A COMPARISON OF SMART CITY INDICATORS FOR THREE TOP TEN US CITIES

By

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Abstract

A COMPARISON OF SMART CITY INDICATORS FOR

THREE TOP-TEN US CITIES

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The world population has been increasing each year, and the immigration from rural to urban cities has increased as well. The United Nations has estimated that more than 66% of people worldwide live in urban area, and this urbanization trend will continue to increase, thereby generating challenges to the cities as they strive to provide health care, schools, and transportation. The urban population explosion has also caused problems to the environment and overall urban economy as the need for more housing, jobs, and community services require smart solutions. The term, smart city, has many definitions, but all of them agree that technology is needed to improve sustainability, workability and livability in cities. Researchers have identified six factors that need immediate attention: transportation, economy, environment, people (society), living, and governance. The main objective of this study is to identify indicators for the above six factors to compare three of the top ten US cities of Los Angeles, Chicago and Houston based on these smart city indicators. A comprehensive literature review was conducted, which helped identify the six factors in each city and what each city needed to do to become a smart city, Chicago was determined to have the most smart city attributes,

while Los Angeles and Houston needed more improvement considering these smart city factors.

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Chapter 1

Introductions

1.1 Introduction

In this chapter, the background on the topic of smart cities is described. This description includes six factors that affect smart cities: smart transportation, smart economy, smart environment, smart (educated) people, smart living, and smart governance. The research needs, objectives and scope of this study are defined.

1.2 Smart Cities

In the last two and a half decades, words like, “smart city”, “smart growth”, “digital city,” “intelligent city,” and a “successful city,” have become more common in some countries and in engineering literature. To understand these concepts, it is very important to consider that cities are a key element for the future because cities have a huge impact on social, economic and environmental aspects (Mori and Christodoulou, 2012). Several approaches have been developed depending on technology, which helped to create what is now called “smart cities.” The concept of smart cities is not limited to one definition, one idea, or one application of the technologies of cities; the definitions of smart cities differ and mean different things to various people. Definitions vary from city to city, town to town, and country to country as they relate to development. Washburn et al. (2010) defined smart cities as “the use of smart technologies to make the critical infrastructure components and services of a city—which include city administration, education, public safety, healthcare, and utilities—more intelligent, interconnected and efficient” (Washburn et al., 2010). Washburn et al. investigated the ability of those components to enhance the livability, workability and sustainability of cities. Caragliu (2011) defines the concept of Smart City as "The city which invests in people and social capital, builds conventional transportation and modern information and communication technologies (ICT)

infrastructures; provides sustainable economic growth and high standard of life-quality, and administrates its natural sources with participative governance." To meet smart city criteria, Caragliu concluded the aspiring city needs six factors: "a smart economy, smart mobility (transportation), smart environment, smart people (society), smart life and smart governance.

Robert Hall of the US Office of Scientific and Technical Information (2000) had the following to say about a smart city in a 2000 report to the US Department of Energy:

> "A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rail/subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens," Hall (2000).

The US Office of Scientific and Technical Information's "vision of a smart city" (Hall 2000) indicated that livability, workability and sustainability of cities could be achieved when the infrastructure is developed. For example, livability provides a better quality of life for people. Even before Hall (2000), the Brundtland Commission Report (1987) had determined that citizens should have more access to a green, clean, safe, comfortable, healthy lifestyle while workability means developing an economy with more good jobs and sustainability is using resources to meet the needs of the present without compromising the ability of future generations to meet their own needs. Therefore, the smart city factors can be broken down into six categories based on Purnomo et al. (2016): mobility (transportation), economy, environment, people, living and government. Many indicators have been chosen in smart city to measure those factors, for example, growth in population, crime rate, and people without insurance, gross domestic product,

income levels, median house value, population density, education levels, poverty, green space, and access to information (see Figure 1-1).

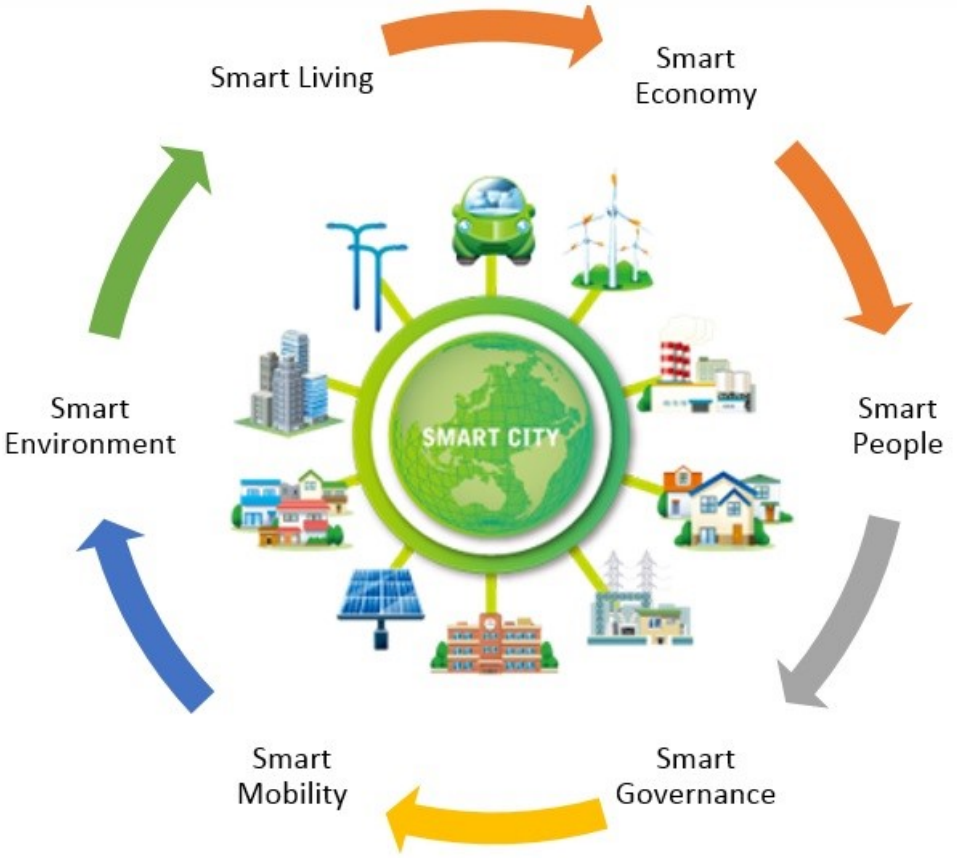

Figure 1-1 Smart City Factors

Source: Kompasina (2015)

1.2.1 Smart Transportation

Transportation is the movement of people or goods around the cities and from one location to another and around the world. In other words, “transportation is really a simple idea. We want to move ourselves or our things from one place to another

efficiently, reliably and safely" (Foxx, 2015). For example, commuting to work, attending college, enjoying a night out, delivering pizza and other activities in cities depend on transportation roads and transportation modes such as vehicles, cars railways, scooters, buses, bicycles, car shares, streetcars, ferries, and so on.

1.2.2 Smart Economy

Smart economy is the interface between an intelligent city and the economy. The smart economy objective is to improve business life, to facilitate and generate faster finding of business services, to participate in urban development, to increase gross domestic product, and to create jobs.

1.2.3 Smart Environment

A smart city environment is designed to enhance the sustainability, clean energy, clean air and clean waterfront. By reducing air pollution, water pollution, and CO_2 emissions, environmental conditions can help to develop a smart city. These developing sustainability and managing resources are dependent on technology as the core concept of smart cities.

1.2.4 Smart People

According to Nam and Pardo (2011), people with diversity, education and creativity are important to the growth of a smart city because people are generators for other factors. Smart people can create a smart economy, smart education, and smart transportation. Many indicators can measure smart people such as level of education, academic and technical degrees and additional training, as well as the ability to communicate in more than one language.

1.2.5 Smart Living

One smart city goal is to enhance the quality of life. Therefore, smart living is defined by providing a better life for citizens through health care, safety, quality of housing, social cohesion and other activities in society (Batagan, 2011).

1.2.6 Smart Government

Smart governance means various stakeholders are engaged in decision-making and public services. Information and communication technologies (ICT)-mediated governance, also called e-governance, is fundamental in bringing smart city initiatives to citizens to keep the decision and implementation process transparent. However, the spirit of e-governance in a smart city should be citizen-centric and citizen-driven

1.3 Research Needs

"A smart city is a city that monitors and integrates conditions of all of its critical infrastructure to include roads, bridges, tunnels, streets, subway, rails, seaport, airport, even major building, and can better optimize its resources, plan its preventive maintenance activities, and monitor security aspect while maximizing services to its citizens" (Pielage, 2000).

The United Nations reports that more than 54% of the world's population lives in urban cities, which means 3.6 billion people. By 2050, the percent is expected to rise to 66%, or 6.3 billion. In addition, the US population is 321 million with 80.7% living in cities; moreover, this population is projected to reach 424 million by 2075 (United Nations Funds, 2015). As the population increases, the economy will grow as well. This growth will affect cities in many different ways. Cities are facing many problems in healthcare, education, safety, transportation, and the environment. This means it is increasingly important for cities to come up with smart solutions to enhance sustainability, workability

and livability. Implementing smart city concepts will help solving some of the problems that growing cities face

1.4 Motivation

Finding solutions to the problems caused by increasing urbanization, cities struggling to manage extraordinary population growth and the effect this has on city populations. Cities are facing many problems in healthcare, education, safety, transportation, and the environment. To help solve these problems engineers and researchers have created a new concept called the "smart city." They chose the smart city concept because it has smart solutions for the previously defined six factors that influence city development.

1.5 Objectives and Scope

The main objectives of this study are:

- To identify indicators for the six smart city factors, and
- To compare the three top-ten US cities based on smart city indicators

The scope of this thesis describes smart city components and the different problems that face cities. At the same time, the research includes comparing three large cities in the United States with smart city indicators.

1.6 Methodology

To achieve the proposed objectives of this study, the following tasks were undertaken:

- Review the literature on smart city concepts using UTA databases, which include technical journals from ASCE, Engineering Village, and ProQuest to find research, and reports that are relevant to the smart city concept.
- Develop indicators for the six factors needed to achieve smart city development.

- Collect data about the three top ten cities in the United States and compare this data with Columbus, Ohio, which recently has been awarded smart city status.

Figure 1-2 shows the research methodology flowchart

1.7 Expected Outcome

Several outcomes will be presented and their potentials discussed in this thesis. As mentioned previously, the population is expected to increase in the next few decades and the economy will increase as well. This growth will affect cities in many different ways. Implementing smart city concepts will help solve some of the problems that growing cities face. The questions that this thesis attempts to answer are: How do the six smart city factors affect city growth? What are meaningful indicators of smart city development, and how do the three top-ten US Cities compare with smart city indicators?

1.8 Organization of this Study

This study consists of six chapters. The first chapter introduced the research topic. The second chapter includes the literature review for smart city concepts and the components that influence cities. The third chapter represents case study methodology needed to achieve the objectives. The fourth chapter contains the organization, evaluation and analysis of the data and results of this research. Chapter five represents comparisons of the three top ten cities with smart cities. Finally, the sixth chapter includes conclusions and recommendations for future research.

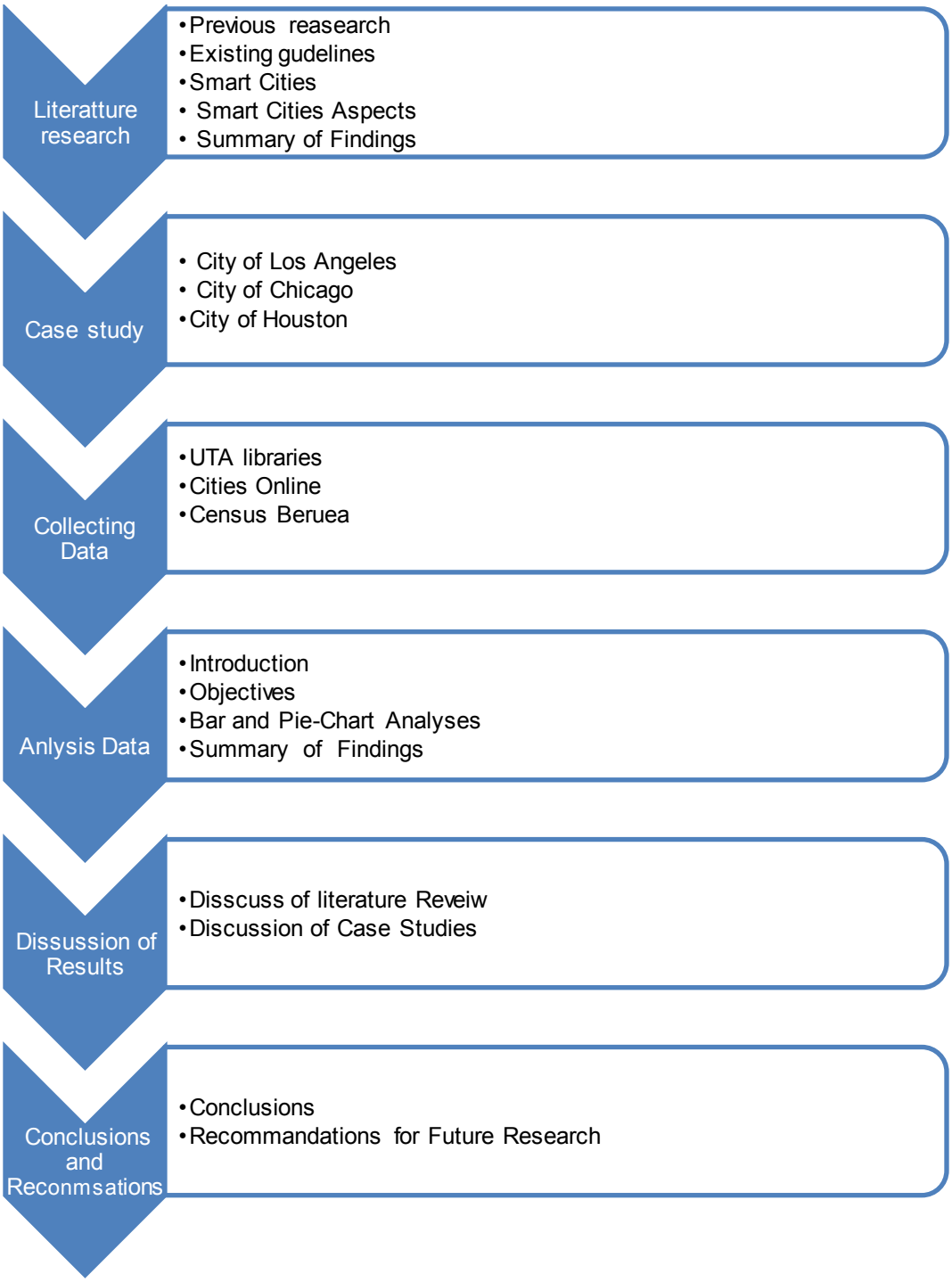

Figure 1-2 Research Methodology Flowchart

1.9 Chapter Summary

This chapter described the introduction of smart city concepts with current and future problems of cities. It also presents the plan developed for this study. The objectives, scope, methodology and expected outcomes of this research were presented.

Chapter 2

Literature Review

2.1 Introduction

Previous studies on smart cities, smart city indicators, and smart city factors are the foundation for understanding current studies. The concept of smart cities is so recent that studies need to be closely connected to ensure the continuity of research and its ability to show the way forward.

The goal of this review is to present available literature on smart cities, smart city indicators, and the six factors for a city to be accepted as a smart city. As stated in the Chapter 1, these six factors are transportation, economy, environment, people, living, and smart governance. In the literature, two groupings are represented. The first defines smart cities and the second discusses the six factors that make smart cities. Figure 2-1 illustrates smart city factors.

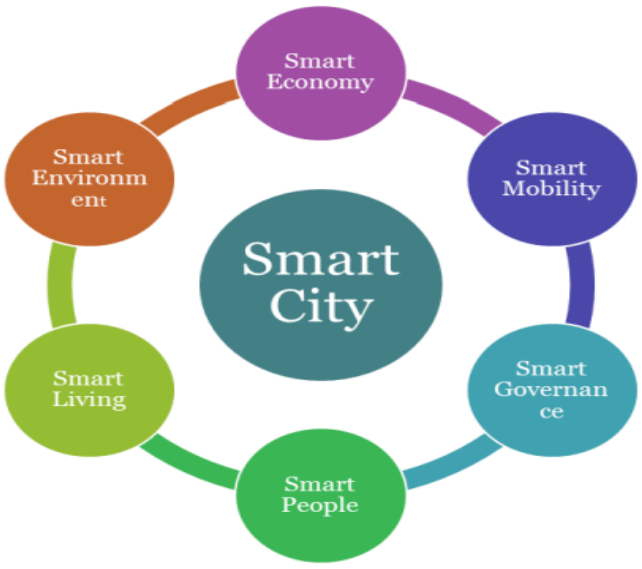

Figure 2-1 Smart Cities Factors
Source: Adapted from Batagan (2011)

2.2 Smart Cities

Currently, fifty-four percent of world's people live in urban regions, and 80% of the world's people will live in urban areas in the future. Urban dwelling is expected to increase in coming decades. This growth in population has generated many problems for cities in areas such as transportation, goods, energy, and others. Cities will need to find new ways to face these challenges in population growth and urbanization. Several studies and approaches have been developed that depend on technology to help to create the "smart city." Andrea (2011) defines smart city as a

> "city which invests in people and social capital, builds conventional transportation and modern Information and Communication Technologies (ICT) infrastructures, provides sustainable economic growth and high standard of life-quality, and administrates its natural resources with participative governance."

Anthopoulos and Fitsilis (2013) investigated 31 major cities in the world and identified many important e-services in cities such as environmental, e-government, e-business, e-security, and e-health services. At the same time, they discussed smart transportation, communication services, and e learning that will improve quality of life. Although they described the important aspects of smart cities, smart cities are still complicated in contexts and ideas.

Anthopoulos (2014) discussed three crucial concepts related to smart cities, which are fundamental theories, models and connotations. In fundamental theories, the urban space, smart growth, living labs, and creative industry are considered essential to a smart city, and ICT is the preferred methodology for leadership in these fundamental areas. On the other hand, eight various models have been identified to explain smart city analyses. These models have built a common conceptual framework for smart cities.

Anthopoulos (2014), in a case his study, depended on previous literature research and papers that were published between 1998 to 2012 by engineers, planners and architectural engineers in addition to the researches that published in conferences.

The purpose of a smart city is to provide better modes of life and good city living for people, along with basic utilities (Yuan and Li, 2014). Sustainability, less waste, better social life, and good efficiency are required in smart city concepts. With these requirements, transportation and communication are important keys to building smart cities (Roche et al. 2012). There will be more needs for infrastructure as more citizens move into a district or municipality.

Zubizarreta et al. (2016) investigated the smart city and provided a multidisciplinary analysis of actual developed cities throughout the world. In their study, they chose 63 applications from 31 cities in North America, Asia, Europe and South America. In the same study, European smart cities were described in terms of six important categories: economy, people, governance, living, environment, and mobility. Within these six categories, major problems, future problems, and smart solutions were discussed. A strong economy needs a large investment in new technology and new fields. The growth of population in cities requires more mobility. The authors faced difficult issues in some of the applications used. It was difficult to find technical and specific details because much of the information was private. This survey fell short in some areas, but it did help scholars define the main needs of smart cities.

As previously mentioned, population growth generates extensive challenges in cities in several areas such as air pollution, traffic congestion, waste management, safety, and health care. Ahvenniemi et al. (2017) investigated the differences and similarities between smart cities and sustainable cities to find a common framework. Many definitions and explanations are presented in the literature, but most of them can

be aligned with “achieving a balance between the development of the urban areas and protection of the environment with an eye to equity in income, employment, shelter, basic services, social infrastructure, and transportation” (Hiremath et al. 2013). A smart city is defined as using the newest technology to enhance quality of life in various domains such as infrastructure, transportation systems, logistics, and greenhouse gas emissions.

The many definitions for the smart city concept and its consequent framework have made it difficult for authors to decide which framework standard is the best for analysis. For these reasons, three criteria make up the framework, which allows them to measure information depth, details and constraints within the framework for a smart city. This analysis depended on the literature review, scientific sources, non-scientific sources, and websites. Based on their analysis, Ahvenniemi et al. (2017) concluded that the main aspects of a smart city include education, culture, innovation and Internet and Communication Technology (ICT), whereas a sustainable city focuses on transportation, environment, water, and waste management. Their survey showed that safety and healthcare are connected to both. They concluded sustainability should be a part of smart city analysis and can address all city challenges. Finally, they recommended using smart sustainable cities rather than the smart city.

Liu and Li (2013) investigated three domains for the smart city. The first domain is development of the smart city; the second focuses on the process of urban construction, and the third concentrates on land uses patterns. They discussed three core components of smart cities: technology, organization, and policies; Liu and Li (2013) further contend that these factors have high impact on government, people, environment, communities, economy, and infrastructure. They also discussed the problems facing cities worldwide, such as air pollution, unclean water, erosion, and climate change. Finally, they concluded that the smart city has a beneficial impact on environment and

provides smart preventative solutions. The economy would also profit with proper land use for smart city development.

Wang (2015) investigated intelligent transportation technology as a part of the smart city, and focused on traffic congestion forecasting abnormal conditions like events and bad weather. He copes with this problem by using a GPS to collect data from taxis to monitor unexpected conditions. Wang (2015) recommended internet, technology, mobile internet, phone apps, and cloud technology to locate large traffic congestion. This enables a driver to avoid those areas. This work has had a great impact on industry by regulating the traffic.

Wu et al. (2017) studied the risks and ideas in developing the framework for a smart city by using Chinese characteristics to evaluate background data. Regarding their ideas, they pointed to some important targets that have been achieved in a smart city such as sustainable development, affordable housing, enhancing quality of civilian life, and economic growth. Risks can be determined based on limitations of budgets, scarce resources, traffic jams, air pollution, unexpected accidents, and others. They concluded from the study that the use of technology and ICT contributed widely to solving problems and avoiding risk in cities. Internet and mobile communications work together to collect data in the cloud and provide the ability to analyze them for getting the total picture for the problems. This study contributes sustainability to our understanding of a smart city and inspires great goals for local government to help that segment understand the smart city.

The use of technology is the key to building smart cities. Technology is used to generate smart solutions for urban problems and in making cities a great place to live. The majority of the literature shows that a smart city can be achieved with smart factors. As stated previously, these smart factors are grouped into:

- Smart transportation (mobility),
- Smart economy,
- Smart environment,
- Smart people,
- Smart living, and
- Smart governance.

Each of these factors is discussed in more detail in the following sections.

2.2.1 Smart Transportation

Former Secretary of Transportation Anthony Foxx (2015) stated that, "Transportation is not just about concrete and steel. It is about how people move to live. "In the past 20 years, the concept of smart growth or a smart city has become very popular in the world. In terms of smart growth, many sustainable activities have been incorporated to enhance the quality of life in urban areas. Smart city projects have focused on transportation aspects because other smart growth principles can be achieved by increasing transportation options (VanderJeugdt 2014).

Advanced technology, such as cloud computers, sensor networks, actuators, and other technological devices can improve smart transportation systems (Singh, 2015). Sensors can be used to control and detect traffic congestions on the roads and highways, to improve and enhance safety and at high levels to maintain traffic flow levels. Singh (2015) concluded that smart transportation systems support several activities in cities such as economy, congestion, pollution, and affordable life. At the same time, this system has other benefits like easy collection of statistical information for accidents and alerting travelers.

Litman (2008) discussed the reduction of energy consumption and pollution emissions. He was building a process to evaluate emission reduction strategies as well

as cost effectiveness of pollution elimination. That was important because some activities inside the community such as economy and environment are dependent on transportation activities. None of these impacts should be ignored in the process of evaluating problems. Specifically, the problems related to air pollution caused by traffic congestion should be considered in any master plan of cities.

Rabieh (2016) proposes vehicular ad hoc networks, or VANET, which can address transportation problems such as pollution, congestion, and high fuel consumption. VANET depends on technology and a computing network that provides data for the analysis process. Transportation is one of the most important factors because it can change a city to a smart city (VanderJeugdt, 2014). Many problems relate to transportation. Several engineers and scholars define transportation as the movement of people, animals, or goods from one location to another. People and freight movement have always been the basic elements of economic and social life in communities. This movement could be on land (road, rail, and pipeline), water (shipping and boats) and air.

2.2.2 Smart Economy

Telecommunication Standardization ITU[1] (2015) defines the economy as "the ability to create income and employment for all the citizens in the livelihood for all people who are living the city." Besides, the Center of Regional Science (CRS) (2007) defines the smart economy related to jobs and companies. The CRS measured economy to be employment, unemployment and companies with high quality. Smart economy affects cities by creating jobs, employment and investing places. Today, deployed technology assists in growing the economy. For example, people can buy what they need online and

[1]Telecommunication is one of the sector Union which is called International Telecommunication Union. This office is working to generate Standard factors for sustainable city and smart city. http://www.itu.int/en/annual-report-2015/goals/Pages/goal3.aspx

then receive after one hour. By using this technology, the economy has been changed in some cities, which has helped these cities to attain the classification of smart city. Los Angeles, Chicago, Houston and other cities in the world have used the online market to develop their trades. At the same time, many advantages have achieved in the cities, when the people used online markets. For example, environment enhanced, crowd decreased and others.

2.2.3 Smart Environment

The smart city has six key standards, which can lead the city to be accepted as a smart city (Figure 2-1). Smart environment is one of the important of these standards. The concept of smart city deals with various activities such as residential, economical, office, and entertainment. To develop or build any activity, the developers should consider the concept of smart environmental protection (EPA 2015). Many different definitions have been found to explain the concept of smart environment, but all of them shared the ideals of the cleaner, greener, and safer environment. With the smart city, the quality of life enhances with a low ecological footprint. To achieve a good clean, green and safe environment in a city, the smart city will deal with the concepts of water features and waterways, including lakes, ponds, wetlands, and rivers. Besides these concepts, the smart environment entered trashes and landfilled areas. Nowadays, the cities municipalities have been using Technology to recycle and to get benefits, the environment protection has played as a key role in field that made people used technology to treated environmental problems. The problems can be reduced in the cities when several things should be considering in the master plan of cities.

Figure 2-2 Smart Environment

Source: Jaipur-Phulera-Ajmer Smart City (2017)

In the design for a smart city, engineers and designers should consider the following aspects to ensure low carbon with a low ecological footprint in the city's infrastructure.

- Reducing solid waste generation and improving waste management,
- Improving water efficiency and recycling,
- Reduction of emissions of traditional air pollutants and greenhouse gases,
- Increased provision of parks and open spaces,
- Reduced consumption of fossil fuels and increased use of renewable energy
- Educated people of protecting environment

2.2.4 Smart People (Society)

The Center of Regional Science (2007) defines smart inhabitants as people who have education. Batagan (2011) defines "smart people as having had a smart education which describes the investment in education systems, education of people, affinity to lifelong learning, education for employees, and social interaction regarding integration and public life, research and investment in innovation and creativity."

2.2.5 Smart Living

The term infrastructure has a two-part of meaning. First, infra means within. Second, structure refers to form. However, infrastructure has various meanings based on the context and its use. An example for infrastructure is underground pipelines and utilities for water, sewer, gas, oil, and conduits for telecommunications, which are lifelines to quality of living. To enhance the quality of life in smart city, Dr. Najafi el al. (2001) studied trenchless technology methods for improving construction activities in urban areas. Trenchless technology includes all the methods, pipeline, utility installation, and replacement with minimum surface and subsurface disturbance (Najafi and Gokhale, 2005). Trenchless technology can reduce negative environmental impacts of utility construction, enhance safety, and at the same time, reduce construction costs in crowded downtown areas, etc. Dr. Najafi et al. attest that the trenchless methods have more advantages than traditional excavation methods. For example, traffic disruptions at the jobsite are minimized by using trenchless technology over traditional digging. They concluded that trenchless is the best alternative to conventional open-cut installations to enhance the utility services in cities.

Al-Hader and Rodzi (2009) stated that: "Infrastructure represents the underground and aboveground cables and pipe networks supported with all related assets." Meanwhile, civil engineers are concerned with other urban area service functions

such as road networks, bridges, train and bus stations, schools, hospitals, universities and other public services. Faust et al. (2016) says infrastructure "is the lifeline providing goods and services to our cities, regions and nation." This infrastructure includes transportation, services, schools, etc. In the city, infrastructure plays a crucial role in creating change in society, economics, natural resources, structure, etc. Shahi (2012) divides infrastructure into three categories. The first category includes roads, bridges, houses, transportation facilities, telecommunications and safe drinking water. The second category consists of building facilities such as schools, colleges, universities, hospitals, industry and marketing. The third category encompasses communications facilities and informational aids such as computer communication software, televisions, magazines, mobile phones, radios and newspapers.

2.2.6 Smart Governance

Former Secretary-General of the United Nations, Kofi Annan[2], has stated: "We will witness a historic transformation in this life including living, learning, working, communicating and doing business…." Technology has enabled information to be spread around the world. Additionally, Boldyrev (2015) urged the usage of information technology in government and spoke of how information technology affected management in cities. He used articles that were published before the electronic revolution, which made our current cyber connections and instant communication possible. He did this to compare his results on evaluation of city administrations and concluded that the implementation of e-government needed long-term matched action in the information process. He also recommended that local government should train their employees with technological programs.

[2]Kofi Annan is the seventh Secretary-General of the United Nations. www.un.org/sg/en/formersg/annan.shtml

On the other hand, Meijer and Bolíva (2016) investigated smart cities using three factors: smart technology, smart people and smart governance. The methodology that they used was collecting and gathering data and information from previous studies and guidance of the Smart City Council (SCC). They concluded that smart governance is more complex and confuse than other factors

2.3 Classification of Cities

Cities can be divided into three categories based on population: small, mid-size, and big cities. Each category includes a number of cities based on the size of their population. Therefore, three of the top ten US cities were chosen for this study. This division in the research uses the classifications from the US Census Bureau[3], an organization that works to create data related to the population, economy, and cities in the United States.

Figure 2-3 divides the United States into four areas: South, Northeast, West and Midwest. The south area covers 16 states, and these states are known for culture, agriculture, oil industries and history. The southern states have a high rate of population growth, lower cost and lower income households compared with other states. The northeast area has nine states. This area has the lowest amount of land compared with other areas in the US. The northeast area can be classified into parts: Mid-Atlantic and New England. The Mid-Atlantic region includes Maryland, Delaware, Pennsylvania, and Virginia along with parts of New York, New Jersey, and North Carolina. New England is made up of New Hampshire, Rhode Island, Vermont, Connecticut, Maine, and Massachusetts. The western area of US has 11 states. The states in this part have mountains, dessert, and forests. The West covers more than half of the United States

[3]US Census Bureau can be define as official count of survey in United States of America https://www.census.gov/data.html

and is the largest section. California is the largest state in the West. The Midwest has 12 states, including Missouri, Wisconsin, Illinois and Michigan. Several large industries are located in the Midwest because it located in the center of the US each state contains some cities where these cities have classified into three types: small, mid-size and large cities. Many organizations study the ways that can consider the type of cities. Small, mid-size and large cites will now discussed in turn.

2.3.1 Small Cities

Several factors can be considered to classify cities as small, but the most important one is population. The US Census Bureau (2013) determined that if the population has less than or is equal to 50,000 people, the city is a small city. Other classifications as the Geographic Areas Reference Manual[4] (GARM) defined small city as one with a population of 100,000 or less. The United Nations (2013) also considers small cities with populations of less than 100,000. On the other hand, some researchers and engineers have classified cities using A, B and C levels, where level A represents cities have more than one million people, level B ranges from 250,000 to one million people, and level C is less than 250,000 people (Brown et al. 1994).

[4]Geographic Areas Reference Manual (GARM). https://www.census.gov/geo/reference/garm.html

Figure 2-3 The United States Map Division by Areas

Source: US Census Bureau Regions (2013)

Intaratip (2013) investigated city categories of small, medium and big cities in his MS thesis. He used levels B and C, but he ignored level A because based on his study, the level A would come up with very small number results for these categories. At the same time, the methodology used in the study consisted of three factors: population, land size and population density. In term of population, less 50,000 is considered small, from 50,000 to 250,000 is a medium city, and more 250,000 is a large city. The minimum population of small cities is about 2000. Land size is the second factor that can be used to classify cities, where the average land size is about 11.8 square miles. Therefore, small cities have the smallest number on average, medium and standard deviation. Finally, the third is the population density. The average of small cities is about 2,883

persons per mile. Intaratip (2013) concluded that the classification of cities as small, mid-size and big cities is important because cities affect the cost of developing facilities, and the small cities have a small size of land and population. On the other hand, a large city has a big population and large land size, while typical mid-size cities have a moderate population and a large land use. The results showed that the utility service needed to develop a small city is less than those in mid-size and large cities.

Frazier (2000) investigated three small cities in the southern area of the United States: Roanoke, Asheville, and Johnson City. These criteria for selecting of the cities were that they should be in the southern part of the US and should have a population less than 100,000. In the study, the comparison among three small cities showed that Roanoke and Asheville had a basic 1920s revival for small cities with landscaping while Johnson City did not. In Addition, this study addressed the biggest problem in southern cities, which was creating cities with different classes that ignored each other. For this reason, the authors came up with a design, which reinforced the social stability and civic unity in the community. On the opposite side, the study did not look at the problems related to the growth of the population and community divisions.

2.3.2 Mid-Size Cities

As noted previously, according to the US Census Bureau classification general scheme, a mid-size city is a city, which has more than 250,000 and up to 1,000,000 people: however, this range could change according to the authors, researchers or organizations involved in classification of cities. For example, the United Nations Human Settlements Program (2013) used the classification that if the cities have between 100,000 to 500,000 people, these cities considered medium cities.

On the other hand, the National League of Cities[5](NLC) published a report in 2005, which investigated 996 cities with populations between 250,000 and 500,000. The study did not include cities less than 250,000 because they believed that in small cities, it was harder to find the necessary data for classification. At the same time, the study excluded the cities of more than 500,000 to avoid data abnormalities. The study included six factors, which included population, density of population, rate of growth, and medium age of residents, education level and medium house income. The report found that the urban sprawl cities are located in the Midwest and South. In these two parts, the result was an average population size with an average density, but a low birth rate. The West had high levels of older citizens, better education, wealth and good income with high homeownerships. The North had good education, a low number of homeowners, high income, and younger people. Finally, the East had a high population, older housing, a medium income, less education and citizens that are more diverse.

Blankenship (2007) examined functions of 963 cities like expending, the taxing and debt. Cities have classified using the National League of Cities (NLC), and 903 cities included more than 500,000 population. The methodology used in the study included both regression and descriptive analysis to explain the fiscal behavior of the cities. Conclusions were divided according to strengths and weaknesses. The strength was fresh insight data into the fiscal behavior of cities based on the classification above. The cities established a good framework of finance for large US cities, and the study provided empirical information in the cities. On the other hand, the weakness was that some data of government data failed to differentiate among cities without revenue sources and expenditures.

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[5]National League of Cities, (2005). *From Meltingpot cities to Boomtowns: Redefining how we talk about America's cities*. Retrieved April 22, 2006, from http://www.nlc.org/content/Files/RMPtypologiesrpt06.pdf

Giffinger et al. (2007) classified cities based on cultural and social aspects as well as quality of health, geographic and economic terms. They ignored the population and city size in their classification. The methodology used in this study was a collection of data using the internet and interviews based on the importance of the position in academia and in local government. The research included 85 cities, the medium-size cities were divided into five classes. All classes were important to name in medium-size cities. In addition, they found disadvantages in medium-size cities because of their lack of size.

2.3.3 Large Cities

The definition of large cities is not limited to one idea or criterion, but the classification depends on the factors that are used. The United Nations (2013) has defined large cities from 500,000 to 1,000,000 and metropolitan cities more than 1,000,000 people. The Urban Audit (2012) divided cities into six parts: small (50,000 to 100,000), medium (100,000 to 250,000), large (250,000 to 500,000), X large (500,000 to 1,000,000), XX Large (1 million to 5 million) and global city (more than 5 million). This research selected three of the top ten cities in the United States. The three big cities were Los Angeles, Houston, and Chicago.

2.4 Chapter Summary

This chapter reviewed the current literature on smart cities with six factors, which are transportation, economy, environment, people, living and governance affecting cities. Additionally, this chapter included the classifications of cities into small, middle and large cities. The classifications were based on the size of population. Standards were analyzed from the US Census Bureau, the National League of Cities (NLC), the UN, and Centre of Regional Science (2007) report on “Smart Cities Ranking of European Medium-Sized Cities,” as well as studies by different authors.

Chapter 3

Methodology

3.1 Introduction

The previous chapter presented smart city concepts and described elements that make a smart city. Classification of small, medium and large cities based on their population, population density and land size was provided. This chapter includes the methodology implemented to fulfill the goals of this thesis stated in the first chapter.

3.2 Background

The main objectives of this study were to identify and compare six smart city factors with comparing three top-ten US cities with smart city indicators. Smart city indicators vary in literature, but all of them have the same perspective, which is to enhance cities in several areas.

3.2.1 Selecting Cities

As stated in chapter 2, the classification of cities is dependent on the population and population density. In this study, the large cities have more than one million people living in the urban area. For this reason, three US cities, Los Angeles, California; Chicago, Illinois; and Houston, Texas were selected as case studies for this research. These cities have a population of more than 2 million people, In addition to population; each city is located in a different US region, West, Midwest and South. These cities also rank in the ten top cities of the United States (Census Bureau 2015). Figure 3-1 shows the ten top cities in the United States.

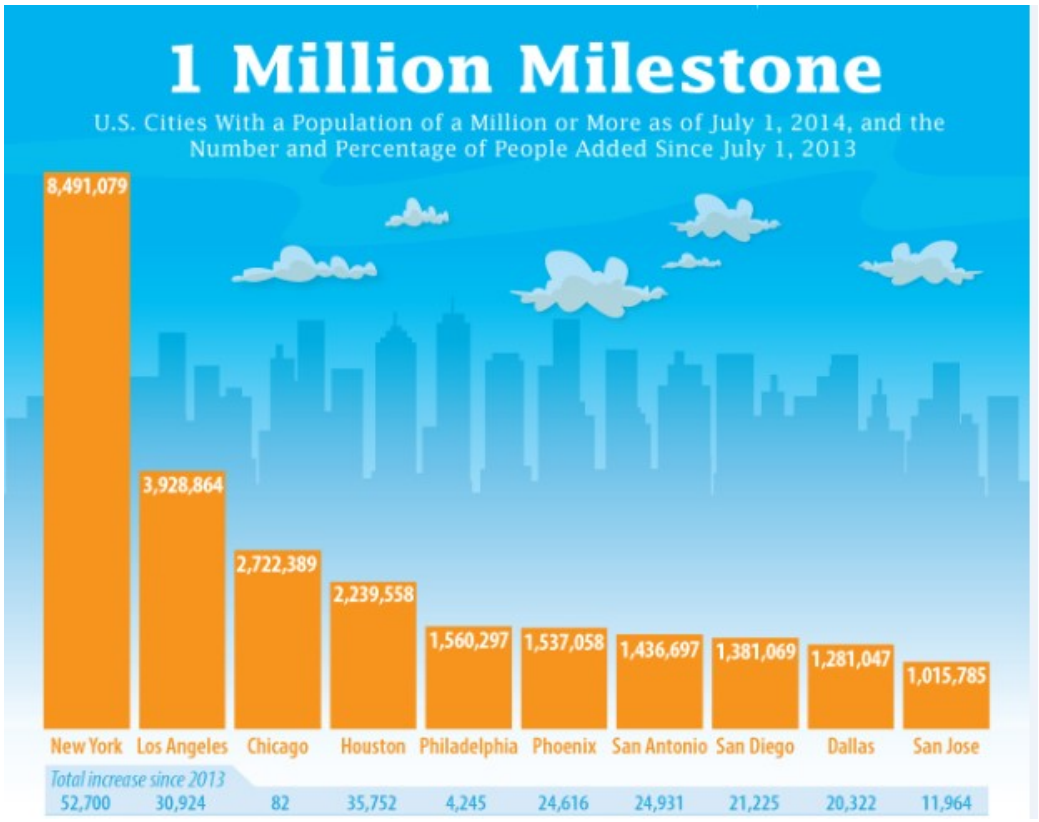

Figure 3-1 Ten Top Cities by Population in the United States

Source: US Census Bureau (2015)

3.2.2 Identifying Indicators for the Smart City

The indicators that were selected for describing the smart city factors were derived from previous studies and literature in addition to smart city websites. Thirty-five indicators were designated for this research with different measures or weight (see Table 3-1). The quality of each indicator for the three cities and for the newest designated US smart city, Columbus[6], Ohio was compared. Quality comparisons were applied to plan for these cities such as development of sidewalks, waterfronts, universities, parks, schools and some other programs unique to each city.

[6]Department of Transportation selected Columbus Ohio state as smart city. (https://www.columbus.gov/smartcolumbus.

Table 3.1 Indicators for Smart Cities

Factors	Indicators
Transportation	• Taxi one mile (normal tariff) • Main means (walking, car, bike, motorbike, bus, tram/streetcar, trains/metro)
Economy	• Number of companies • Poverty • Median income • Employment • Unemployment • Growth domestic product • Growth rate • Gasoline prices
Environment	• Air pollution • Air quality • Drinking water pollution and Inaccessibility • Dissatisfaction with sanitation service (garbage pickup/landfill site) • Dirty and untidy areas • Noise and light pollution • Water pollution
People (Society)	• Education attainment • High school graduates • Bachelor's degree graduates • MS, PhD or professional degrees
Living	• Housing (own or rent) • Median house value • People with health insurance • Median average age • Apartment rental prices • Crime

3.3 Data Collection

In this research, data sources were collected from existing literature. The literature used consisted of transportation, environment, water management, and development.

3.4 Analysis

Data and information collected are analyzed and evaluated to compare with smart city indicators, and the conclusions were derived. The analysis and collected data explained in chapter 4 while the comparisons are in chapter 5. The results of analysis have illustrated with use of bar charts, pie charts, histograms and tables.

3.5 Chapter Summary

This chapter covered an overview of the methodology used in conducting this research. Besides the methodology, selected cities were selected; Los Angeles, Chicago and Houston, from a list of ten top US cities. Finally, several methods and techniques were used to collect data and information for this study.

Chapter 4

Results and Discussion

4.1 Introduction

In the previous chapter, the methodology of this research was described. This chapter presents results and analysis for this study.

4.2 Three Top Cities in US

Figure 4-1 shows the on-map distribution of the three large cities that have chosen for this research. As stated previously, these cities were selected based on population, population density and location.

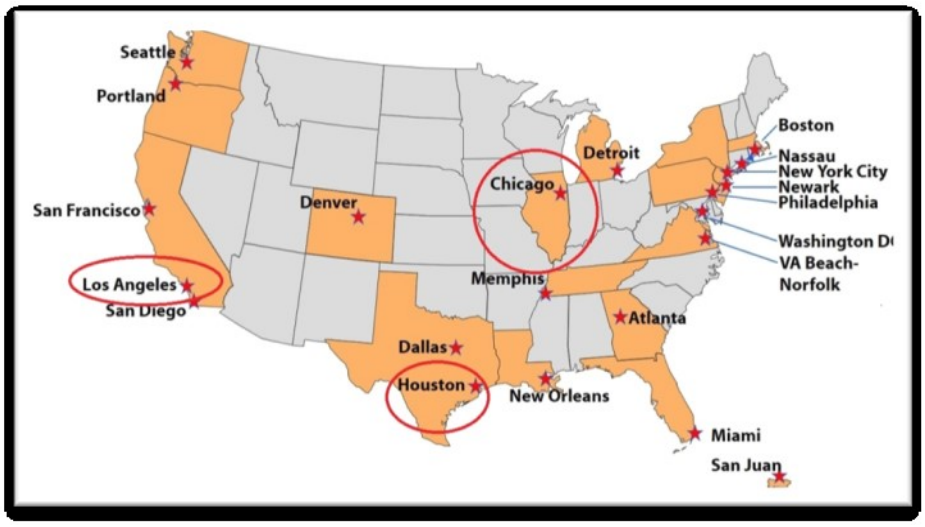

Figure 4-1 Location of Select Cities Study

Source: US Census Bureau Regions (2015)

Table 4-1 represents the top ten US cities in population. This table shows ranking, and population. Los Angeles, CA, has the highest population with 3,971,883 Chicago, IL, is the second with a population of 2,720,442, and Houston, TX, and is the third with a population of 2,296,224. The City of New York has not selected because its

population is too large for the comparison used in this thesis. Each of the three cities are now discussing in turn.

Table 4.1 Population in Ten Top US Cities

Source: Adapted from US Census Bureau (2015)

Ranks	Name of State	Name of City	Population (2015)
1	New York	New York	8,550,405
2	California	Los Angeles	3,971,883
3	Illinois	Chicago	2,720,546
4	Texas	Houston	2,296,224
5	Pennsylvania	Philadelphia	1,567,442
6	Arizona	Phoenix	1,563,025
7	Texas	San Antonio	1,469,845
8	California	San Diego	1,394,928
9	Texas	Dallas	1,300,092
10	California	Son Jose	1,026,908

4.2.1 Los Angeles

Los Angeles is located in the state of California in the West Region of the United States (Figure 2-4). The population of Los Angeles has grown from 50,000 in 1890 to its

current population of 3,971,883 (Census[7], 2015). The population expected to reach 7,888,340 by 2050. The city occupies an area of is 234 square miles. Population density is 8,474.8 persons per square mile. Los Angeles consists 15 districts (Figure 4-2). The growth of the population together with increasing visitors has been affecting the city's infrastructure. For these two reasons, the government launched Plan 2035[8]. This plan has addressed several problems within Los Angeles. At the same time, the focus was on major topics such as transportation, environment, economy, education, etc. For example, the transportation plan has included many ideas like developing a transportation network, which includes roads, streets and highways. It also includes freight, pedestrian, motorists, and bicyclists.

On the other hand, the Los Angeles local government works to connect all services in all departments. Technology has played a key role to link the services. In addition to government, people from different organizations help the decision makers. The open data to the public and citizens have built a strong connection among people, officials, students, and others fulfilling the need to help each other and the society. The people in Los Angeles have whole access to open data and they can attend the city council meeting.

[7]Census can be defined as the official bureau or website that deals with information or data related to the people or cities such as population, project population, density, area, environment, economy, transportation issues and some others activities linked to the society. https://www.census.gov.

[8]Plan 2035 named by Los Angeles government as general plan for current and future plan of city where the plan included transportation issue, safety, environment, health care, move of commercial goods.

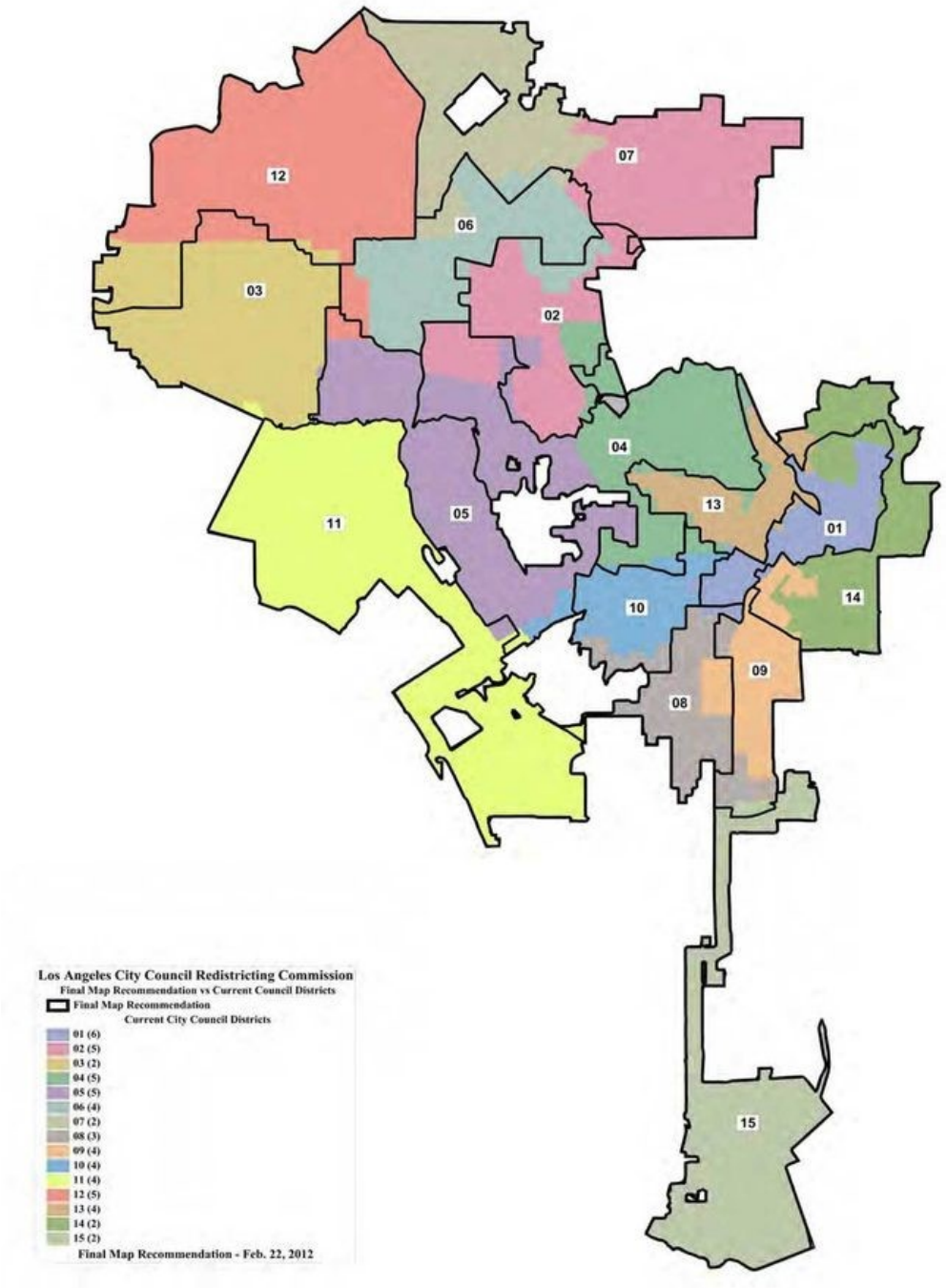

Figure 4-2 Los Angeles Districts

Source: City Council of Los Angeles (2012)

4.2.1.1 Transportation (Mobility)

Table 4.2 shows the most important data related to the plan of Los Angeles. The plan named Plan 2035, includes waling, bicycle network, vehicle network, fright movement, street design and others activities as shown table 4.2. In addition to the plan 2035, Technology has invested in the transportation and they are trying to connect all indicators together, which provide more services.

Table 4.2 Transportation Plan for Los Angeles for 2035

Source: Comprehensive Plan City Council

Transportation plan	Description
Walking (64,000 people walk to work)	• Provide wider sidewalks (10,750 miles) • Add pedestrian signalizations • Plant street trees • Upgrade all sidewalks to good conditions
Bicycle network (16,000 people bike to work)	• Increase protected lanes • Increase bikeway-network mileage and encourage people to use them • Build bike parking near bus stops and rail stations • Plan to provide safety, convenience, and comfort within the network • Start bike sharing program
Vehicle network	• Increase vehicle network • Increase number of parking places • Expand car-share pilot program • Develop first mile and last mile connection • Improve electric vehicles
Goods movement	• Increase freight carried by railroads and other modes by 50% • Develop the freight management work program to reduce traffic and congestion • Designate route for freight vehicles on city street
Street design	• Increase the street • Increase roadway • Build LA river path • Implement new street in the plan
Transit	• Dash bus- using technology to make payment easy and faster • Expand parking for cars • Improve the quality of bus stops

Table 4.3 represents the main mean travel percent in Los Angeles including car, bike, walking, train, motorbike and bus where car has the higher number (76.06) and the walking is second with biking. Table 4.3 also includes the commute time to work which is (30.1) min and the cost of taxis for one mile in normal traffic. Therefore, Los Angeles has ranked as having one of the top ten cities' most congested traffic and crowded cities in the world (Smart City Council 2013).

Table 4.3 Main Transpiration Means for Los Angeles

Source: Numbeo.com (2016)

Factor	Indicator	Measures
Transportation	• Cost of Taxi for one mile (normal tariff)	• $2.7
	Main means of travel • Car • Walking • Biking • Motorbike • Bus • Trains/Metro • Others	 • 76.09% • 4.35% • 4.35% • 2.17% • 2.17% • 2.17% • 8.7%
	• Average commute time to work (min)	• 30.1

Figure 4-3 describes the main means travelling of transportation for Los Angeles. It is clear from the pie chart that car has a larger area than others do. For this reason, the Los Angeles government needs to come up with a plan to reduce car use. By reducing car use, transportation traffic and other related issues can be reduced. Citizens should be encouraged to use other means like mass transportation (if any), bikes or walking.

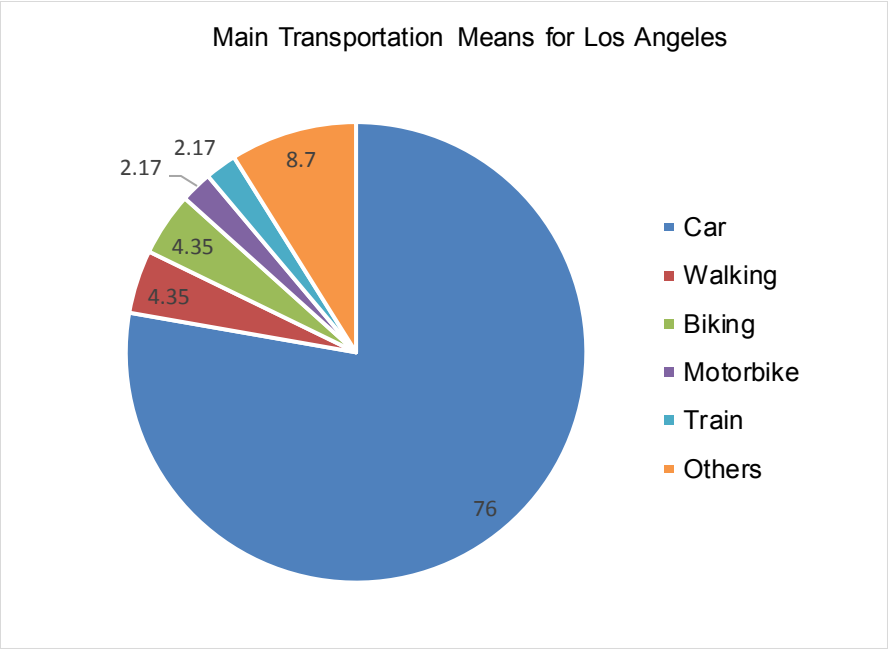

Figure 4-3 Main Transportation Means for Los Angeles

4.2.1.2 Economy

Several economic studies and reports have investigated the economy based on various indicators such as unemployment, labor force, medium house income and other sources. They found that the number of unemployed has fallen from 12.4% in 2010 to 7.4 % in 2014 (Tesoro, 2014). However, economic growth has not been spread equally in the state of California because some counties and cities are facing critical challenges related to education, housing, health care, air pollution, infrastructure and others. The City of Los Angeles has the same conditions. Wherein some areas have improved business, while in other areas, businesses continue to struggle. Overall, the economy of Los Angeles has grown during the last few years.

Employment in Los Angeles County: Pre-Recession Peak to Trough to Current

Indicator	Nonfarm	Household
Peak Month	Mar-07	Nov-07
Peak Employment (000s)	4	4,649.1
Trough Month	Feb-10	Dec-09
Trough Employment (000s)	3,879.5	4,257.9
Peak to Trough Change (000s)	-356.1	-391.2
Peak to Trough Change (%)	-8.4	-8.4
Current Month	Jul-14	Jul-14
Current Employment (000s)	4,185.5	4,615.2
Trough to Current Change (000s)	306.0	357.3
Trough to Current Change (%)	7.9	8.4
Remaining to Previous Peak (000s)	-50.1	-33.9
Remaining to Previous Peak (%)	-1.2	-0.7

Source: Employment Development Department

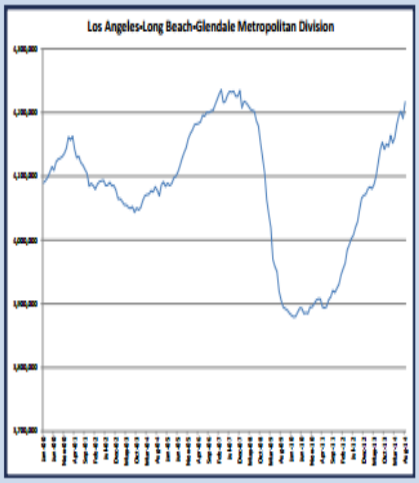

Figure 4-4 Employment in Los Angeles

Source: Tesoro (2014)

Figure 4-4 shows some details about Los Angeles from 2012 to 2013. First, total employment grew by 1.3 percent, with about 1.56 million jobs held by those working for the City. On the other hand, private employment also increased by 1.8 percent with 1.32 million jobs. Second, the average wage increased by 2.4 percent. Finally, construction grew by 4.1 percent with $ 2.75 million.

In this study, the indicators were selected to investigate the economic factors of L.A. to include standard of living and economic development. The indicators of economic standards include income, costs, household expenditures, and poverty. Besides, each indicator has a measurement. For example, the income measure is represented by median and mean income of household. On the other side, the economic development indicator includes economic growth, employment, unemployment, gross domestic product (GDP) and GDP growth rate. At the same time, each indicator is measured by some

factors. For instance, economic growth factors include the measures as estimate average, annual percentage, and total employment by full time work with similar data for others factors as shown in Table 4.4.

Table 4.4 Economic Indicators for Los Angeles

Source: US Census Bureau (2015)

Domain	Indicators	Measure
Economy	• Income	• $50,205 median household[9] • $79,303 mean income
	• Jobs	• 1,858,133 employment
		• 212,907 unemployment
	• Poverty[10] ratio	• 22.1% individuals below the poverty level
	• Companies	• 497,999 number of companies in 2012
	• GDP capita	• $54,629.5
	• GDP growth	• 2.39%
	• Gas (per gallon price)	• $ 2.91

The median household income is about $50,205 a year and the mean income is $79,303. Employment is around 1,858,133, and unemployment, is 212,907. The poverty ratio measures about 22.1 percent below the poverty level. In Table, 4.4. The number of companies with a start-up or origin in Los Angeles is around 497,999. Finally, Table 4.4 describes GDP capita and GDP growth for Los Angeles.

[9]Median household income is the income of household that half of homes are more than median and other half is less. Median is always used to determine the affordable housing

[10]US Census Bureau (2015) defines poverty, as the level of income requires for basic needs of people. If those people or households have less than those incomes, Census measures considered them to be in poverty level. http://poverty.ucdavis.edu/faq/what-are-poverty-thresholds-today

4.2.1.3 Environment

Table 4.5 covers the measures for the environment including air pollution, water pollution, noise and light pollution, dirty and untidy areas of city, and drinking water pollution and inaccessibility. Air pollution comes from many sources: stationary, which contain statistics for factories and plants, and sources, which include cars, trucks and buses. Those measures have ranked from less than 30 to a low, <30 to < 60 is moderate and more than 60 is high. The air pollution has ranked as moderate, and water pollution is high. The noise, and light pollution have ranked high. The drinking water pollution and inaccessibility ranked as moderate. Finally, the dirty and untidy are moderate. As a result, the environment of Los Angeles needs perfect plan to achieve the growth population in the city.

Table 4.5 Environmental Indicators for Los Angeles

Source: Numbeo.com (2016)

Domain	Indicators	Measure
Environment	• Air pollution	• 57.37% (moderate)
	• Water pollution	• 63.33% (high)
	• Noise and light pollution	• 62.3% (high)
	• Dirty and untidy	• 50% (moderate)
	• Drinking water pollution and inaccessibility	• 43% (moderate)

4.2.1.4 People (Society)

Educational attainment is the most important indicator used to measure smart people in the society. Los Angeles has implemented a variety of programs to improve its preschools, primary schools, middle schools, high schools, colleges and universities. A variety of programs has been involved in the education, which contributes to the

development of the education programs. Some programs address youth education while others help to connect education and job opportunities. For these reasons, the education attainment has increased to reach 75.5% of the population. Table 4.6 shows details about the education conditions in Los Angeles for people measured the people over 25 years old. Others degree in Table 4.6 means a degree that does not include high school, e.g., a bachelor's degree.

Table 4.6 Smart People Indicators for Los Angeles

Source: US Census bureau (2015)

Domain	Indicator	Measure
Education	• Population 25 and over	• 2,615,382
	• Higher school graduated	• 19.6% (513,485)
	• Bachelor's degree	• 21.2% (553,583)
	• Graduated or profession degree	• 10.8% (282,529)
	• Other degree	• 23.9% (627,691)
	• Education attainment	• 75.5% high school or higher

Figure 4-5 shows the number of students graduated from high school from 2012 to 2015. In 2011, the education attainment increased by 73.9 to reach 17.5 percent in 2015.

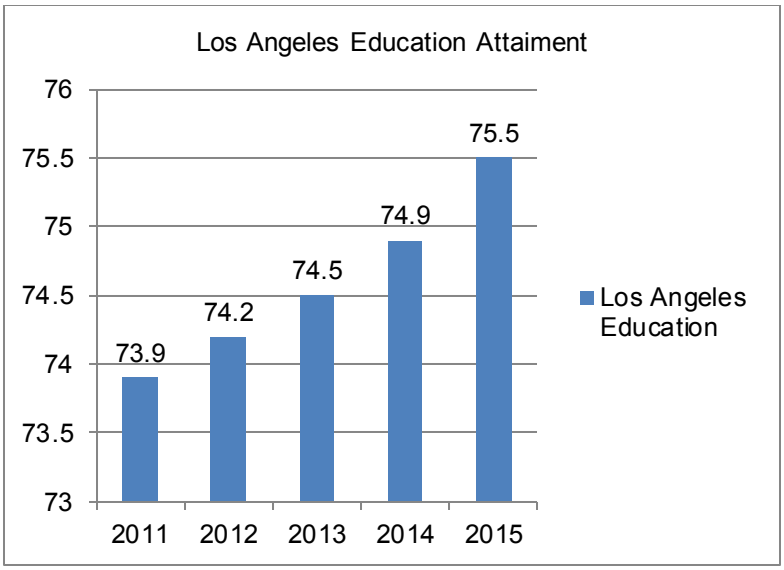

Figure 4-5 Education Attainment for Los Angeles

Resource: US Census Bureau (2015)

4.2.1.5 Living

Table 4.6 shows indicators related to living in Los Angeles. The indicators include housing (owner vs. rent), median house value, people without insurance, median average age and total crime. Table 4.6 shows rental homes are more than owned homes.

Table 4.6 Living Indicators for Los Angeles

Source: US Census Bureau (2015)

Domain	Indicator	Measure
Living	• Housing (1,342,761)	• 36.8% (494,136) owner • 63.2% (448,624) rent
	• Median house value	• $471,000
	• People without insurance	• 21.2%
	• Median average age	• 34.9
	• Buy apartment prices per square feet city center	• $472
	• Total Crime	• 2,994

4.2.1.6 Governance

Los Angeles has used open-data for public and local government works to connect the city's department of services. They used 311 services to answer requests through their online 311 systems. Los Angeles improved its 311 system by changing to another system called MyLA311. For the first time, citizens, civic and city departments can access all requests and the databases from one place by using the MYLA311 system.

4.2.2 Chicago

Chicago, Illinois is located in the Mid-West. As noted previously, the population of Chicago is estimated at 2,720,546 (Census, 2015), and the projected population is around 3,553,035 people by 2050. Total area is 227.63 square mile, and the density of population is about 1,184.8 people per square mile. The city of Chicago has called Windy city, the city of big shoulders, the second city, and the city that works. Besides, more than 40 million people visit the city of Chicago annually.

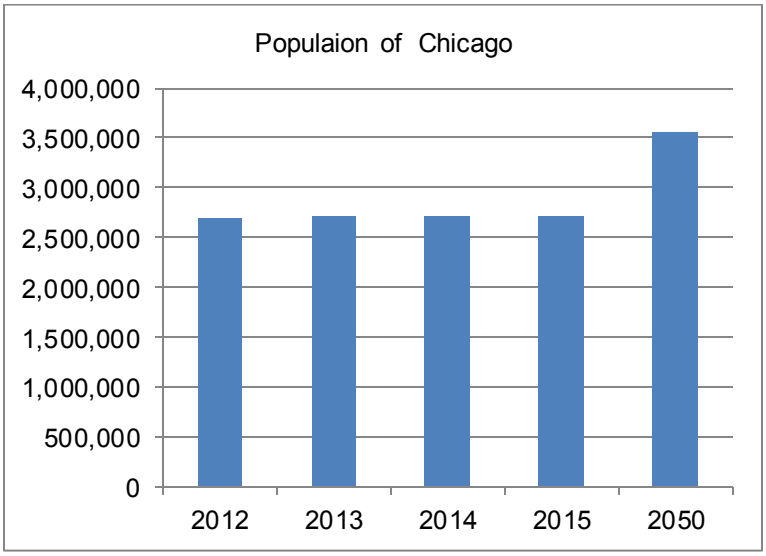

Figure 4-6 City of Chicago Population

Source: US Census Bureau (2015)

4.2.2.1 Transportation (Mobility)

Modes of transportation in Chicago include bike, car, transit, and walking. The Chicago Transportation Department has implemented many plans to develop the transportation modes. For example, the bicycle plan, which is called the Cycling 2020 plan, has been proposed to create new bicycle routes, to encourage people using bicycling and to protect them. Besides these goals, the plan includes reducing using cars. Table 4.7 shows transportation indicators plans. The bike net increase to 13,000 bike racks, and 3000 share bicycles. The red line provides a whole day services. Besides, the plan includes the developing of water movement. The plan contains a new method to build or repair sidewall. The local government and the owner of house are sharing together the prices for reconstruction sidewall.

Table 4.7 Transportation Indicators for Chicago

Source: City Council Comprehensive plan

Transportation Plan	Description
Cycling 2020 plan	• Chicago has more than 200 miles of bike routes and more than 13,000 bike racks • The plan indicates a 746-mile network • Shared 3,000 bicycles with 300 stations in 2013.,and the number increased from 4,000 to 400 stations in 2014
Red line[11]	• Provides red line with 24 hour train service

[11]Red line is one of public transport in the city of Chicago, which provides all day services train. http://www.transitchicago.com/redline/

Table 4.7 - Continued

Bus transit	• Buses ready for increased transportation
Water transportation	• Use water as transportation
Share cost sidewalk program	• Government and owner paid to build sidewalk

Table 4.8 represents indicators related to Chicago transportation. This table presents time for commuting to work. In Chicago, more people used the cars to commute. For this reason, the cars are ranked number one. Train is second ranked after cars. Walking ranked third while Biking, bus and motorbike have come right after. Therefore, the Chicago plan addressed part of the transportation problems from 2013 to 2017. By 2020, the PLan2020 should be complete.

Table 4.8 Transportation Indicators for Chicago

Source: Numbeo.Com (2016)

Domain	Indicator	Measures
Transportation	• Cost of Taxi for one mile (normal traffic)	• $ 2.25
	Main means of travel • Car • Walking • Biking • Motorbike • Bus • Trains/Metro • Others	 • 56.52% • 13.04% • 1.5% • 1.5% • 4.35% • 17.39% • 5.7%
	• Average commute time to work	• 34.1%

Figure 4-7 represents the main transportation means for Chicago. The blue color represents the car usage in the city, and it has the largest area in the pie chart. The train is a second. The brown represents the walking and it has less area than cars. Biking, motorbike, bus and others mean travelling have less area than car and trains.

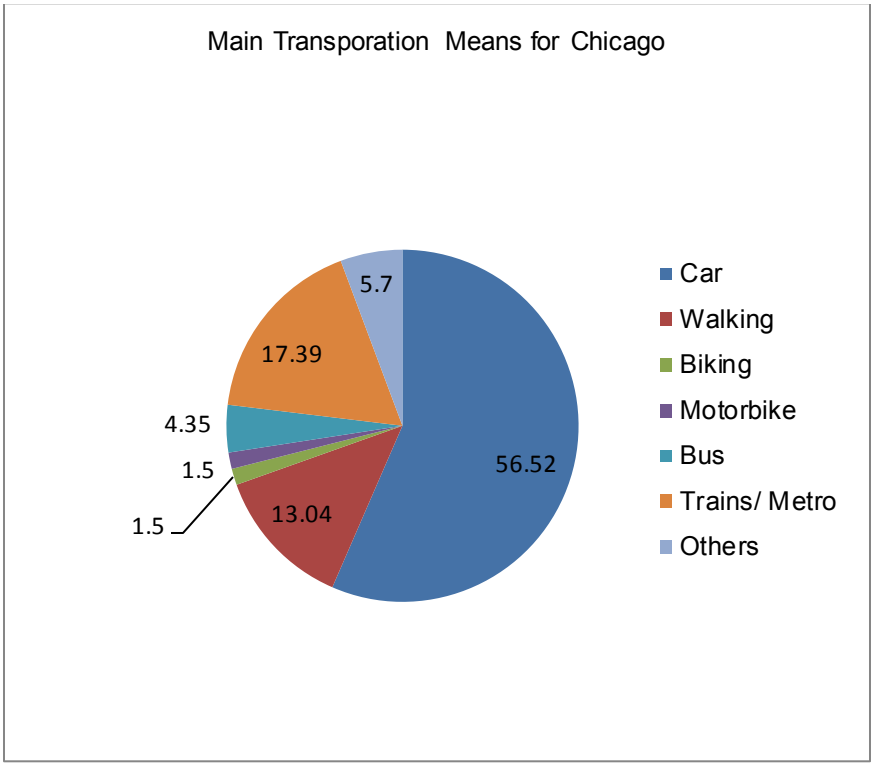

Figure 4-7 Main Transportation Means for Chicago

4.2.2.2 Economy

Table 4.9 covers indicators to measure the economy of Chicago including income, poverty, employment, unemployment, companies, gross domestic product and gross rate besides gasoline. The income includes median household and mean income. The poverty level is the basic needs for households.

Table 4.9 Economy Indicators for Chicago

Source: US Census Bureau (2015)

Domain	Indicator	Measure
Economy	• Income	• $48,552 median household • $74,003 mean income
	• Poverty	• 22.1 individuals below the poverty
	• Employment	• 1,858,133
	• Unemployment	• 212,907
	• Companies	• 291,007 number of companies in 2012
	• GDP per capita	• $45,629
	• GDP rate	• 2.39%
	• Gasoline (gallon)	• $2.61

4.2.2.3 Environment

Table 4.10 represents some indicators linked to the Chicago environment. The table includes air, water, noise and untidy pollution where the air pollution is recorded as 32.29 (low), water pollution is (47.02) moderate, noise and light pollution are also ranked as moderate and others indicators are shown in the Table 4.10.

Table 4.10 Environmental Indicators for Chicago

Resource: Numbeo.com (2016)

Domain	Indicators	Measure
Environment	• Air pollution	• 32.29% (low)
	• Water pollution	• 47.02% (moderate)
	• Noise and light pollution	• 55.81% (moderate)
	• Dirty and untidy	• 33.93% (low)
	• Drinking water pollution and Inaccessibility	• 27.33% (low)

4.2.2.4 People (Society)

Table 4.11 covers indicators to measure people or society in Chicago. Education attainment is 82.3% representing high school graduates and higher. In the same table, the percent of those with high school diplomas, bachelor's degree and professional degree had mentioned as a measure of people.

Table 4.11 People Indicators for Chicago

Source: US Census Bureau (2015)

Domain	Indicators	Measure
Education	• Population 25 and over	• 1,823,261
	• Higher school graduated	• 23.2% (422,626)
	• Bachelor's degree	• 21.2% (387,078)
	• Graduated or profession degree	• 14.3% (261,629)
	• Others degree	• 23.6%
	• Education attainment	• 82.3% high school or higher

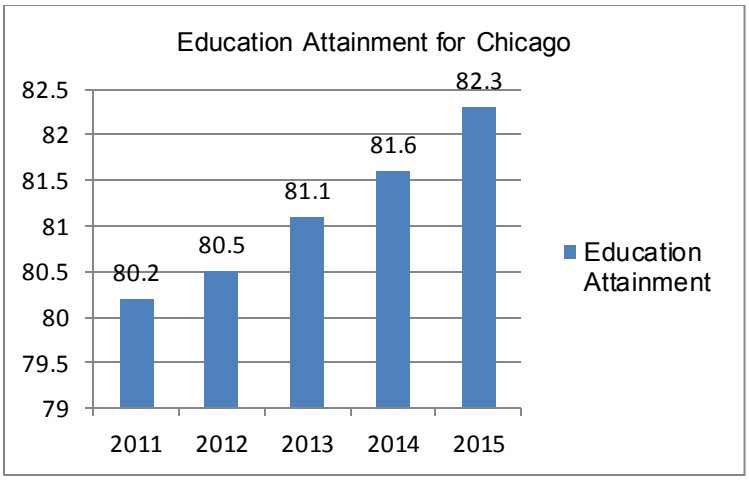

Figure 4-8 Education Attainment for Chicago
Source: US Census Bureau (2015)

Figure 4-8 illustrates education attainment for Chicago from 2011 to 2015.

4.2.2.5 Living

Table 4.12 reviewed indicators to measure the living standards in Chicago.

These indicators include housing, median house value and others as shown in Table 4-7.

Table 4.12 Living Indicators for Chicago

Source: US Census Bureau (2015)

Domain	Indicator	Measure
Living	• Housing (1,035,436)	• 44.% (458,698) owner • 55.3% (576,737) rent
	• Median house value	• $222,900
	• People without insurance	• 16.8%
	• Median average age	• 33.7
	• Buy apartment prices per square feet city center	• $307
	• Total crime per 100 k	• 3,850

4.2.2.6 Governance

In many places, the people have a strong relationship with local government.

Officials harness access to the data and information that people need to make life easier.

For example, the internet is used to change democracy in some countries. Middle East countries are the most important examples for how the technology can change communities. Chicago has been using open data and making information available to the public. Many programs have used online support to help people. There are groups of people meeting roughly once a month to utilize a service known as OpenGov Chicago. Citizens meet monthly to discuss and contribute in the development of Chicago plans in all fields. The Chicago government woks to achieve three goals: increase internet access, improve a new technology and increase the use of data to improve life for Chicago people.

4.2.3 Houston

Houston is located in the South (Figure 4-1). The population has grown rapidly in Houston, which was estimated at about 2,296,224 in 2015 (Census, 2015), and the projection expects to grow to 6,156,098 by 2050. Houston occupies an area of 599.59 square miles. The population density is 3,501 people per square mile. Houston has an important position in Texas, and it plays a key role in the regional economy. Houston has faced many challenges such as population growth, sustainable quality of infrastructure, etc. For these reasons, the local and Texas government together put a plan to develop the city. The plan includes several disciplines with many different approaches to transportation, economy, education, quality of life, environment and government.

4.2.3.1 Transportation (Mobility)

Houston has witnessed the fastest growth in the country. Therefore, the city government balances between growth needs and transportation infrastructure. The city council proposed a plan for transportation development to enhance transportation modes, rebuilding streets, and building new bikeways, etc.

Table 4.13 Transportation Indicators for Houston

Source: US Census Bureau (2015)

Domain	Indicator	Measure
Transportation	• Number of airport	• George Bush International airport • William P. hobby Airport
	• Port	• Ranks as the first in US
	• Maintain miles street	• Sidewalk • Streets • Bikeways • Parking in city center
	• Encourage use	• Transit • Bicycle
	• Cost of taxi for one mile (normal tariff)	• $1.99
	• Car • Walking • Biking • Motorbike • Bus • Trains/ metro • Others	• 89.57% • 1.00% • 0.0% • 0.0% • 5.26% • 0.0% • 4.26%
	• Average commute time to work (min)	• 25.5

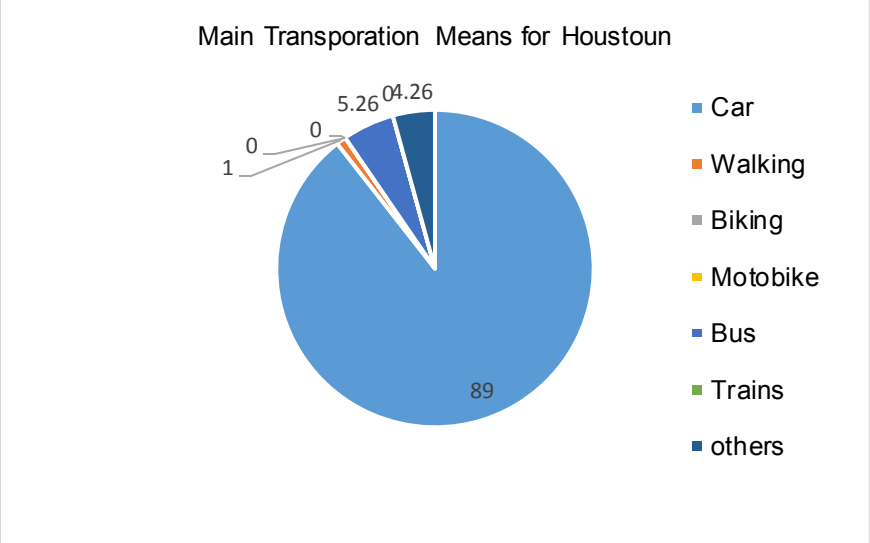

Figure 4-8 Main Transportation Means for Houston

4.2.3.2 Economy

Table 4.14 represents indicators to measure the economy of Houston. In this table, number of companies is about 260,347, poverty is 22.5 percent, income and other measures are included see Table 4-14.

Table 4.14 Economy Indicators for Houston

Source: US Census Bureau (2015)

Domain	Indicator	Measure
Economy	• Number of companies in 2012	• 260,347
	• Poverty	• 22.5%
	• Income	• $46,187 median • $46,322 mean
	• Employment	• 62.4% (1,073,629)
	• Unemployment	• 5.5% (94,178)
	• GDP per capita	• $454,944
	• GDP rate	• 2.39%
	• Gasoline(gallon)	• $2.08

4.2.3.3 Environment

Table 4.15 covers some indicators to measure the environment in Houston. These indicators are represented by air pollution, etc. as shown in the table. The results are between moderate, low and high.

Table 4.15 Environmental Indicators for Houston

Source: Numbeo.Com (2016)

Domain	Indicators	Measure
Environment	• Air pollution	• 56.25% (moderate)
	• Water pollution	• 47.67% (moderate)
	• Noise and light pollution	• 49.40% (moderate)
	• Dirty and untidy areas	• 46.51% (moderate)
	• Drinking water pollution and inaccessibility	• 66.28% (high)

4.2.3.4 People (Society)

Table 4-16 describes Houston education attainment for high school diplomas and college degrees. In addition, the table divided this education attainment into three parts: high school, Bachelor's and graduate degrees. This Table includes only the people 25 years old and over.

Table 4.16 People Indicators for Houston

Source: US Census Bureau (2015)

Domain	Indicator	Measure
Education	• Education attainment	• 76.7% high school or higher
	• Population 25 and over	• 1,421,515
	• Received high school diploma	• 22.6% (321,009 people)
	• Bachelor's degree	• 18.7% (265,572 people)
	• Graduate with MS, PhD or professional degree	• 11.7% (166,445 people)

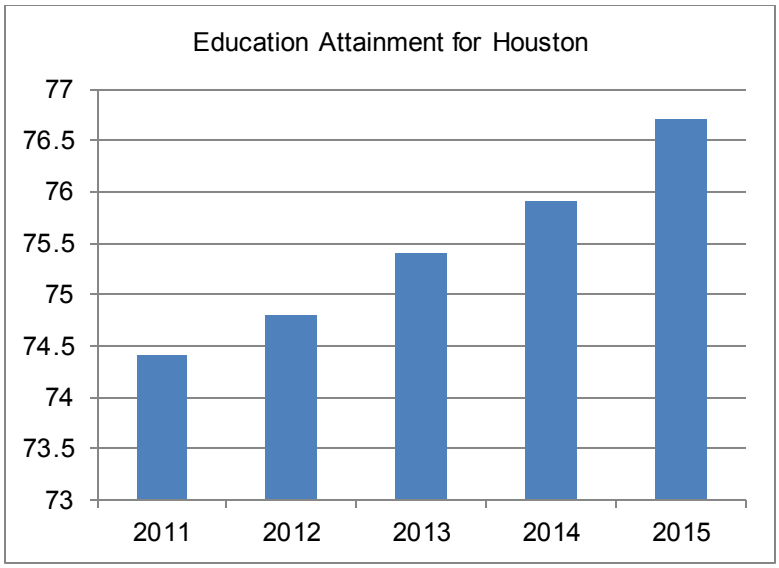

Figure 4-9 Education Attainment for Houston

Source: US Census Bureau (2015)

4.2.3.5 Living

Table 4.17 shows some indicators to measure the city of Houston. This table presents number of home renters and owners. Table 4.16 presents median house value. The healthcare is important to people; the table includes the percent of people who do not have insurance. The cost of per square foot is around 170.25 dollars in the downtown area of Houston. Finally, this table includes the number of crime, which is around 5,362. These crimes have divided into several types, e.g., murder, robbery, kidnapping, looting and other crimes recorded in the city of Houston.

Table 4.17 Living Indicators for City of Houston

Source: US Census Bureau (2015)

Domain	Indicator	Measure
Living	• Housing (814,599)	• 43.7% (355,962) owner • 65.3% (458,596) rent
	• Median house value	• $131700
	• People without insurance	• 26.6%
	• Median average age	• 32.6
	• Price per square foot in city center	• $170
	• Total crime	• 5,362

4.2.3.6 Governance

Houston local government has provided open data and open information to the people, and they established e-government where citizen can participate in and take care of their governmental needs in their homes without going to the office. Local government works with Rice University to announce their data-sharing partners as part of smart city initiative. In these programs, they set up data available for use. The programs include accurate data and information that can answer their constituents' questions. For example, the data can answer questions like, where crimes are committed, where the flooding areas are and other questions that citizens or researchers need.

4.3 Chapter Summary

Chapter 4 collected data and information for three cities that have chosen for this study. These cities were Los Angeles, Chicago and Houston. This chapter presented data on transportation, economy, environment, people, living and governance. Further, some indicators were provided for each of these factors.

Chapter 5

Discussion of Results

5.1 Introduction

Previous chapter compared indicators for Chicago, Los Angeles and Houston. The factors for transportation, economy, people, living, environment and governance are used as domains. In this chapter, these indicators will be compared.

5.2 Transportation Comparison

Table 5.1 represents some measures to compare Los Angeles, Chicago, and Houston with a smart city, Columbus Ohio. This table includes the actual percentages of main means in three cities including: car, walking, bike, metro, bus and others in comparison to Columbus. Figures 5-1 and 5-2 show the main means percent of transportation for compared cities. Cars had the highest percentage as a means of travel in all cities compared with other means. However, Houston had the highest values that are (89.47%) while Chicago had the least value (56.52%). In terms of walking, Chicago had the higher value (13.04%) while Houston had the least by (1.00%). Chicago also had a greater number of trains with 17.39 percent compared to 3.0% for Los Angeles. The Houston and Columbus have (0%) percent. Finally, the smart city, Columbus, had the biggest values for bike and bus usage, sharing that status with Houston. As a result, Chicago had a higher rate of walking citizenry than Los Angeles and Houston Cities. Therefore, both cities need to increase the number of sidewalks and encourage people to use them. Houston needs to add more bike paths to their master plan and encourage citizens to utilize them.

Table 5.1 Comparison of Main Means of Transportation for Select Cities
Source: Numbeo.Com (2016)

Transportation Main Means	Smart city (Columbus)	Los Angeles	Chicago	Houston
Car%	85.00	76.09	56.52	89.47
Walking%	5.00	4.35	13.04	1.00
Biking%	5.00	4.35	1.50	0.00
Motorbike%	0.00	2.17	1.50	0.00
Bus%	5.00	2.17	4.35	5.26
Trains/Metro%	0.00	3.00	17.39	0.00
Working from home and tram/ streetcar%	0.00	7.51	5.7	4.26
Average commute time to work (min)	21.4	30.1	34.1	25.5

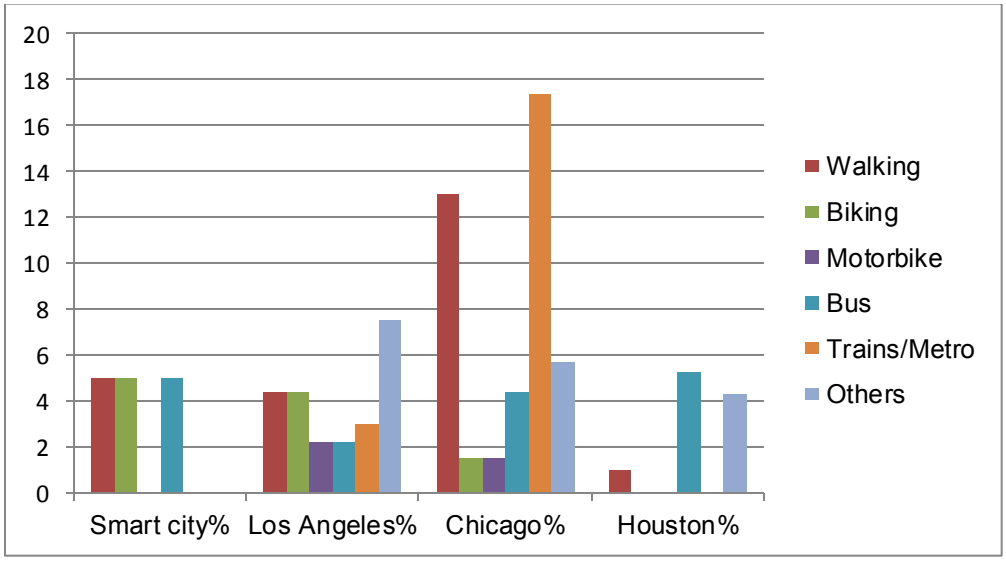

Figure 5-1 Comparison of Main Means of Transportation for Select Cities

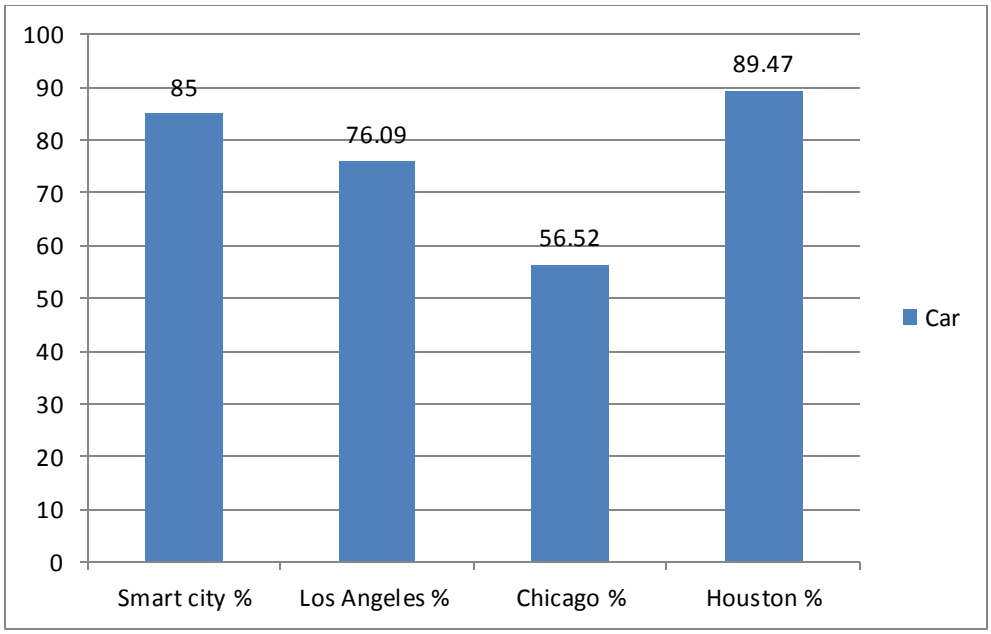

Figure 5-2 Comparison of Car Transportation for Select Cities

Figure 5-3 shows the number of airport passengers for the three cities. In 2010, Chicago O'Hare carried more passengers than Los Angeles and Houston. Table 5.2 shows the accurate number of passengers for each of the three cities where Chicago came in first with 32,200,000 passengers. Los Angeles s came in second with 28,900,000 while the Houston ranked the last with 19,500,000 passengers. This ranking has been changing throughout years. By 2014, the number of passengers had increased at these three city airports. In Los Angeles, the number of passengers reached about 74,936,256. Chicago had 70,000,000, and Houston had 55,000,000 passengers. As a result, Los Angeles took over first place, taking that spot away from Chicago. Thus, the companies mentioned in Table 5.3 played a key role to bringing people to the city of L.A. In addition, the beautiful beaches attract many visitors and increases passengers call for several trips to the Houston airport, which has also had a large increase in the percent of

passengers. The companies have brought a lot of business to Houston in addition to the airport.

Table 5.2 Comparison of Airport Passengers for Select Cities

Source: US Department of Transportation (2016)

Cities	Los Angeles	Chicago	Houston
Airports	• Los Angeles International	• Chicago O'Hare	• Houston George Bush Intercontinental
Passengers (2010)	• 28,900,000	• 32,200,000	• 19,500,000
Passengers (2014)	• 74,936,256	• 70,000,000	• 55,000,000

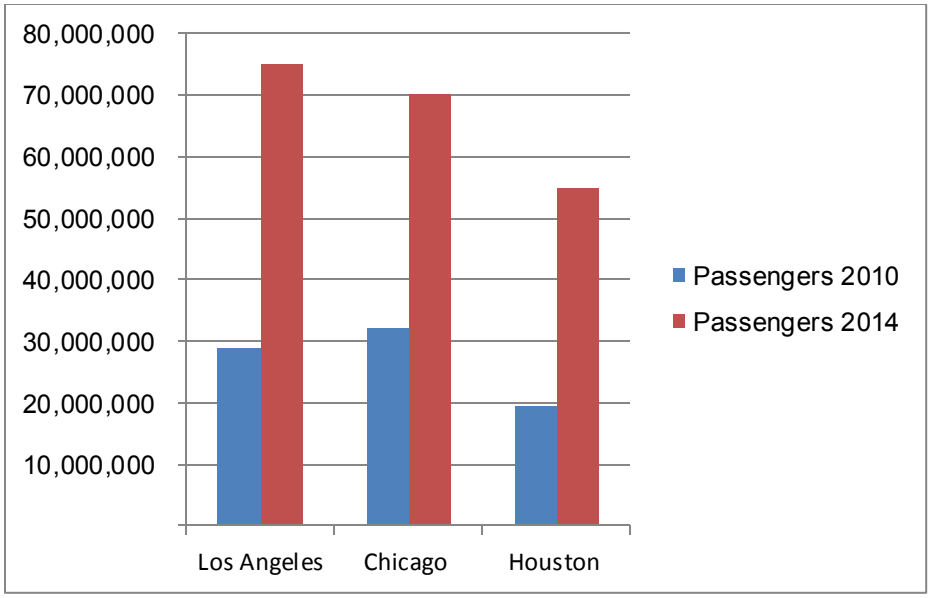

Figure 5-3 Comparison of Airport Passengers for Select Cities

5.3 Economy Comparison

Table 5.3 contains some indicators and measures to compare the economy of the four cities discussed in this thesis. The selected indicators are divided into seven parts: 1) the number of companies in each city, 2) poverty, 3 individual incomes, 4) employment, 5) unemployment, 6) others unemployment, and 7) price-to-income ratio. Table 5.3 shows the measures with units, numbers and dollars. Los Angeles has more companies than the other cities. For this reason, the economy of California ranked number one in the United States. The level of poverty has used as an indicator of economy for all four cities. The smart city of Columbus has poverty of level of 21.7%, which is less than the three cities this thesis is focusing on. However, the difference is not that great as LA, Chicago and Houston have almost the same poverty level. The income median shows that Los Angeles has a higher number than Chicago, Houston and Columbus. Employment and unemployment indicators displays that Houston has the higher employment of the three and less unemployment. As a result, Houston has greater job opportunities than the rest. Finally, the price-to-income ratio for housing in Los Angeles is higher than other cities and Chicago is second while the smart city and Houston have a lower price-to-income ratio for housing than other cities.

Figure 5-4 describes the job conditions and poverty affecting the labor force of the four cities over a period of 16 years. This figure includes four indicators, which are the percent of employment, unemployment and others, and poverty. In this figure, Houston is the second city that has high employment after the smart city, and at the same time, has less unemployment than Los Angeles and Chicago. Employment is important to all the cities because available jobs bring professional people to work in the city. The smart city has a lower percentage of poverty than other does the three cities. For the percentage of healthcare companies, it is clear Columbus has more than other cities.

Table 5.3 Comparison of Economy Indicators for Select Cities

Source: US Census Bureau (2015)

Economy Indicators	Smart City (Columbus)	Los Angeles	Chicago	Houston
Employment	64.2%	59.3%	58.3%	62.4%
Unemployment	5.4%	6.8%	8.0%	5.5%
Other employment [12]	30.3%	33.8%	33.8%	31.7%
Income median	$48,542	$50,205	$48,552	$46,187
Poverty	21.7%	22.1%	22.3%	22.5%
Price to income ratio	2.41	5.78	3.36	1.86
Number of companies	67,994	497,999	291,007	360,347
GDP (millions)	$177,824	$797,697	$555,745	$454,944

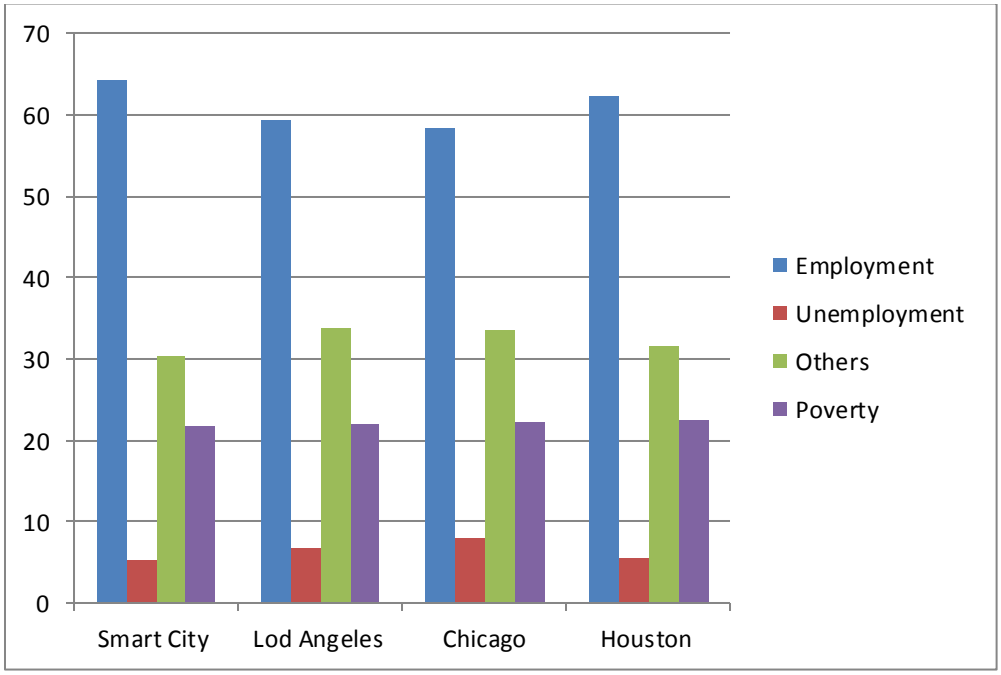

Figure 5-4 Comparison of Employment, and Poverty for Select Cities

[12]Other employment means employments that are not in labor force.

Table 5.4 represents the percentage of types of companies in the four cities, which are smart city (Columbus), Los Angeles, Chicago and Houston. The smart city percent indicators are higher than those for the other three cities are. For example, the percent of construction companies in smart city is about 7.69%, utilities are 0.17 %, and health care is 13.70%, which is higher than all city percentages with only Los Angeles coming close to a match. Other types of companies have different values that are higher than those for Columbus are. The higher numbers in those companies mean building more infrastructures, and by building good infrastructure, the cities will be more sustainable, workable and efficient. These cities can move closer to being smart cities.

Table 5.4 Comparison of Companies for Select Cities

Source: Adapted from US Census Bureau (2015)

Companies	Smart city	Los Angeles	Chicago	Houston
Construction	7.69%	6.49%	7.37%	7.1%
Utilities	0.17%	0.03%	0.05%	0.13%
Manufacturing	1.35%	2.00%	1.30	1.59%
Agriculture, forestry and fishing	0.11%	0.08%	0.06%	0.12%
Mining quarry, oil and gas extraction	0.22%	0.11%	0.01%	1.00%
Health care	13.70%	9.30%	13.00%	7.40%
Art, entertainment and recreation	4.90%	7.80%	5.3%	2.41%
Accommodation and food services	2.99%	2.68%	3.22%	2.35%

Figure 5-5 compares the percent of construction, health care, art, entertainment, and recreation companies in the four cities. As shown in the figure, the percent of smart city construction companies is a higher number than those for other cities, while Chicago has more health care companies, and Los Angeles is recognized as having a higher number of companies in art and entertainment.

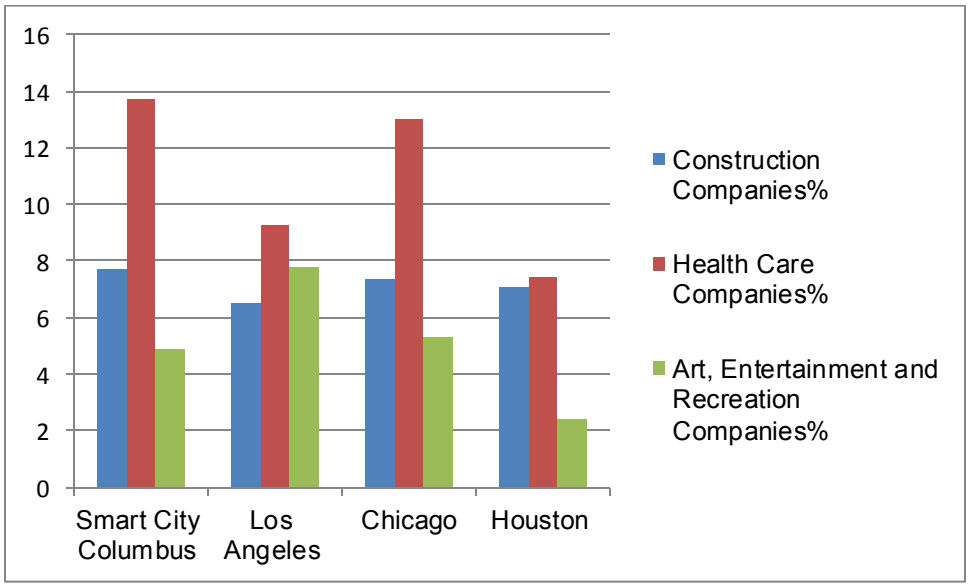

Figure 5-5 Comparison of Construction, Health Care and Art entertainment Companies for Select Cities

Source: US Census Bureau (2015)

5.4 Environmental Comparison

Table 5.4 shows indicator values to measure the environment for the four cities. The range of these values is ranked as: from less than 40 is low; from 40 to 60 is moderate; from 60 to 80 is high; and more than 80 is very high. In the smart city, the air quality is higher than in Los Angeles, Chicago and Houston. In Houston and Los Angeles, the air pollution is higher than in the other cities. In terms of water pollution, noise and light pollution and areas that are dirty and untidy, Los Angeles has the largest values

(problems) compared with the smart city and the other cities. Finally, Chicago has a higher quality of green areas, e.g., parks, compared with other two non-smart cities; however, the quality was recorded as very high when compared to Columbus. As a result, by comparing these values, Los Angeles needs environmental planning to enhance their environment. Houston also needs to improve its environmental plan.

Table 5.5 Comparison of Environmental Indicators for Select Cities

Source: Adapted from Numbeo.com (2016)

Environment	Smart City	Los Angeles	Chicago	Houston
Air quality%	79.17 High	42.65 Moderate	67.71 High	43.75 Moderate
Air pollution%	20.83 Low	57.35 Moderate	32.29 Low	56.25 Moderate
Water pollution%	27.94 Low	63.33 High	47.02 Moderate	47.67 Moderate
Noise and light pollution%	29.41 Low	62.3 High	55.81 Moderate	49.40 Moderate
Dirty and untidy%	27.94 Low	50 Moderate	33.93 Low	46.51 Moderate
Drinking water pollution and inaccessibility%	80.56 Very High	43 Moderate	27.33 Low	66.28 High
Quality of green, e.g., parks%	80.88 Very High	56.36 Moderate	83.14 Very High	59.88 Moderate

Figure 5-6 shows indicators for city comparisons. The bar chart includes air quality, air pollution, water pollution, noise and light pollution, dirty and untidy areas, and quality of green parks. Figure 5-6 shows these indicators in different colors. For example, the quality of air is represented by a blue color, the red covers air pollution, etc. It is clear from the bar chart that the smart city has the higher benefits of these indicators while Chicago comes in the second; then, Houston and Los Angeles.

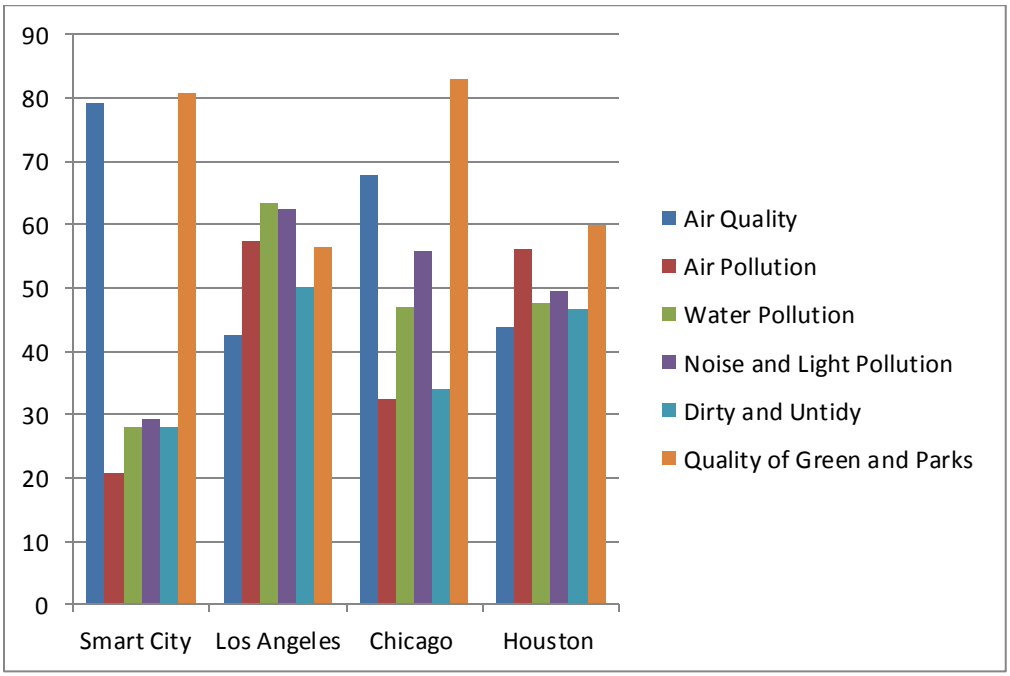

Figure 5-6 Comparison of Environmental Indicators for Select Cities

5.5 People Comparison

Table 5.5 shows the smart people indicators which are represented by education attainment and educated people who are 25 years and over for the three cities; Los Angeles, Chicago and Houston. Educational attainment is shown with percentages. The educational population is grouped into three categories: people with a high school

diploma, those with a bachelor's degree and those with a graduate degree or professional degree representing the three cities.

Table 5.6 Comparison of Smart People Indicators for Select Cities

Source: US Census Bureau (2015)

Smart People	Smart City	Los Angeles	Chicago	Houston
Educational attainment	88.5%	75.50%	82.30%	76.70%
People with high school diploma	25.7%	19.60%	23.20%	22.60%
People with bachelor's degree	22.3%	21.30%	21.20%	18.70%
People with graduate degree	11.9 %	10.80%	14.30%	11.70%

Figure 5.7 illustrates education attainment in Columbus, Los Angeles, Chicago and Houston. The bar chart's blue color represents educational attainment, the red color represents those with a high school diploma, the green covers those with a bachelor's degree, and the purple represents those with graduate or professional degrees. The education attainment indicator applied to 88.5% of the population in the smart city. Chicago had about 82.3 % of their population with educational attainment, which was higher than that population in Los Angeles and Houston. The impetus that gave the educational edge to Chicago at this level is a new program called Chromebook[13]. In the same Figure, Chicago has the higher percent of high school, bachelor and professional

[13]Chromebook is a laptop that works with chrome operating program and it is called cloudbook. The students can use that education program at any time. At the same time, the students can connect with each other by using this program.

degrees. Houston has the higher percent of professional degrees compared with Los Angeles. Los Angeles has the lowest percentage of educational attainment among the cities shown in this figure. Based on these results, Chicago has the most potential to attain classification as a smart city based on the smart people indicator first mentioned in chapter one.

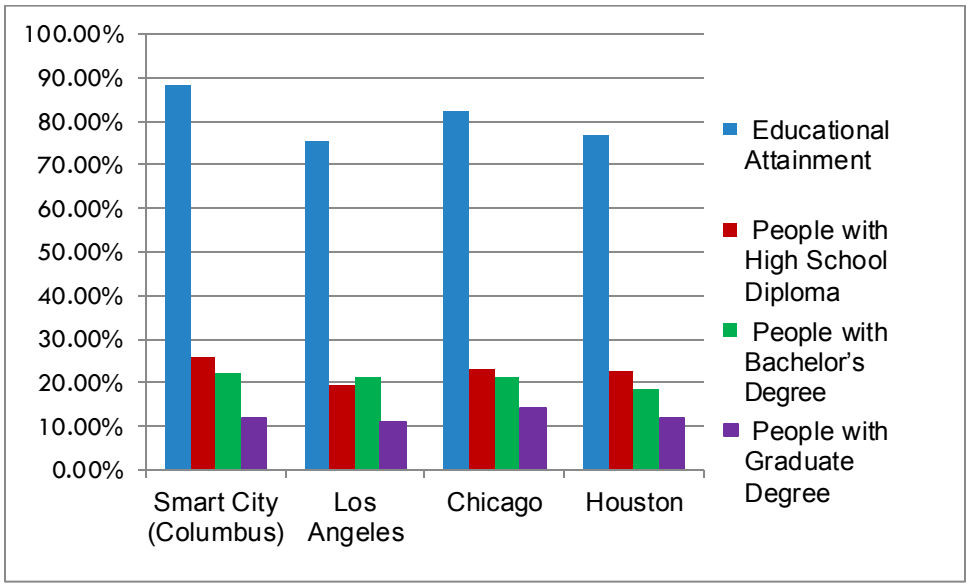

Figure 5-7 Comparison of Education Attainment of Smart City (Columbus) with Los Angeles, Chicago and Houston.

Source: US Census Bureau (2015)

5.6 Living Comparison

Table 5.9 contains the living indicators. These indicators include some measures represented by the owned housing, rental housing, median house values and people without insurance, as well as those more subject to total crime, housing with and without mortgages, types of utilities and average age of the four cities. The first owned housing indicator shows that Chicago has more owned housing than Houston or Los Angeles. This table shows that the cost of rental housing in Los Angeles is more than in Houston

and Chicago. With median house value, in this measure, Los Angeles has the higher value than that of other cities. For people without insurance, Houston has more people without insurance and, thus, do not have more insurance than Los Angeles and Chicago. Based the discussion thus far, Chicago has the first rank in insurance coverage.

Table 5.7 Comparison of Living Indicators for Select Cities

Source: US Census Bureau (2015)

Smart Living	Smart city	Los Angeles	Chicago	Houston
Housing • Own unit • Rent unit	 45.4% 54.6%	 36.8% 63.2%	 44.3% 55.7%	 43.7% 56.3%
Median house value	$129,100	$471,000	$222,900	$131,700
House heating fuel % • Utilities gas • Electricity • Others	 70.9% 27.9% 1.7%	 62,9% 29.6% 7.5%	 62.9% 13.4% 3.5%	 36.1% 62.6% 1.3%
House with mortgage	75.7%	75.5%	70.2%	57.3%
House without mortgage	24.3%	24.5%	29.8%	42.7%
Health care people without health insurance	14.6%	21.2%	16.8%	26.6%
Total crime per 100 k	4,481	2,994	3,850	5,362
Median average age	32	34.9	33.7	32.6
Price of square foot in city center	$180	$472	$307	$170

Figure 5.8 explains the median house value for the three non-smart cities. The value in Los Angeles of $471,000 is higher than the Chicago value of $ 222,900 and Houston's value of $131,700. Therefore, the result for this figure proves that Los Angeles has very expensive values, which are almost four times that of Houston and two times that of Chicago. Chicago values are almost two times more than that of Houston while Houston is the lowest.

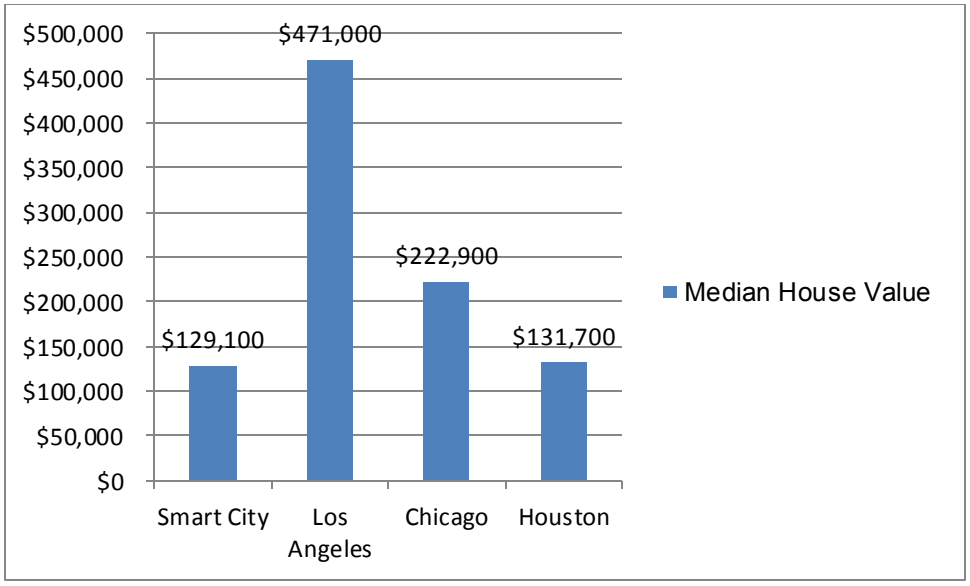

Figure 5-8 Median House Value

Source: US Census Bureau 2015

Figure 5.9 describes the indicators for living in the cities of Los Angeles, Chicago and Houston. The blue color measures the owned housing, and the figure is still showing that Chicago has more homeowners with 44.3% while Houston is the second with percent 43.7%, and Los Angeles has the least. In addition, the same figure displays the results for the renting in the cities. As a result, the number of rental housing units in Los Angeles is more than Chicago and Houston. It is clear that all three cities have more rental housing than owned housing. The green color, in Figure 5.9 represents the people

without insurance. Obviously, Chicago has the lowest number of people without insurance with 16.8 % compared with Los Angeles at 21.2% and Houston at 26.6%.

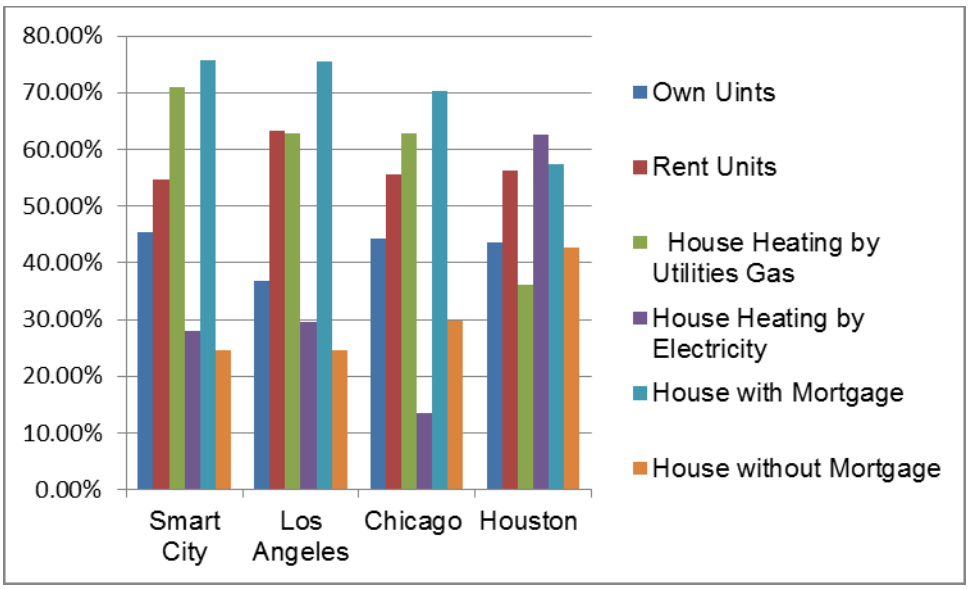

Figure 5-9 Living Comparison

Source: US Census Bureau (2015)

5.7 Governance Comparisons

Smart governance was found in all three non-smart cities. Los Angeles has used e-government, open data, and information with open access to visitors and citizens. At the same time, the local government has used the technology to connect the department's services with people. Chicago has also used the open data and information programs. Finally, Houston used e-government early, and they work with Rice University to develop a smart city initiative that former president Obama announced and advocated for all US cities to aspire.

5.8 Chapter Summary

This chapter included comparisons for the three non-smart cities with the smart city of Columbus. Comparisons consisted of six categories: transportation, economy, environment, people (society), Living (life) and governance. Indicators were selected to measure these six factors.

Chapter 6

Conclusion and Recommendations for Future Research

6.1 Introduction

The previous chapter described the results and presented a comparison analysis of three of the top ten cities along with the smart city, Columbus. This chapter discusses the conclusions pertaining to this research and recommendations for future study in this field.

6.2 Conclusions

The following list presents conclusions of this study:

- The transportation indicators of Chicago showed various modes while Houston and Los Angeles were missing bike paths, trains and metro transportation.
- The economy indicators of Houston include more employment compared with other cities since it has one of the biggest ports in the US as well as two international airports, while Los Angeles has the higher income and GDP.
- The environmental indicators show that Chicago has better air quality and less water pollution with more open and green space.
- High school diplomas, bachelors and professional degrees represented the smart people indicators. Chicago still has the highest educational attainment percentages, while the percentage in Houston was higher than that of Los Angeles.
- Quality of life characterized Chicago as in the first place, but Chicago has more crime than Los Angeles and Houston.
- Smart governances and e-government are represented by open data that is accessible to citizens. All select cities have some form of smart government.

6.2 Recommendations for Future Study

The list below represents the recommendations for expanding this research:

- Compare smart cities for different sizes, such as, large, mid-size and small.
- Study smart city challenges with freight transportation as a problem that must be solved due to its impact on streets, pedestrians, traffic safety, environment and sustainability.
- Study how infrastructure affects smart cities and how new technologies provide solutions to renew, replace and repair underground utilities. For example, advanced digital cameras and drones can be used to collect data in hard to reach places that people cannot access.
- Study smart construction like trenchless or no-dig technology, which is less costly, environmentally friendly, and does not interfere with traffic in urban areas.

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Appendix

List of Acronyms

ADA	Americans with Disabilities Act
L.A.	Los Angeles
ASCE	American Society of Civil Engineers
CO_2	Carbon dioxide
CA	California
CB	Census Bureau
CRS	Center of Regional Science
EPA	Environmental Protection Agency
GDP	Growth Domestic Product
ICT	Information and Communication Technology
IL	Illinois
ITU	International Telecommunications Union
NLC	National League Cities
SCC	Smart City Council
TxDOT	Texas Department of Transportation
TX	Texas
UNF	United Nations Funds
UTA	The University of Texas at Arlington
VANET	Vehicular Ad hoc Networks

BIOGRAPHICAL INFORMATION

Rasoul Adnan Abbas presently has a Bachelor of Civil Engineering from Technology University in Baghdad, Iraq. He was awarded the Master of Science in Civil Engineering at the University of Texas at Arlington in May 2017. His area of focus has been in Construction Engineering and Management. Having maintained a strong academic standing, his work has paid off and Rasoul now is a City Manager in Dujail City, Iraq.