls made to calling centers have been fallen to 36 percent. This is the most remarkable indicator of how much people have satisfied because of smart technology. Besides, 106 liters fuel conservation per year has been accomplished thanks to falling in the number of vehicles carrying the staff commissioned for meter readings. The relevant smart project is more oriented to smart environment and smart economy.

In Hong Kong (China), one of the most stringent conditions is belonged to the transportation. Being transported of over 12 million passengers through one of the most sophisticated transportation networks, which has 2086 km distance, around the world in Hong Kong per day result into that transportation phenomena is the most emergent problem needs to be solved in the city. To this end; the smart routing service, the road traffic information service and the smart road network can be taken into account as the developed solutions for transportation problem (Url-11). According to the analysis of corresponding smart city projects in Hong Kong based on smart city characteristics, it is apparent that they have been built up for smart mobility.

According to the results of smart city studies in Groningen (Netherlands), the Groningen Municipality has been announced to make savings as 92 000 euros thanks to sending message of rubbish bins when they were entirely full. The garbage trucks are merely departed from their stations in the direction of coming messages from rubbish bins around the city. This is substantially enabled savings about the labor and fuel costs. The main focuses of this project are smart economy and smart environment.

In Barcelona (Spain), an innovative bus transportation system allowing the energy and time savings has been designed with the purpose of smart mobility. The bus lines have been reorganized and the arrival information boards informing passengers about locations of buses have been placed at bus stations. The traffic lights are turned into green when the buses get closer. The times of shuttles have been abridged.

In Leeds (United Kingdom), the studies are being conducted for performing the restoration and maintenance operations of street lights by using remote controllable drones with robotic arms. Apart from this, a special robot is also being devised in order to repair underground pipelines and cables of the city. These smart city techniques lead to minimize the time waste and energy consumption and to procure labor savings. Therefore, the project is mainly contributed to smart economy.

In Santa Cruz (United States), a smart system analyzing the police records has been developed so as to enable an instant inspection for the identification of security need depending on the city. Hence, the specified places including security gaps are able to be reinforced by additional security forces in necessary times. The situations when are needed to gear up or vehicle support can be efficiently managed. At the same time, this advantageous smart system has allowed to reduce the security costs. It may be stated in the light of given information that smart governance and partially smart economy are supported by this smart city project.

An eco-city which has been built up in a suburb of Tokio is emitted zero carbon dioxide. In across the city, highly productive devices are used for diminishing the electricity consumption. Additionally, 100 percent LED bulbs are used for building and street illumination. The getting warm or cold of buildings, as well as the operation of laundry machines, are able to be automatically arranged toward weather conditions. This example directly supports smart environment.

Within the operation scope of Songdo City Management System in South Korea; there are an energy transfer from regions with low consumption to the regions with high consumption, keeping away the public transport vehicles from the routes with traffic congestion; if there is excessive trash piled up in a certain region, the garbage trucks are directed to that region not depending on their routine program. The abovementioned services are principally focused on smart environment, smart economy, smart mobility and smart governance.

In Los Angeles (United States); the stoppage times of 35 percent, the latencies at junctions of 20 percent, the transportation time of 13 percent, the consumed fuel amount of 12,5 percent and the emission of 10 percent has been decreased by using the automated traffic control and surveillance system. The investment that has 9,8/1 benefit cost ratio has been made up its own total cost in one year (Aksoğan and Duman, 2019). The smart city project is mainly effective on smart economy, smart environment and smart mobility.

Another example is the use of Oyster Cards that are able to be matched with credit cards allowing contactless interaction at public transport stations in London. In this way, the Oyster Card users can effortlessly make their transactions without waiting in a line. This example is more oriented to smart living, smart people and smart mobility.

In a hospital operating in Boston (United States), the special surveillance devices that is able to be used at home has been delivered to 3000 patients suffering from heart failure. The information of patients related to tension, weight and others has been properly sent to the hospital at particular time intervals. The software developed for these special surveillance devices is able to be warned corresponding medical authorities in the case of immediate treatment for patient. Therefore, just only 3 nurses have been enough for taking care of 250 patients, the applications for treatment at the hospital depending on relevant patients have been reduced 44 percent and more than

10 million dollars has been saved. Boston example is more about smart living, smart governance and relatively smart economy.

According to the pilot study conducted at four schools in North Portugal, it has been tried to be taught the curriculum to a group of students who were 12-13 ages by a simulation method. The results have been showed that the relevant group of students has become more successful than others by 20 percent (Sarabando et al., 2014). The aforementioned study is straightforwardly concerned with smart living.

In Amsterdam (Netherlands), the translation service has been presented for tourists by means of beacons which are a kind of interaction technology using Bluetooth based on location. By this means, the crowd can be intelligently manipulated across the city (Walravens, 2015). This smart city project may directly be an example of smart governance.

According to the general evaluation of international smart city projects across the world, it seems that there are several insufficient sides of the projects not satisfying the smart city characteristics. On the other hand, 3D modelling and visualization is simply shown as the most remarkable deficiency about the projects. The smart city modelling which meets the requirements in an expected manner is directly depending on the elimination of these problems. The future studies should be mostly conducted in this direction.

7. EVALUATION OF SMART CITY PROJECTS IN TURKEY

Although the smart city projects have been newly begun to be operated across Turkey, the transition to the application stage has been quite fast because of the increased needs. Researches in Turkey have shown that smart city applications allowed some important benefits such as contributing to the gross domestic product as 25-30 quadrillion Turkish liras per year, providing energy savings by 20 percent and compensating of millions of hours wasted in roads due to traffic jamming (Aksoğan and Duman, 2019). Unfortunately; despite there is no a comprehensive project which covers all smart city characteristics in Turkey, there are manifold examples operated or about to be operated in different cities.

Istanbul IT and Smart City Technologies established by Istanbul Metropolitan Municipality with the intent of planning of the operation of application services by traffic-system engineering in 1986 has been initiated the first signalization system of Turkey, as well as more many novel services making easier the urban life. There are three the electricity generation center from the landfill gas in Hasdal, Kemerburgaz-Odayeri and Şile-Kömürcüoda. The landfill gas formed resulting from the rotting of household wastes are stored in dug wells at household waste collection centers. Then, this gas is transferred to the gas collectors via a special vacuum. The collected gas is exposed to particular processes for the refinement. Firstly, the refined gas is converted into the mechanic energy by being burnt in internal combustion engines, afterwards converted into the electricity energy. By this means, the electricity need of 300.000 homes are annually provided. When taking into consideration the basic smart city characteristics, the abovementioned projects support smart mobility, smart environment and smart economy.

The automatic traffic control, management and synchronization system has been implemented at 23 different points on the part, which is 6,5 km, of Bursa City Square-Heykel-T1 tramline in order to enable the right of way to the tramway. When the tramway comes to the relevant tramline part, the system automatically send red-light signals to all traffic lights placed at roads coinciding with the tramline. This project can be shown as an example to smart mobility in Turkey.

The contactless card filling and ticket sale machines are provided the time savings for passengers in Bursa. So, the citizens can more swiftly reach to their destinations in the city without much time loss. This smart city application has been brought the flexibility to dynamic urban structure in terms of smart mobility.

At the mud burning and power plant facility with fluidized bed in Bursa, the mud is burnt in the way of being minimized as much as possible the negative effects on the nature and being abided by all environmental restrictions so as to obtain the energy. The overall 96 tones solid materials are able to be burnt as couple of sessions per day at the facility. The ashes risen from the operations of burning are used as raw material for asphalt production and at concrete facilities. The mud is entirely exterminated thanks to the transfer of ashes to these facilities. The part as 1 MW of generated electricity is used to provide the electricity need of this facility, the rest of it is used for the needs of waste water treatment facility incorporating the facility where the mud is burnt. This project promotes smart environment and smart economy.

Eskişehir Tepebaşı Municipality has been found a solution for the water problem by utilizing solar energy panels. The solar energy generated by means of deployed panels at suitable points is preserved in batteries. Then, this energy is used to operate the water pump and the water engine. On the other hand, the placing of free charge stations at different sites of Tepebaşı District is another remarkable service in the course of the transition to smart city applications. The charge stations which supply its own energy requirement from the solar energy are delivered the service for citizens during the day. In this context, the happiest group is the students because of this service. They are mostly benefitted from these stations for charging their tablets and mobile phones without any fee. These addressed projects are interested with smart environment and smart economy.

Konya Metropolitan Municipality is used the traffic control center to manipulate the traffic flow, especially, at critic points such as crowded junctions. Thanks to using this system, the stoppage times at junctions has been reduced by 18 percent. Therefore, 1 million liters' fuel can be saved in a year. This project is an important example to smart mobility and partially smart economy.

Some smart applications have been started to be operated in charge of Vodafone in Yalova. These ones are the smart illumination which allows being remotely controlled of park lights according to the need, the smart watering which enables remote control and resource savings in watering operations and the smart garbage which provides the remote tracking of dustbins. The aforementioned smart applications are covered smart environment, smart economy and smart governance.

In order that the citizens can more readily report their requests to the management units, The Mukhtar Information System has been made operative in the overall of Turkey. The solving of problems in the direction of citizen's demands had taken lots of time before the establishment of an interactive platform like The Mukhtar Information System making connection among municipalities and mukhtars. The time interval being necessary to take constructive steps for the solution has been quite abridged whereby this governance system that allows more efficient interaction between the relevant units. Thus, it has been assured that the reporting and tracking of complaints and requests getting from citizens by mukhtars in mobile platform as online, being given an information about the results via e-mail or text messages, being able to be automatically done the conveyance processes to the municipalities and, being made definition and documentation of the solution processes by municipalities. With this system, it has been created a platform that the requests and complaints can be electronically recorded by mukhtars and can be tracking by one center (Url-11). The system is a good example for smart governance.

Battalgazi Municipality Building in Malatya has been designed as a green building producing own electricity and hot water. Additionally, the building can be stored rain and snow waters for using in the watering operations. The solar panels deployed on building's roof is generated 327.000 KW electricity and by this means, 840 tones carbon dioxide gas emission is eliminated. In the city, electricity can be also generated through the landfill gas. According to the statistics, 3 MW electricity is annually generated in the landfill gas power plant constructed in 2014. In this way, the municipality earns 3 million Turkish liras. In 2015, the "Trambüs Project" that promotes the less fuel consumption than the vehicles using fossil fuel and, zero carbon monoxide emission has been made operative. In this way, the more comfortable transportation has been provided by being transported more 3 times of passengers than that the standard buses were able to be transported. Besides, the solar panels built up on the roof of Trambüs Maintenance Station are used in the electricity generation and in this way, the needs of facility are met. The rest of energy is transferred to the Trambüs line. Ultimately, Malatya Metropolitan Municipality has been established 6 different bicycle stations in where the citizens can be rented the bicycles, at different sites of the city with the intent of inducing the bicycle riding in urban life. The main purpose is to highlight the importance of riding a bicycle in terms of having a cleaner environment and being healthier. The abovementioned smart city projects that are being operated in Malatya generally focus on smart environment, smart economy, smart mobility and smart living (Aksoğan and Duman, 2019).

According to the evaluation of smart city projects in Turkey, whole projects have been confined at small scale compared to the smart city characteristics. The coverage of these projects must be extended in a way that includes all smart city characteristics for urban activities. Moreover, another major problem is that none of them include 3D urban modelling within the scope of smart city concept. As in international projects, the studies in Turkey should also be carried out to solve these problems.

8. CONCLUSIONS AND RECOMMENDATIONS

The concept of smart city is one of the most common trends drawing the attention in the information age when we live. There are numerous causes making smart cities remarkable. Examples of these causes are the difficulties experienced in the management of metropolitan cities, which are composed of many important components, the increasing complexity of urban life, the increase in people's expectations and needs, and the serious problems caused by environmental pollution. When taking into account urban needs and expectations related to the modern age we live, some important recommendations and future works that will enable a better understanding of smart city vision and smart city concept can be listed follows as:

Despite the concept of smart city is a general term, its application way in different cities will be different since each city has own dynamics and characteristic properties. Before starting the application processes related to smart city projects, these dynamics and characteristic properties should be distinctively specified. Therefore, the planning of smart city projects will be done in the harmony with urban fabric. Each city management council should take a step in the light of a determined guideline by being considered relevant aspects connected with the urban area.

The core of the smart city concept is human, in other words citizens who reside in the urban area. This point should never be ignored and all steps that need to be taken should be supportive for citizen participation. The needs and complaints of them should be meticulously examined. In this context, the officials of city management units can take a poll over the websites of municipalities or other relevant organizations. The main idea must be to reach as much as possible more citizens through different studies so as to discover their demands.

Another core matter about smart city projects is to assure the maximum peoples' utilization from smart services. These services which are made operative should not just be oriented to a particular group in urban population. The service coverage must have a broad structure in the way of which all citizens including ones who have different cultural norms and assets, elderly people, disabled people, children, young and adult people have equal opportunity in benefitting from the smart services. Because the rate of utilization of a service indicates the degree of that service's quality. In this regard, various representations or applications transformed into more funny and attractive forms via some gamification techniques can be helpful for a faster and easier adaptation of people.

The establishment of a spatial data infrastructure in the way of meeting the requirements is quite important. As it is known, spatial data is fundamental for smart city systems. The solving of inconsistencies regarding spatial data and providing data integrity is possible by spatial data infrastructures. In this regard, the main issues of spatial data infrastructures must be urgently solved. Because one of the basic missions of spatial data infrastructures is to ensure the spatial data standardization and integration with the intent of providing a proper framework for futuristic projects that are at organizational, regional, national and global scales. According to the researches about these issues, it highlights that most of them emerge during the data integration process. At the same time, this is nontrivial task and geomatics engineers have significant responsibilities related to this subject. The relevant issues have been displayed in two groups as technical and non-technical issues in the Table 8.1.

Table 8.1 : Data integration issues (Williamson et al., 2010).

TECHNICAL ISSUES	NONTECHNICAL ISSUES		
INSTITUTIONAL ISSUES	POLICY ISSUES	LEGAL ISSUES	SOCIAL ISSUES
Computational heterogeneity (standards and interoperability) Maintenance of vertical topology Semantic heterogeneity Reference system and scale consistency Data quality consistency Existence and quality of metadata Format consistency Consistency in data models Attribution heterogeneity Utilization of consistent collaboration models Funding model differences Awareness of data integration	Existence of supporting legislation Consistency in policy drivers and priorities (sustainable development) Pricing	Definition of rights, restrictions, and responsibilities Consistency in copyright and intellectual property rights approaches Different data access and privacy policies	Cultural issues Weakness of capacity-building activities Different backgrounds of stakeholders

An open platform covering all domains about smart city phenomena and allowing a guideline for countries putting in effort to build up their own smart cities should be created. All standards, basic tools, methods, techniques, data formats, software systems, the results of researches, especially the newest ones, and so forth can store within the body of this platform which will be common. Also, this kind of a platform will present the opportunity to have a broad data bank embodying a variety of information associated with smart city phenomena on a global scale. Countries can carry out their own smart city studies in faster and more efficient way by utilizing the eases provided by this platform. A working environment based on collaboration, participation and transparency should be formed. These kinds of developments will allow for the faster progression of countries that are similar to each other thanks to the following of international studies.

Before the planning of smart city services, 3D spatial city models that covers both underground and above-ground features should be prepared in an easily understandable and detailed manner. These models will provide to be properly familiar to the topography of cities and to be accurately made spatial analyses about the urban areas. The regions which have high energy consumption can be determined via these models to produce more effective solution ways. On the other hand, the urban areas which have an intense environment pollution can be marked by being made spatial analyses over the models in digital form. The more important point about these models in this context is that they can allow for more accurate detection of deployment places of devices and other tools which will enable to be operated the smart city services as a result of spatial analysis, queries and environmental impact assessments. Moreover; the maintenance operations associated with a city infrastructure or the existing situation assessment of pipelines, cables and channels can be done by being benefitted from the models and so, some possible accidents can be blocked whilst the application of new projects.

The impact of smart city services on people in terms of the satisfaction should be investigated in particular times via questionnaires on various official websites. The results should be diligently analyzed to see if citizens have satisfied. Also, citizen’s propositions are quite important. The city managers should pay attention to these propositions and complaints about smart services in order to plan more useful, practical and efficient smart city systems.

The election of city managers is another important matter. The managers should be elected among people who have an international proficiency. So, they can more actively take part in the international meetings about the city management and smart cities. They must have the conscious of that the people who do not follow the current developments and innovations will never perform the requirements of the smart city vision. The vision of cities should be planned according to the current parameters of the modern age and the values of the future by being considered the results reached in the light of international or national meetings associated with the smart cities.

In the transition process to smart cities, it should be paid attention to that the corresponding officials related to all stakeholders playing a role in the establishment of smart cities are in the planning and application crews. The concept of smart city is an extensive subject embodied a variety of urban application domains. Being able to carry out a study which is suitable for smart city vision is depending on the transfer of this extensive context to the application site with a high attention. Geomatics engineers, civil engineers, architects, urban and regional planners, academicians, researchers, computer engineers, software engineers and so forth play an active role at this point. The participation of all stakeholders should be provided to be able to make healthy common decisions.

The studies about smart cities across the world should be scrutinized with their pros and cons to understand which approaches have been adopted by different city management units in the world. This kind of an investigation will play a key role as a guideline for new projects which will be commenced.

The electing of city managers should be done by taking into account the degree of their capabilities corresponding to the effective planning and raw material process. To measure this, some extraordinary and funny methods can be applied. For example, some games like Sim City and Cities Skylines that are based on city planning and management approach can be used to inspect the decisions of manager candidates in terms of consistency, effectiveness, designing, planning, creativity and problem solving (Url-12). In this way, some suggestive results about the manager candidates, even if they are not entirely definite, can be attained.

The city communities consist of various groups who have different skills from each other. To this end, the novel approaches should be developed for enabling a high utilization from smart services by being taken into consideration the relationships of these groups with technology. Different preparations can be made in order that different groups of people are able to consciously benefit from smart services in any case. The relevant groups can be expressed as children, young people, adults, elderly people, disabled people or people with various education levels. In this context; the special broadcasts in similar to cartoons for children, short and informative videos, attractive pamphlets or educative representations may be offered.

One of the most important topics is also the cybersecurity. As it is known, the smart cities contain numerous hardware and software systems. There are many databases that stored the sensitive and important information corresponding to users in these systems. Users naturally want to take a guarantee regarding the protection of their privacy. Therefore, the privacy and information security should be strictly guaranteed for all users. On the other hand, stringent precautions should be taken against the attackers. The vulnerability of a smart city system is equal to the sum of vulnerabilities of devices and tools within that smart city system. Especially, the smartphones are the most serious contact point in this regard, since lots of smart city application are used via mobile platforms. A malicious software uploaded on an unsuspected smartphone by the attacker may result in the crippling of whole system. This case may cause serious drawbacks over the life-cycle of cities. Attackers who aim to gain access to the main server may lead to take place perilous consequences having huge impacts on all smart city systems. On the other hand, the attackers may simultaneously commence multiple attacks called Botnet on the smart network by infecting the malicious software to multiple smartphones. The situation like this can also trigger the collapse of the smart city systems. Apart from this, the sensitive information about users may be stolen by being used of spywares. These kinds of information stolen by attackers may turn into very hazardous weapons descending upon people’s life like a nightmare. The most critical smartphone vulnerabilities are malicious smartphone applications, botnets, location and GPS, spywares, threats from social media, unsecured Wi-Fi and Bluetooth connections and finally the Internet. Particularly, citizens should be informed about possible threats and processes that need to be avoided.

Principally in Turkey, the mentality of municipalism needs changing. An approach which is far from the politic conflicts and discriminations should be adopted. Thus, the high productivity and continuity will ensure for the upcoming studies and projects. Meanwhile, this situation will lead to a national and holistic progression.

The evaluation of international smart city projects around the world has been shown in the Table 8.2 and the evaluation of smart city projects in Turkey has been shown in the Table 8.3. According to tables, it can be said that there are important problems about application stage of smart city models. The models generated around the world and in Turkey can not wholly satisfy the smart city characteristics. It seems that the projects are mostly focused on economy, mobility and environment. Besides, the subject of 3D modelling and visualization has been ignored. In the direction of solving these problems, geomatics engineers have to take on more responsibilities. Sharing and updating of spatial data, developing common standards for data integration, making analysis of existing projects to determine the major bottlenecks of 3D modelling and visualization in smart cities and developing new methods that provide producing the high quality smart city models with 3D modelling and visualization should be the mission of geomatics engineers oriented to the future development of smart city modelling. To this end, it can be said that 3D GIS, BIM and CityGML are primary drivers about 3D modelling and visualization. BIM presents an enriched context for building modelling and it can be used within the scope of smart building management thanks to this feature. Even if 3D GIS offers different visualization opportunities for urban modelling, GIS can be mostly evaluated as an important tool for making spatial analysis and queries to solve various urbanization problems. On the other hand, CityGML seems as a more effective and preferable software in the urban modelling area. It has different levels of detail to be represented an urban fabric in more realistic manner. Apart from this, it can be said that there is an extension in the vertical dimension in big cities because urban lands cannot response to the rapid growth of the urban population. This situation results in the overlapping of different rights and using purposes, associated with different building parts. Therefore, it arises some challenges in cadastral meaning, at the same time, affecting the operational performance of smart cities in terms of smart governance and smart economy. Not to allow this, it should also be given weight to the development of 3D cadaster within the studies carrying out to visualize the urban places. At least, 3D cadaster will accurately ensure the determination of building parts which have different using purposes in complicated areas such as commercial complex, shopping center, bazaar and so forth. Moreover, it will offer a better registration system that meets 3D space requirements. Because traditional cadaster is inadequate in the definition of multilayered structure of modern constructions in big cities. A 3D cadaster system working in an efficient manner will have crucial importance in smart management of real estate, smart land valuation and so forming of a real estate market that reflects the realities.

As it is seen in the Figure 4.8, the concept of smart cities needs multiple data resources to be able to serve for urban requirements in an expected way. This means that meeting the needs of single or some city service areas without focusing on all of them would definitely be insufficient for the building of a smart city model that is suitable for the smart cities' vision. The situation that appears in the Table 8.2 and 8.3 results from this issue. To this end, geomatics engineers should collaboratively work with other responsible disciplines.

Smart city systems include different service groups. One of the important service groups which must consider in this context is spatial services. According to the Figure 4.8; transport and mobility, infrastructure, built environment, geo-spatial, natural environment and water reveal the spatial services which contribute to the urban development and the sum of these services corresponds to 37 percent in the general service pool. Moreover, Table 5.2 indicates environmental phenomena with spatial dimension. When these data sources take into account, the importance of spatial services comprehends better within the scope of the smart city concept. Therefore, the more efficient integration of corresponding service groups into smart city applications and the development of them in the direction of sustainable development vision are necessary.

In the light of the Table 8.2, it seems that smart economy comes into prominence at international scale when compared to other smart city characteristics. There are diverse reasons of this situation. The most important reasons are the economic interests of governments and their efforts to acquire a better place in competitive international market. Also, rapid urbanization means lots of expenditures and over resource consumption. This situation, seeming as unpreventable nowadays, makes anxious many governments around the world. Therefore, the concept of smart cities is also interpreted as the better controllable and manageable city models without over resource waste. Other the most applied smart city characteristics are smart environment and smart mobility. The irregular increase in the urbanization rate is being triggered the destruction of natural lands and natural balance. The rapid concretion breaks the relationship between human and nature. The studies regarding the smart environment have serious importance in terms of this.

Table 8.2 : The evaluation of international smart city projects.

International Smart City Projects	SMART CITY CHARACTERISTICS						3D Visualization
	Smart Economy	**Smart People**	**Smart Living**	**Smart Governance**	**Smart Mobility**	**Smart Environment**	
Tokio (Japan)	NO	NO	NO	NO	NO	YES	NO
Barcelona (Spain)	NO	NO	NO	NO	YES	NO	NO
Hong Kong (China)	NO	NO	NO	NO	YES	NO	NO
Amsterdam (Netherlands)	NO	NO	NO	YES	NO	NO	NO
North Portugal	NO	NO	YES	NO	NO	NO	NO
Leeds (U.K.)	YES	NO	NO	NO	NO	NO	NO
Columbia (U.S)	YES	NO	NO	NO	NO	YES	NO
Groningen (Netherlands)	YES	NO	NO	NO	NO	YES	NO
San Francisco (U.S.)	YES	NO	NO	NO	NO	YES	NO
Santa Cruz (U.S.)	YES	NO	NO	YES	NO	NO	NO
Los Angeles (U.S.)	YES	NO	NO	NO	YES	YES	NO
Oss (Netherlands)	YES	NO	NO	NO	YES	YES	NO
London (U.K.)	NO	YES	YES	NO	YES	NO	NO
Boston (U.S.)	YES	NO	YES	YES	NO	NO	NO
Songdo City (South Korea)	YES	NO	NO	YES	YES	YES	NO
Smart Santander (Spain)	YES	YES	YES	YES	YES	YES	NO

Table 8.3 : The evaluation of smart city projects in Turkey.

Smart City Projects In Turkey	SMART CITY CHARACTERISTICS						3D Visualization
	Smart Economy	Smart People	Smart Living	Smart Governance	Smart Mobility	Smart Environment	
The Mukhtar Information Sys.	NO	NO	NO	YES	NO	NO	NO
Eskişehir	YES	NO	NO	NO	NO	YES	NO
Konya	YES	NO	NO	NO	YES	NO	NO
Istanbul	YES	NO	NO	NO	YES	YES	NO
Bursa	YES	NO	NO	NO	YES	YES	NO
Yalova	YES	NO	NO	YES	NO	YES	NO
Malatya	YES	NO	YES	NO	YES	YES	NO

According to the evaluation of smart city projects around the world, it has also been seemed that the subject of smart mobility has substantially been included into smart city applications. The increased population density results in arising numerous negative factors affecting the quality of urban life. In this context, one of the most affected factors is transportation. Smart projects are being developed by governments in order to be able to overcome the problems associated with transportation. The studies carrying out have enabled that transportation came into prominence. On the other hand, other smart city characteristics need to be developed more. 3D urban models that produced according to the needs must be integrated into these aforementioned studies.

According to the Table 8.3, the existing situation in Turkey is more or less same. Whereas smart economy is the most supported feature, smart environment and smart mobility follow it. Like within the international smart city projects, the matter of 3D modelling and visualization attracts attention as the most explicit absence. Smart city studies must be pursued to complete corresponding deficiencies in the direction of smart cities' vision.

When the smart city studies around the world examine, it has seen that economical expectations were primary, the concept of human was not come into prominence, more handling of the studies providing flexible mobility in an urban environment, the studies regarding the smart cities were solely associated with environmental protection and the matter of 3D modelling – visualization was not included the scope of studies. This case is same for Turkey as well. The smart city model which has been shown in Figure 8.1 has been developed within the scope of this thesis by being considered the afore-mentioned deficiencies.

According to the developed smart city model; the emerged activities in the domains of smart economy, smart people, smart living, smart environment and smart governance called as smart city characteristics should be considered as a whole and should be incorporated into the body of smart city systems with this approach. Like in the studies which conduct across the world, the studies which generally focus on a single aim are not suitable for the general definition of smart city concept. These studies may evaluate as concrete and forward-looking steps that benefit from the advanced technology in the direction of smart cities' creation.

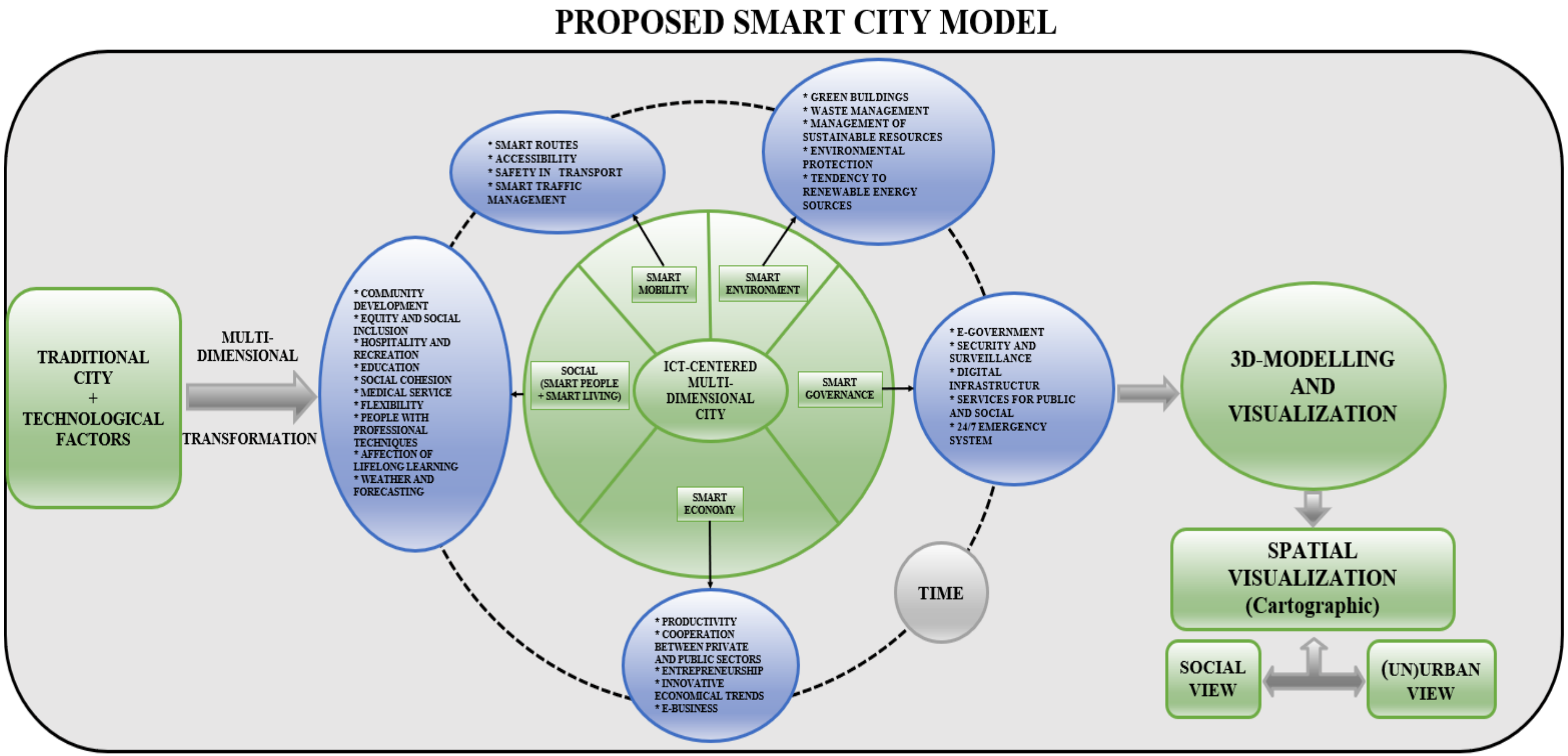

Figure 8.1 : Proposed smart city model (It has been developed based on the schema of European Investment Bank Institute).

The results of these steps must be turned into service groups that have a holistic and systematic working mechanism by blending with other activities. The matter of 3D modelling – visualization in smart cities must handle in a similar way. All activities which are indicated in the Figure 8.1 must visualize in an understandable manner for smart city users (including different age categories, people with different proficiency levels, decision makers etc.). The aim at this point should not be the singular spatial visualization of activities among themselves but should be the spatial visualization of the holistic system composed of the integration of these activities. Spatial (cartographic) visualization that is handled within the context of scientific visualization is inadequate in visualizing whole indicated activities. That’s why the theoretical structure of smart city – 3D visualization relationship should be improved.

According to the author in light of the research and the examinations that have made, a smart city model that will be planned should not be considered independently of 3D modelling and visualization. However, the remarkable point is merely not that being presented the construction state in urban areas or the urbanization in a visual form via modelling. Phenomenons associated with the human that have a centred role for smart cities and different acts scrutinizing under smart city characteristics needs to be included in spatial models in an suitable way according to cartographic methods. In this context, spatial visualization, as well as it includes underground and above-ground structures, must be able to visualize the phenomena associated with human or acts, based on the location by using cartographic methods. Factors like the number of children or disabled people in a family, the number of unemployed people in a building, the number of people who have a criminal record in a building, the ethnic distribution of a region or the distribution of elderly people population can be evaluated within the scope of spatial visualization. The matter of time should not be ignored during these processes. The values should be updated in particular time intervals and the changes should be examined. Smart city models that will be created by being integrated the technological components with a 3D modelling and visualization form that defined in this way will offer more effective city management and more efficient service distribution in every sense

REFERENCES

Abu-Matar, M., & Davies, J. (2018). Data driven reference architecture for smart city ecosystems. 2017 IEEE SmartWorld Ubiquitous Intelligence and Computing, Advanced and Trusted Computed, Scalable Computing and Communications, Cloud and Big Data Computing, Internet of People and Smart City Innovation, SmartWorld / SCALCOM / UIC / ATC /CBDCom / IOP / SCI 2017 - , 1–7. https://doi.org/10.1109/UIC-ATC.2017.8397556

Aksoğan, M., & Duman, M. Ç. (2019). Akıllı Şehir Uygulamaları; Malatya Örneği, Smart City Applications; Malatya Example, 1. Uluslararası Battalgazi Multi DisplinerÇalışmalar Kongresi Tam Metin Kitabı, Cilt 1, 183-202.

Amicis, R. De, Conti, G., Patti, D., Ford, M., & Elisei, P. (2012). I-Scope – Interoperable Smart City Services through an Open Platform for Urban Ecosystems Raffaele de Amicis, Giuseppe Conti, Daniela Patti, Martin Ford, Pietro Elisei. 0(May), 1219–1226.

Angelidou, M. (2014). Smart city policies: A spatial approach. Cities. https://doi.org/10.1016/j.cities.2014.06.007

Anthopoulos, L. (2015). Defining Smart City Architecture for Sustainability. Electronic Government and Electronic Participation: Joint Proceedings of Ongoing Research and Projects of IFIP WG 8.5 EGOV and EPart 2015, (AUGUST 2015), 140–147. https://doi.org/10.3233/978-1-61499-570-8-140

Barns, S. (2018). Smart cities and urban data platforms: Designing interfaces for smart governance. City, Culture and Society, 12(December 2016), 5–12. https://doi.org/10.1016/j.ccs.2017.09.006

Batty, M., Axhausen, K. W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., … Portugali, Y. (2012). Smart cities of the future. European Physical Journal: Special Topics, 214(1), 481–518. https://doi.org/10.1140/epjst/e2012-01703-3

Bawany, N., Z. & Shamsi J., A. (2015). Smart City Architecture: Vision and Challenges. International Journal of Advanced Computer Science and Applications, 6(11), 246–255. https:// doi.org/ 10.14569/ ijacsa. 2015. 061132

Bélissent, J. (2010). Getting clever about smart cities: new opportunities require new business models. Forrester Research, Inc, 33. Retrieved from http://groups.open.org.nz/groups/ninja-talk/files/f/19710-2010-11-04 T092134Z /getting_clever_ about_smart_cities _new_opportunities .pdf

Berkhin, P. (2006). A survey of clustering data mining techniques. In Grouping Multidimensional Data: Recent Advances in Clustering. https://doi.org/10.1007/3-540-28349-8_2

Bibri, S. E., & Krogstie, J. (2017). Smart sustainable cities of the future: An extensive interdisciplinary literature review. Sustainable Cities and Society, 31, 183–212. https://doi.org/10.1016/j.scs.2017.02.016

BSI (2014). The Role of Standards in Smart Cities, Issue 2. Retrieved from: https://www.bsigroup.com/LocalFiles/en-GB/smart-cities/resources /The-Role-of-Standards-in-Smart-Cities-Issue-2-August-2014.pdf

Caragliu, A., Bo, C. D. E. L., & Nijkamp, P. (2009). Paper Nijkamp et al Smart cities in Europe 2009. 45–59. https://doi.org/ 10.1080/ 10630732. 2011. 601 117

Chen, M., Wan, J., & Li, F. (2012). Machine-to-machine communications: Architectures, standards and applications. KSII Transactions on Internet and Information Systems, 6(2), 480–497. https://doi.org /10.3837/tiis.2012.02.002

Chen, C. P., & Zhang, C. Y. (2014). Data-intensive applications, challenges, techniques and technologies: A survey on Big Data. Information Sciences. https://doi.org/10.1016/j.ins.2014.01.015

Furht, B., & Escalante, A. (2010). Handbook of Cloud Computing. In Handbook of Cloud Computing. https://doi.org/10.1007/978-1-4419-6524-0

Dobrilovic, D. (2018). Networking Technologies for Smart Cities: An Overview. Interdisciplinary Description of Complex Systems, 16(3), 408–416. https://doi.org/10.7906/indecs.16.3.13

(EIP-SCC), E. I. P. for S. C. & C., & BSI, B. S. I. (2016). EIP-SCC Urban Platform Management Framework Enabling cities to maximize value from city data. Bsi, (October), 1–27.

El-Hallaq, M. A., Alastal, A. I., & Salha, R. A. (2019). Enhancing Sustainable Development through Web Based 3D Smart City Model Using GIS and BIM. Case Study: Sheikh Hamad City. Journal of Geographic Information System, 11(03), 321–330. https://doi.org/ 10.4236/ jgis.2019.113019

Elhoseny, H., Elhoseny, M., Abdelrazek, S., Bakry, H., & Riad, A. (2016). Utilizing Service Oriented Architecture (SOA) in Smart Cities Utilizing Service Oriented Architecture (SOA) in Smart Cities BSC Faculty of Computer Science and Information Systems , Mansoura Lecturer of Information Systems , Faculty of Computer Scienc. International Journal of Advancements in Computing Technology, (June).

Elste, R. (2018). Paradigmenwechsel im Vertrieb – Konsequenzen neuer Technologien für das Kundenmanagement in: Binckebanck, Lars; Elste, Rainer (Hrsg.) (2018): Digitalisierung im Vertrieb. 73037. https://doi.org/10.1007/978

Estivill-Castro, V. (2002). Why so many clustering algorithms- A position paper. SIGKDD Explorations.

European Investment Bank Institute (2015). Assessing Smart City Initiatives For The Mediterranean Region (ASCIMER) Projects Work Package 1. Part 1, Smart Cities : Concept & Challenges, January 2015.

Foster, I., Zhao, Y., Raicu, I., & Lu, S. (2008). Cloud Computing and Grid Computing 360-degree compared. Grid Computing Environments Workshop, GCE 2008. https://doi.org/10.1109/GCE.2008.4738445

Fu, Y., & Zhang, X. (2017). Trajectory of urban sustainability concepts: A 35-year bibliometric analysis. Cities. https://doi.org/ 10.1016/j.cities. 2016. 08. 003

Gandomi, A., & Haider, M. (2015). Beyond the hype: Big data concepts, methods, and analytics. International Journal of Information Management, 35(2), 137–144. https://doi.org/10.1016/j.ijinfomgt.2014.10.007

Gil, J., Almeida, J., & Duarte, J. P. (2011). The backbone of a City Information Model (CIM). 29th ECAADe Conference, (Cim), 143–151.

Gurin, J. (2015). Big Data and Open Data: How Open Will the Future Be? I/S: A Journal of Law & Policy for the Information Society, 10(3), 691–704. Retrieved from: http://search.ebscohost.com/login.aspx? Direct = true & db = lgs & AN = 112529654&site = ehost-live

Hamilton, A., Wang, H., Tanyer, A. M., Arayici, Y., Zhang, X., & Song, Y. (2005). Urban information model for city planning. Electronic Journal of Information Technology in Construction, 10(January), 55–67.

Harrison, N., & Avgeriou, P. (2007). Pattern-driven architectural partitioning balancing functional and non-functional requirements. 2007 Second International Conference on Digital Telecommunications, ICDT'07. https://doi.org/10.1109/ICDT.2007.65

Hashemi, S., Hashemi, S. Y., & Monfraredi, K. (2013). A Novel Service Oriented Arhitecture (SOA) to Secure Services in a City, International Journal of Security, Privacy and Trust Management (IJSPTM), Vol: 2, No: 6, December 2013, 23-29.

Helfert, M., & Mouzhi Ge. (2016). Big Data Quality - Towards an Explanation Model in a Smart City Context. Iciq 2016, 2:1-2:8.

Hu, Y., & Li, W. (2017). Spatial Data Infrasructures, The Geographic Information Science & Technology Body of Knowledge, John P. Wilson (ed.). http://dx.doi.org/10.22224/gistbok/2017.2.1

International Telecommunication Union. (2005). Executive Summary. ITU Internet Reports 2005: The Internet of Things, 28. https: //doi.org/ 10.1109/ IEEESTD. 2007.373646

ITU-T FG-SCC (2014). ITU-T Group on Smart Sustainable Cities, Overview of Key Performance Indicators in Smart Sustainable Cities. Retrieved from: https://www.itu.int/ITU-T/scc/index.html

Janssen, M., Matheus, R., & Zuiderwijk, A. (2015). Big and open linked data (BOLD) to create smart cities and citizens: Insights from smart energy and mobility cases. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in

Bioinformatics), 9248, 79–90. https://doi.org/10.1007/978-3-319-22479-4_6

Johansson, B. (2004). An Introduction to RFID – Information Security and Privacy Concerns Björn Johansson Supervisor : David Byers An Introduction to RFID – Information Security and Privacy Concerns**.**

Kagioglou, M. (2003). Developing a Vision of nD-Enabled Construction. In Construct IT Centre of Excellence, University of Salford.

Kakarontzas, G., Anthopoulos, L., Chatzakou, D., & Vakali, A. (2014). A conceptual enterprise architecture framework for smart cities: A survey based approach. ICE-B 2014 - Proceedings of the 11th International Conference on e-Business, Part of ICETE 2014 - 11th International Joint Conference on e-Business and Telecommunications, 47–54. https://doi.org/10.5220/0005 021400470054

Kim, T. H., Fang, W. C., Ramos, C., Mohammed, S., Gervasi, O., & Stoica, A. (2012). Ubiquitous sensor networks and its application. International Journal of Distributed Sensor Networks, 2012. https://doi.org/10.1155/2012/310271

Kitchin, R. (2014). The real-time city? Big data and smart urbanism. GeoJournal. https://doi.org/10.1007/s10708-013-9516-8

Kruchten, P. B. (1995). The 4+1 View Model of Architecture. IEEE Software, 12(6), 42–50. https://doi.org/10.1109/52.469759

Kumar, S., & Jailia, M. (2018). Smart Cities with Spatial Data Infrastructure and Big Data -A Critical Review.

Laney, D. (2001). Laney D, '3D Data Management: Controlling Data Volume, Velocity and Variety.' (2001) 6 META Group Research Note 703D data management: Controlling data volume, velocity and variety. META Group Research Note. https://doi.org/ 10.1016/j. infsof.2008. 09.005

Li, Z., Zhu, Q., & Gold, C. (2005). Principles and Methodology, In Digital Terrain Modeling, CRC Press.

Maguire, D. J., & Longley, P. A. (2005). The emergence of geoportals and their role in spatial data infrastructures. Computers, Environment and Urban Systems. https://doi.org/10.1016/j.compenvurbsys.2004.05.012

Maraşlı, F., & Çıbuk, M. (2015). RFID Teknolojisi ve Kullanım Alanları. Bitlis Eren Üniversitesi Fen Bilimleri Dergisi, 4(2). https://doi.org/ 10.17798/ beufen.19847

Marjani, M., Nasaruddin, F., Gani, A., Karim, A., Hashem, I. A. T., Siddiqa, A., & Yaqoob, I. (2017). Big IoT Data Analytics: Architecture, Opportunities, and Open Research Challenges. IEEE Access, 5, 5247–5261. https://doi.org/10.1109/ACCESS.2017.2689040

Mell, P. & Grance, T. (2011). The NIST Definion of Cloud Computing. Recommendations of the National Institute of Standards and Technology. Special Publication 800-145. U.S Department of Commerce.

Naranjo, P. G. V., Pooranian, Z., Shojafar, M., Conti, M., & Buyya, R. (2019). FOCAN: A Fog-supported smart city network architecture for management of applications in the Internet of Everything environments. Journal of Parallel and Distributed Computing, 132, 274–283. https:// doi.org/ 10.1016/ j.jpdc. 2018.07.003

Open Data Institute (2016). 'What is open data'? (Accessed November 2016 at: http://theodi.org/what-is-open-data)

Palmieri, F., Ficco, M., Pardi, S., & Castiglione, A. (2016). A cloud-based architecture for emergency management and first responders localization in smart city environments. Computers and Electrical Engineering, 56, 810–830. https://doi.org/ 10.1016/ j.compeleceng. 2016.02.012

Pan, Y., Tian, Y., Liu, X., Gu, D., & Hua, G. (2016). Urban Big Data and the Development of City Intelligence. Engineering, 2(2), 171–178. https://doi.org/10.1016/J.ENG.2016.02.003

Pfaffl, M. W. (2001). A new mathematical model for relative quantification in real-time RT-PCR. Nucleic Acids Research. https://doi.org/ 10.1093/nar/ 29.9.e45

Piro, G., Cianci, I., Grieco, L. A., Boggia, G., & Camarda, P. (2014). Information centric services in Smart Cities. Journal of Systems and Software, 88(1), 169–188. https://doi.org/10.1016/j.jss.2013.10.029

Prandi, F., Soave, M., Devigili, F., Andreolli, M., & De Amicis, R. (2014). Services Oriented Smart City Platform Based On 3d City Model Visualization. ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences. https://doi.org/10.5194/isprsannals-ii-4-59-2014

Publication, B. S. I. S. (2015). Smart cities overview-Guide BSI Standards Publication. Retrieved from http: // shop. bsigroup. com / upload / Shop/ Download/PAS/30313208-PD8100-2015.pdf

Rahul, A., G, G. K., H, U. K., & Rao, S. (2015). Near Field Communication (NFC) Technology: A Survey. International Journal on Cybernetics & Informatics, 4(2), 133–144. https://doi.org/10.5121/ijci.2015.4213

Roche, S. (2014). Geographic Information Science I: Why does a smart city need to be spatially enabled? Progress in Human Geography, 38(5), 703–711. https://doi.org/10.1177/0309132513517365

Rolim, C. O., Rossetto, A. G., Leithardt, V. R. Q., Borges, G. A., Dos Santos, T. F. M., Souza, A. M., & Geyer, C. Á. U. F. R. (2014). An ubiquitous service-oriented architecture for urban sensing. Communications in Computer and Information Science. https://doi.org/10.1007/978-3-662-46241-6_1

Ryan, P., & Lee, M. W. (2019). SC24 Study Group: System Integration Visualization ISO/IEC JTC 1/SC24 Meetings, 20-25 January 2019 [PowerPoint slides]. Retrieved from: http:/ /www.web3d.org/sites/default/files / attachment/ node/2326/edit/23_ Peter Ryan_ SC24_ Systems Integration Visualization_ Smart Cities_Study_Group_2019.pdf

Sarabando, C., Cravino, J. P., & Soares, A. A. (2014). Contribution of a Computer Simulation to Students' Learning of the Physics Concepts of Weight and Mass. Procedia Technology. https://doi.org/ 10.1016/j.protcy. 2014.02.015

Schaller, J., Ertac, Ö., Freller, S., & Mattos, C. (2015). Geodesign Apps and 3D Modelling with City Engine for the City of Tomorrow.

Sexton, M., Dixon, T., & Van De Wetering, J. (2017). Smart Cities, Big Data and the Built Environment: What's Required? (March). https://doi.org/ 10.15396/ eres 2016_336

Sharma, P. K., Moon, S. Y., & Park, J. H. (2017). Block-VN: A distributed blockchain based vehicular network architecture in smart city. Journal of Information Processing Systems, 13(1), 184–195. https://doi.org/10.3745/JIPS.03.0065

Sharma, P. K., & Park, J. H. (2018). Blockchain based hybrid network architecture for the smart city. Future Generation Computer Systems, 86(2018), 650–655. https://doi.org/10.1016/j.future.2018.04.060

Silva, B. N., Khan, M., & Han, K. (2018). Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities. Sustainable Cities and Society, 38(January), 697–713. https://doi.org/10.1016/j.scs.2018.01.053

Söğüt, E., & Erdem, O. A. (2017). Günümüzün Vazgeçilmez Sistemleri : Nesnelerin Haberleşmesi ve Kullanılan Günümüzün Vazgeçilmez Sistemleri : Nesnelerin Haberleşmesi ve Kullanılan Teknolojiler (February).

Strömmer, E., Kaartinen, J., Pärkkä, J., Ylisaukko-oja, A., & Korhonen, I. (2006). Application of near field communication for health monitoring in daily life. Annual International Conference of the IEEE Engineering in Medicine and Biology - Proceedings. https://doi.org/ 10.1109/ IEMBS.2006.260021

TechAmerica Foundation's Federal Big Data Commission. (2012). Demystifying big data: A practical guide to transforming the business of Government. Retrieved from:http://www.techamerica.org/Docs/file Manager. cfm?f = techamerica- big data report-final.pdf

Voas, J., & Zhang, J. (March/April 2009). Cloud computing: New wine or just a new bottle? IEEE ITPro, 15–17.

Walravens, N. (2015). Mobile city applications for Brussels citizens: Smart City trends, challenges and a reality check. Telematics and Informatics. https://doi.org/10.1016/j.tele.2014.09.004

Washburn, D., Sindhu, U., Balaouras, S., Dines, R. A., Hayes, N. M., & Nelson, L. E. (2010). Help CIO understand smart city initiative. Forrester Research, Inc, 1–7. https://doi.org/10.1029/2004RS003041

Williamson, I., Enemark, S., Wallace, J., & Rajabifard, A. (2010). Land Administration for Sustainable Development Sustainable Development.

Url-1 <*https://en.wikipedia.org/wiki/Software-defined_networking*>, date retrieved 25.08.2019.

Url-2 <*https://www.investopedia.com/terms/h/hash.asp*>, date retrieved 18.08.2019.

Url-3 <*https://www.mindmeister.com*>, date retrieved 29.07.2019.

Url-4 <*http://www.nesnelerininternetizirvesi.com* >, date retrieved 15.08.2019.

Url-5 <*http://www.dublindashboard.ie*>, date retrieved 16.08.2019.

Url-6 <*http://rodger.global-linguist.com/smart-city-standards*>, date retrieved 03.09.2019.

Url-7 <*https://www.sedris.org/sdk_4.1.4/src/lib/srm/docs/srm_c_users_guide.htm*>, date retrieved 14.09.2019.

Url-8 <*https://www.iso.org/standard/60505.html*>, date retrieved 23.08.2019.

Url-9 <*https://www.iso.org/standard/38442.html*>, date retrieved 13.09.2019.

Url-10 <*https://www.web3d.org/working-groups/mixed-augmented-reality-mar*>, date retrieved 11.09.2019.

Url-11 <*http://www.ebelediye.info/dosya/akilli-sehir-cozumlerinde-dunya ornekleri*>, date retrieved 15.10.2019.

Url-12 <*https://medium.com/@canerguney/geleceğin-akıllı-şehirlerinde-kentlileri-neler-bekliyor*>, date retrieved 12.10.2019.

CURRICULUM VITAE

Name Surname **:** Emre Baştürk

Place and Date of Birth **:** Kırklareli, 18 January 1993

E-Mail **:** basturk761@gmail.com

EDUCATION **:**

- **B.Sc.** **:** 2016, Istanbul Technical University, Civil Engineering Faculty, Geomatics Engineering Department

PROFESSIONAL EXPERIENCE AND REWARDS:

- Internship – Bayraktar Mapping Agency (20 Days)
- Internship – LİHKAB 3905 (15 Days)