PEWAN ABDULSALAM MOHAMMED
EVALUATION OF SUSTAINABLE URBAN FORM: A STUDY IN ERBIL, NORTHERN IRAQ
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A THESIS SUBMITTED TO THE INSTITUTE OF GRADUATE STUDIES OF NEAR EAST UNIVERSITY

By
PEWAN ABDULSALAM MOHAMMED

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Architecture

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Approval of Director of Institute of Graduate Studies

Prof. Dr. K. Hüsnü Can Başer

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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To my parents …

ABSTRACT

Development in urban areas is evolving and has tremendous negative effects on natural resources, ecosystems, and climate conditions. It should be mentioned that urban areas are the key sources of pollution on our planet, and sustainability is the only way to save our environment and future generations from this danger. Therefore, implementing sustainability in urban areas has become a paramount goal. During the last decades, many studies have considered the investigation of sustainable urban form in the urban areas with regard to several indicators, and different scales. However, there is the lack of knowledge based on scientific data for the analysis of sustainable urban form in Northern Iraq. The study firstly aims to achieve a thorough understanding of important characteristics of sustainable urban form affecting sustainable urban planning and design. For this purpose, the most effective indicators on the sustainable urban form have been identified. In addition, the study investigated sustainable urban form as one of the pillars of environmental sustainability in Erbil, northern Iraq as the core issue. The quantitative method has been approached in the current study, through depending on mathematical and empirical data to evaluate the indicators of sustainable urban form in Erbil. Mixed land-use, transportation and density have been used as parameters to evaluate sustainability in urban form of Erbil. The results demonstrated that there is a partial response to sustainability in urban form, and opportunities to achieve sustainability in Erbil urban form are promising; this situation can be accurate through better management of the land-use.

Keywords: Sustainability; sustainable urban form; case study; Erbil, northern Iraq.

ŐZET

Kentsel alanlardaki değişip dönüşen gelişme, doğal kaynaklar, ekosistemler ve iklim koşulları üzerinde muazzam olumsuz etkilere sahiptir. Kentsel alanların gezegenimizdeki en önemli kirlilik kaynağı olduğu ve çevremizi ve gelecek nesilleri bu tehlikeden kurtarmanın tek yolunun sürdürülebilirlik olduğu belirtilmelidir. Bu nedenle, kentsel alanlarda sürdürülebilirliği uygulamak en önemli hedef haline gelmiştir. Son on yıllarda birçok çalışma, çeşitli göstergeler ve farklı ölçekler açısından kentsel alanlarda sürdürülebilir kent formunu araştırmıştır. Ancak, Kuzey Irak'ta sürdürülebilir kent formunun analizi için bilimsel verilere dayanan bilgi noksanlığı vardır. Çalışma ilk olarak, sürdürülebilir kent planlama ve tasarımı etkileyen kent formunun önemli özelliklerinin kapsamlı bir şekilde anlaşılmasını amaçlamaktadır. Bu amaçla, sürdürülebilir kent formuna ilişkin en etkili göstergeler belirlenmiştir. Buna ek olarak çalışma, Kuzey Irak'ın Erbil kentinde çevresel sürdürülebilirliğin ayaklarından biri olarak sürdürülebilir kentsel biçimini, vaka çalışması olarak araştırmıştır. Bu çalışmada, Erbil'deki sürdürülebilir kentsel biçim göstergelerini değerlendirmek için matematiksel ve ampirik verilere dayalı olarak nicel yöntemden faydalanılmıştır. Erbil'in kentsel biçiminde sürdürülebilirliği değerlendirmek için parametreler olarak karma arazi kullanımı, ulaşım ve yoğunluk değerlendirilmiştir. Sonuçlar, kentsel biçimde sürdürülebilirliğe kısmi bir yanıt olduğunu ve Erbil kent biçiminde sürdürülebilirliğe ulaşma fırsatlarının umut verici olduğunu göstermiştir; bu durum, arazi kullanımının daha iyi yönetilmesiyle sağlanabilecektir.

Anahtar Kelimeler: Sürdürülebilirlik; sürdürülebilir kentsel biçim; Erbil, Kuzey Irak.

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LIST OF ABBREVIATIONS

AND: Average Network Density

CBD: Central Business District

CG: Center of Gravity

CHP: Combined Heat and Power

CMP: City Master Plan

CMA: Copenhagen Metropolitan Area

HCECR: High Commission for Erbil Citadel Revitalization

HD: Higher Density

GHG: Greenhouse Gas

ISTAT: Italian National Statistical Institute

LUTI: Land Use and Transport Interactions system

TOD: Transit-Oriented Development

UDPFI: Urban Development Plans Formulation and Implementation

WCED: World Commission on Environment and Development

WI: Walkability

CHAPTER 1

INTRODUCTION

1.1 Background and Significance of the Study

The form of the contemporary city is understood nowadays as a serious cause of environmental problems (Alberti et al. 2003). After the era of modernization with the domination of the industrial systems and the radical growth of population beside the selfishness and greed of human being, the invasion of ecology and destruction of land have started by humankind(Walker, 2016). Then humankind noticed that changing the equilibrium of the planet has created many unacceptable consequences and will be coming out with worldwide crises (Dawson, 2006). The development in urban areas are changing and posing huge negative effects on natural resources, biodiversity and climate conditions (Mersal, 2016). Mersal further highlighted that as a result of urbanisation several urban green areas and green fields are increasingly becoming polluted, scattered and becoming small. There is not much limit to the way urban development such as the development of transportation networks has imposed negative effects on environment. Notable examples include pollution, noise, congestion and irrational energy consumption.

Studies on the effects of urban development are increasingly pointing out that notable environmental effects of urban development are as a result of unsustainable urban design (Béné et al., 2018; Mycoo, 2018; Verma & Raghubanshi, 2018). This can be supported by ideas established by Serrano et al., (2019) which highlighted that depletion and degradation of urban landscapes has risen over the past few years. As a result, the depletion of urban landscapes is imposing serious health threats on human beings and animals. The other growing problem that is attached to unsustainable urban design is climate change and studies have shown that global temperatures have risen by 1.5°C over the past 10 years (Michaelowa, Allen & Sha, 2018).

All these problems can be controlled if attention is placed towards the introduction and adoption of sustainable urbanism. This is because suitable urban planning is capable of dealing with numerous problems posed by increased population growth (Pandey, Mishra & Pathak, 2019).

The evolution of sustainable development as a common concept has revived debate about the form of cities (Jabareen 2004). Hence, this study argues and proposes the introduction and adoption of sustainable urban planning. As mentioned previously, one of the most serious crisis is the environmental dimension of urban planning, which is occuring because of the excessive use of the resources and tremendous consumption of energy. This has resulted to increase the pollution and emitting more carbon emission to atmospher.

Carbon emission is the most effective factor for global warming increasing the temperature of the planet. The cities are the main sources of CO_2 emission and pollution on our earth, and ~~the~~ sustainability is the only solution to save the next generations from the risks and dangers that our earth facing. But it is not easy to make our existing cities sustainable completely.So one of the main solutions is to understand the factors that affect sustainability in urbanism, and to emphasize on one of the three pillars of sustainability, which is the environmental pillar. The environmental ~~aspect of~~ sustainability in urbanism is related significantly with the geographical and climatic characteristics of the region (Long & Rice, 2018). Within the discourse of environmental pillar of sustainable urban planning, urban form is a significant topic to evaluate (Yin, 2014).

1.2 Research Problem

Recent years, cities show increasing signs of environmental problems due to the negative impacts of urban activities. The form of the urban area is seen as a source of environmental problems (Alberti et al. 2003). The degradation and depletion of natural resources, climate change pressure on green areas have become major concerns for cities. In response to these problems, urban developement policies have shifted to a sustainable focus and cities have begun to develop new strategies for improving the quality of urban eco systems (Hague,

2018). An extremely important function of an urban ecosystem is to provide healthy and sustainable environments for natural systems and communities (Pandey, Mishra & Pathak, 2019).

But such urban eco systems in Northern Iraq have not been developed based on the principles of sustainable urban design standards. This is because the urban standards in Northern Iraq have been based on the need to address the high rising demand for residential buildings (Amin & Al-Din, 2019). The increased demand for new urbanism development has been stirred by a surge in Northern Iraq's population which increased from 3,910,329 million in 2003 to more than 5,601,227 million in 2016 (Ministry of Planning, n.d.). As a result, Northern Iraq's urban development standards have been neglecting the need to safeguard sustainable environmental protection and management through sustainable urban development (Amin & Al-Din, 2019).

The implementation of sustainability in urban areas has become a a crucial demand. Many types of research have considered the investigation of sustainable urban form in the urban areas with regard to several indicators, and different scales. However, there is a lack of knowledge based on scientific data for the analysis of sustainable urban form in Northern Iraq. This study claims to examine how sustainable urban form indicators are presents in existing scenario of the main cities in Northern Iraq to support the development of sustainability in urban design through the study of Erbil in Northern Iraq.

1.3 Aim and Objectives of The Study

The aim of this thesis is to reach a comprehensive understanding within the discourse of urban development in Northern Iraq, through the evaluation of sustainable urban form indicators. The study tries to analyze the urban sustainability in contemporary urban design of Erbil. Erbil, the capital of Northern Iraq is the case study to apply this analysis. The following objectives are considered in the thesis:

1. Investigation of the sustainable urban planning and design features, and emphasizing on sustainable urban form.

2. Examining urban form indicators and evaluating them within international cases

3. Identification of the sustainable urban form factors in Erbil in Northern Iraq.

1.4 Research Questions

A brief analysis of the current state of these problems, as well as an initial literature review brings up these research questions

1. What are the most important characteristics of sustainable urban form affecting environmental urban sustainability?

2. Whether or not the sustainable urban form is applied in Erbil in Northern Iraq in terms of environmental dimension of urban sustainability?

3. What are the most effective sustainable urban form factors that affect environmental sustainability to be applied in the design of the future urbanism in Erbil in Northern Iraq?

1.5 Research Methodology

First, a literature review is used to draw a theoretical framework, and to formulate the initial factors of the evaluation of sustainability in urban form. Several international case study cities have analyzed based on the formulated factors to assessurban form in urban areas. This study also includes analysing existing urban form in the study area (Erbil city) and proposing ways to enhance the development of sustainable urban form in northern Iraq. Case study methodology is approached to answer the questions raised in the beginning of the study and to reach the conclusion of the study. In addition within the case study, the quantitative method is used to evaluate collected data and observations. For this pourpose mathematical approaches have been conducted to evaluate the existing condition of the urban form in Erbil as a selected case study area, based on the initial indicators that formulated from the literature.

1.6 Limitation of the study

Erbil in Northern Iraq is the limited region of the study. Erbil in Northern Iraq region is selected as the context of study, because of its rapid urban development after 2003. The master plan up to outer-ring road of 120 meters is considered, because the future development behind this part is not yet decided. Moreover, it is considered as one of the oldest cities in the region, in addition to its political situation. The study has a focus on the environmental urban form aspect of sustainability in urban development of Erbil in Northern Iraq. Therefore, the study evaluates the most effective indicators on sustainable urban form in terms of environmental sustainability, because of the lack of studies regarding the issue in the study area.

1.7 Research Structure

The study will be structured into five chapters as follows.

- **Chapter One: Introduction.** It introduces the study and covers aspects such as background and significance of the study, research questions, aims of the study, research method and outline, and the limitation with the structure of the research.
- **Chapter Two**: **Sustainable Urban Form: A Theoretical Framework**. It focuses on the examination and review of related theoretical and literature on sustainable urban development.
- **Chapter Three:Evaluation of International Cases in Terms of Sustainable Urban Form-** It contains international overview of case studies about urban form and evaluation of Erbil with details including different characteristics and also urban form.
- **Chapter Four:Evaluation of Erbil City in terms of Urban Form as Case Study.** Chapter Four identifies the methodology of the study and describe the region of study as well as the description of the selected case studies.Moreover, it involves the findings that obtained from the current study.
- **Chapter Five: Conclusion, and Recommendations.** This chapter contains the discussion of findings made in chapter four and the conclusion of the study.

CHAPTER 2

SUSTAINABLE URBAN FORM: A THEORETICAL FRAMEWORK

2.1 Sustainability

Because of the urgent need to overcome the problems of global warming and climate change facing the world in the twenty-first century, action towards sustainability is a critical issue at present. Population growth and urbanization will continue to increase construction of the building. The need for a healthy and good life for coming generations is also significant in the same way. There is a crucial need for city planning, design and development to be managed in order to achieve this objective. Therefore, sustainability in planning and design has become crucial to the storage of natural resources for future generations. The first important alert was released as a report in 1987 by the World Commission on Environment and Development (WCED). A report known by Brundtland report has addressed that reforms are necessary to protect resources for future generations (Jarvie, 2016).

The Brundtland Report defines sustainable development as the development meeting current needs without jeopardizing future generations' rights to meet their own needs (Al Surf, 2014). Furthermore, The United Nations Commission on Environment and Development (UNWCED) identified sustainability as "*meeting the needs of the present without compromising the ability of future generations to meet their own needs*" (Al-Surf, 2014).

However, the urban development is an important factor in harming environmental damage through the exhaustion of traditional sources, damage to natural and environmental areas. Sustainability consists of three main interlinked levels to shape sustainability. Three dimensions of sustainable development have been recognized: conservation of the environment, economy and social growth (Adams, 2006). These three conditions must be available to achieve sustainability in any area, as shown in Figure '2.1'.

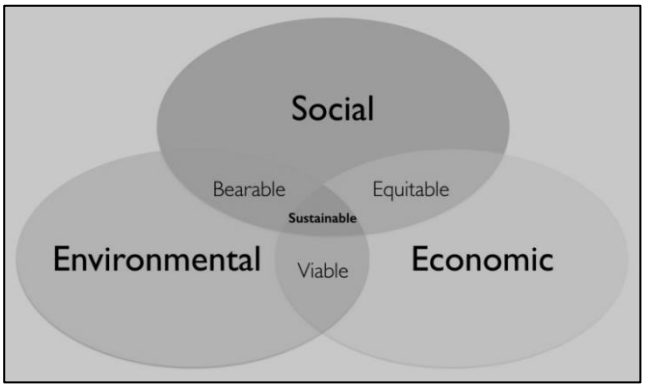

Figure 2.1: The three terms constitute the concept of sustainability (Adams, 2006)

The 2050 Environmental Perspective of the Organisation for Economic Co-operation and Development 'OECD', (OECD, 2012) highlights the need for the introduction of new models for growth focusing on people and the environment. In comparison with alternative and more sustainable solutions, the Commission must think about future fiscal, environmental and social costs and gain from business-as-usual development models. Absent policy changes, International demand for natural resources increases, often beyond the environmental potential for self-compensation.

By 2030, 1 billion more people are supposed to live in extreme water-stressed areas and a 10% reduction in the global earth's biodiversity is supposed to lead to a loss of critical ecosystems (OECD, 2015). By 2050 the worldwide rise in premature deaths from airborne particulate matter will be more than doubled by 3.6 million people per year and increasing levels of hazardous pollution pollutants from transport and industry. If the system fails, global greenhouse gas emissions could rise by 50% by 2050. The global average temperature rises by the end of the century by 3–6 ° C, which in turn could lead to serious and sometimes more frequent natural disasters including heatwaves, tropical cyclones, floods, and landslides (OECD, 2015).

The environment usually refers to an object's surroundings. The environment may refer to the built environment, the environment, the environment systems which refer to a physical

system's surroundings and interact with the system through the exchange of weight, energy etc., (Almamoori, 2014).

The aim of sustainability is to improve the environment, the planet, make a better living and preserve the ecosystem while opening up new economic opportunities. As a response to the degeneration of the environment and also of human well-being, the sustainability revolution evolved. The accelerated environmental impacts and the awareness of natural resource limits merged in order to create a new ethic expressed in the revolution in sustainability (Andrew, 2005). The revolution of sustainability affects the environmental, and global economic, as well as social dimensions.

2.2 Environmental Dimension of Urban Sustainability

This part will focus on the environmental dimension as previously mentioned, because the study tries to tackle sustainability in urban development through environmental aspect of sustainability.

There are claimed environmental benefits resulting from more compact urban models, where the application of clusters means lower travel requirements and therefore lower vehicle emissions. Furthermore, arguments regarding higher densities indicate energy-saving benefits through combined heat and power (CHP), however this advantage could be exceeded by the lack of open area. Many types of research have concentrated on providing various types of space in the evaluation of aspects of environmental sustainability. Outdoor green spaces have environmental benefits, including lower surface and air temperatures induced by sunshades, re-radiation of solar heat to the sky and trees evapo-transpiration leading to better summer thermal comfort; urban emissions and noise (Tyrväinen, 1997); and wind-reduction buffering (Vu et al., 1997). The advantages include improved market value for surrounding buildings (Savard et al., 2000); increased availability of natural light, decreased energy charges for buildings and the provision of passive solar heat in homes (Yannis 1994). Finally, green spaces will increase the impact on urban warming and give ' freely ' buildings refrigeration (Watkins, et al., 2002). Thus, this will come out with reducing energy consumption and

emissions of CO_2 as well as operating set backs and and more heat released inside the urban area by reducing the use of active heating/cooling systems.

Environmental benefits are proposed for outside green area, including the provision of biodiversity and environmental benefits that can have implications on various issues, such as the control of floods, wastes, and pests (Bolund and Hunhammar, 1999; Pauleit & Duhme, 2000). Environmental benefits are suggested for open greenery space, including the provision of biodiversity and environmental benefits that can have implications on various issues, such as the control of floods, wastes, and pests (Bolund and Hunhammar, 1999; Pauleit & Duhme, 2000); providing area for bio-diversity (Savard et al. 2000; Gilbert 1989) enhanced the comprehensive understanding among inhabitants about environmental problems (Cannon 1999). Despite this multitude of perceived benefits, relatively little work has been done to evaluate whether they materialize, especially in the area of study. No empirical research quantity or decides the magnitude of the gain. Few works are done on the effects of urban shape on comfort in open places and the effects on energy and climate. The full impacts of energy and pollution were neither analyzed at the same time for different combinations of building type, urban structures and open space (e.g. the compound effects of heating of homes, cooling, the lighting of non-domestic buildings on urban sustainability in one time), (Jenks and Jones, 2010).

There are generally the physical and environmental aspects of sustainability which are most easy to develop, but not totally related to the urban form, only the bold ones in Table ‘2.1’ below. These are common parameters that contribute to sustainability based on professional opinions with some proofs.

Table 2.1: Indicators of a sustainable built environment (Jenks and Jones, 2010)

Land use and built form	**Environmental-energy Conservation**	**Environmental-recycling and re-use**	**Communication and transport**
Intensive use of urban land	Combined heat and power (CHP)-local power generation	'Grey' water systems	Light transit routes, eco-friendly buses and bikeways
Networks of green corridors	Micro power generation	Recycle water for gardening and car washing	Car clubs and cycle facilities
Community buildings, self-managed	Renewable energy	Reuse water and filter, to be directed to ecology parks or green spaces	Pedestrian- friendly infrastructure
Mixture of land uses at relatively high density	Reduced energy consumption and embodied energy	Water recycling, and use for protection of biogas	Restricted car parking
Affordable homes	High level of insulation	Reduced domestic and construction waste	Environmental advice-bus/transit times, energy and water monitoring
Local identity	Intelligent lighting and integrated security, heating, and IT systems	Carbon- neutral lifestyle	IT enabled
Sustainable building materials	'A' rated white goods		
Flexible design and good space standards	Eco-rating e.g. BREEAM 'excellent'		
Improved noise insulation			

2.3 Sustainable Urbanism

Sustainable urbanism is both an inquiry into cities and policies designed to build urban development, which focuses on supporting the long-term viability of cities by improving efficiency and reducing pollution and adverse effects on people and sites while increasing their overall well-being. The physical, ecological, cultural, social, health and equity factors that include cities and their population, among others, are part of well being. In the context of

contemporary urbanism, the word cities refer to a number of human settlements in the peripheries/outskirts/suburbs of cities metropolitan areas and gigantic-cities (Neuman and Hull, 2011).

In the 19th century, the first analyses of the city planning model started as industrialization grew and population movement into cities increased. Burgess proposed in 1923 the model of a circular city with concentrated functional rings. This model has been used in Chicago Area. It has a large industrial and commercial core and concentration circles of increasingly higher class residential areas when the distance is increased from the center (Barcelona Field Studies Centre, 2013). See Figure '2.2'.

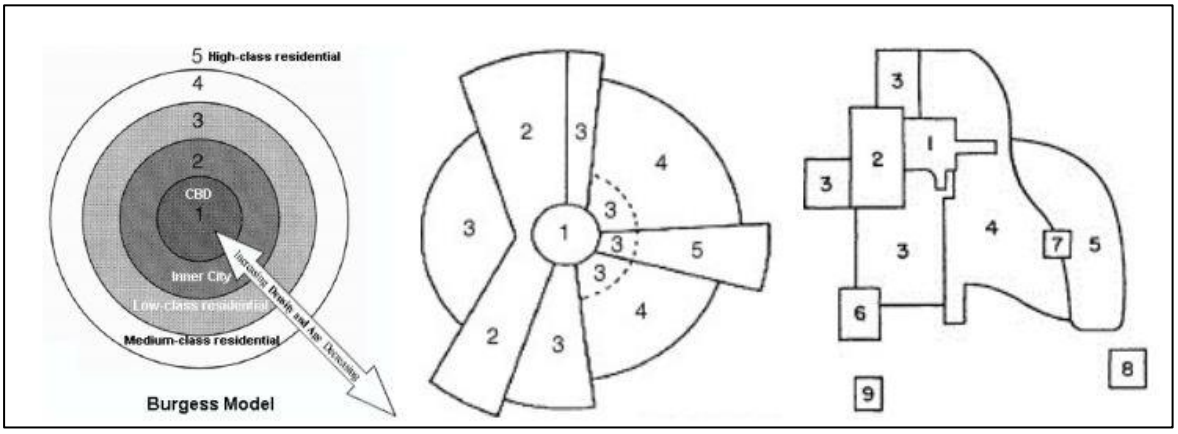

Figure 2.2: Model of Burgess (Left), Model of Hoyt (Mid.), and Model of Harrys and Hullman (Right)(Barcelona Field Studies Centre, 2013)

The general agreement and foundation of the discussion today is that, although the city creates excessive environmental stress, it's socially stratified, economically inefficient and expensive to manage. Sustainable development has been transformed into a popular idea, hence, the shaping of the cities are discussed as a whole (Jabareen 2006). This necessarily led scholars to look out for ways that benefit human settlements and to meet the requirements for functionally sustainable environments after present-day conditions (in several related disciplines). The dimensions of sustainable urbanism in brief can be explain as follow:

***a) Urban ecology*:** is the objective study of the relationship of life forms in an urban area with each other and their surroundings (Niemela, 1999).Therefore, it can be characterized as the

study of spatio-temporal paradiems, environmental impacts and urban sustainability with emphasis on biodiversity, ecosystem processes and ecosystem services (Wu, 2014).

b) Energy Use:A city can use energy through services and goods by mean of the embodied energy. Accordingly, energy usage has an effect on an urban area's environmental quality by; smog, air pollution, island heat effect, etc. This is due to the type of economic activity, infrastructure and planning, human activities and geographic factors as well (Rosales, and Worrell, 2018).

c) Transportation: Itgives access to all communities of residents of the city in a way that is within the city's capability to preserve the environment and is cost-effective to both systems providers and users. accordingly, it fortifies sustainability in environmental, economic, and social dimensions.It is one of the significant issue for sustainable discussions defining urban structure (Burton, et al., 2003).

***d) Urban waste management*:** It is a public service managed and provided by authorities to inhabitants and encompasses the domestic waste collection that generates and conveys to treatment plants. In simple words, it can be defined, as the waste collected from the residential and industrial areas of urban area (Mesjasz-Lech, 2014).

***e) Urban form*:** It is the physical characteristics that compose built-up areas, encompassing the size, compose, density, and settlement configuration. It can be regarded by various scales: from regional to urban, neighborhood, block, and street (Williams, 2014). The study will focus on urban form, and emphasize the importance of design concepts derived from a sustainable urban form.

2.4 Sustainable Urban Form

Urban form is the physical shape of the city. It helps to define the life of the city. The urban-type is defined by Anderson et al. (1996) as the spatial modeling of human activities at a certain point in time. Urban form influences energy use, amount of carbon emissions from houses, transport, and other climate-change affecting sectors. In theory, the creation of urban forms has three priorities: Transportation priorities: road extension and transit facilities;

Economic priorities: greenfield projects or systems of reconstruction; Priorities in culture: Socio-cultural public space understanding "(Kostof, 1991).

Urban form is at a certain level a spatial pattern of human activity. The concept of Urban Form is, as per Silva (2015), geared towards three items: the appearance, functionality, and arrangement of the building with respect to the use of the available space. the emergence of global megacities, and global environment change, environmental and social external parameters consequences have become ever more prevalent.

The information available defines attempt to strike a balance between environmental protection, economic growth and social justice. Sustainable cities are not only improves living standard of people but also their health, activities attract more activities to area make its livability (Cuthill, 2010).

The sustainable network sorting contains the elements of (Adhya, 2010):

1. Connectivity and place accessibility
2. Block scale relationship
3. Relationship of the neighborhood scale: network connectivity to exposure to land use movement.
4. City scale concept: network interrelationships organized by settlement scale.

5. All the terms and relationships mentioned above must be considered simultaneously and arranged to the fullest extent possible.

In fact, there is some controversy regarding even the simplest assumptions about sustainable urban form. However, there are some widely accepted frameworks of sustainable urban form that might serve as criteria for evaluating particular urban form alternatives. The accessible data describes sustainability as a flourishing means of achieving equilibrium between environmental health, financial growth, and social equity. Sustainable urbanism not only improves people's living standards but also their safety (Cuthill, 2010).

Sustainable urbanism is required to be equipped with energy generation and governance, water generation and governance, waste management, design, engineering and architecture,

equipment for sustainable construction and planning and management of housing. According to Jabareen (2006), the sustainable urban form ideas or principles are created and classified as follows;

1. *Compactness*: Built environment compactness is a commonly recognized approach for achieving more viable urban types. Compactness also relates to urban contiguity and connectivity (Wheeler, 2000). Compactness is the key typology to be enforced in order to attain sustainability for many planners and scientists. For instance, Dumreicher *et al.*, (2000) contend that a compact, varied, and extremely embedded viable town should be.

2. *Sustainable Transport /Accessibility*: Transport is apparently the single greatest issue for discussions identifying with urban structure (Burton, et al., 2003). Hillman (1996) contend that feasible urban structure must be a structure and scale fitting to strolling, cycling, etc.

3. *Density*: Density is a critical typology, and it is the proportion of individuals or residential part of property, and the sustainable cities are a question of density in a broader context (Carl, 2000; Walker and Rees, 1997).

4. *Mixed Land Uses*: Contradictory zoning or mix of land-uses enables compliant land use to be located in close proximity to each other, thereby reducing the distance of transport between operations (Parker, 1994). Mixed land use refers to the variety of functional land use such as housing, business, industrial, financial and transportation-related activities (Alberti, 2000; Van and Senior, 2000).

5. *Diversity*: Activity of diversity is refers to the social variety and it is vital to cities sustainability. The diversity dimension was developed by Jacobs (1961). There are a few similitudes among decent variety and blended land utilizes; be that as it may, assorted variety is "a multidimensional wonder" that advances further attractive urban highlights, including more prominent assortment of lodging types, building densities, family unit sizes, ages, societies, and salaries (Turner & Murray, 2001).

6. *Passive Solar Design*: The concept of this form is to decrease energy demand and provide the highest sustainable use of passive energy through particular design interventions. The urban density and angle of buildings for instance, has a direct effects on the form and shape of the built environment (Thomas, 2003). It is obvious that, there is relationship between

orientations, location, design, landscape and layout with the excellent use of microclimate circumstances and solar gain, which it may help to minimize the usage of electricity in order to reduce the usage of building cooling and heating system (Owens, 1992; Barry and Chorley 2009; Yannas, 1998).

7. *Greening*: City greening, or green urbanism, seems to be a significant notion of architecture for sustainable urban form (Beatley, 2012). Green space has the capacity to make a positive contribution to some main metropolitan agendas, including sustainability (Swanwick, et al., 2003).

8. *Legibility*: Legibility is "the degree of distinction that allows the listener to comprehend or categorize a scene's contents, the higher the readability, the higher the choice" (Bell et al., 2005: 45). Also, it is described as "the ease with which to recognize and organize its components into a consistent structure" (Lynch, 1960:2). Lynch sees 'Legibility' as a physical and spatial feature of the environment. This description is based on the creation of mental maps in the mind of the wayfarer (Arthur & Passini, 1992).

9. *Imageability*: The features of environmental components, whether natural or man-made, determine the visual value of the constructed setting, these features are what Lynch called Imageability, "it is that quality in a physical item that provides it a greater likelihood of evoking a powerful picture in any viewer" (Lynch, 1960:9).

10. *Permeability*: Permeability relies on how many alternative paths from one stage to another it provides. But these options must be noticeable, otherwise they can only be exploited by individuals who already understand the region, so visual permeability is also significant (Lynch, 1960). See Figure '2.3'.

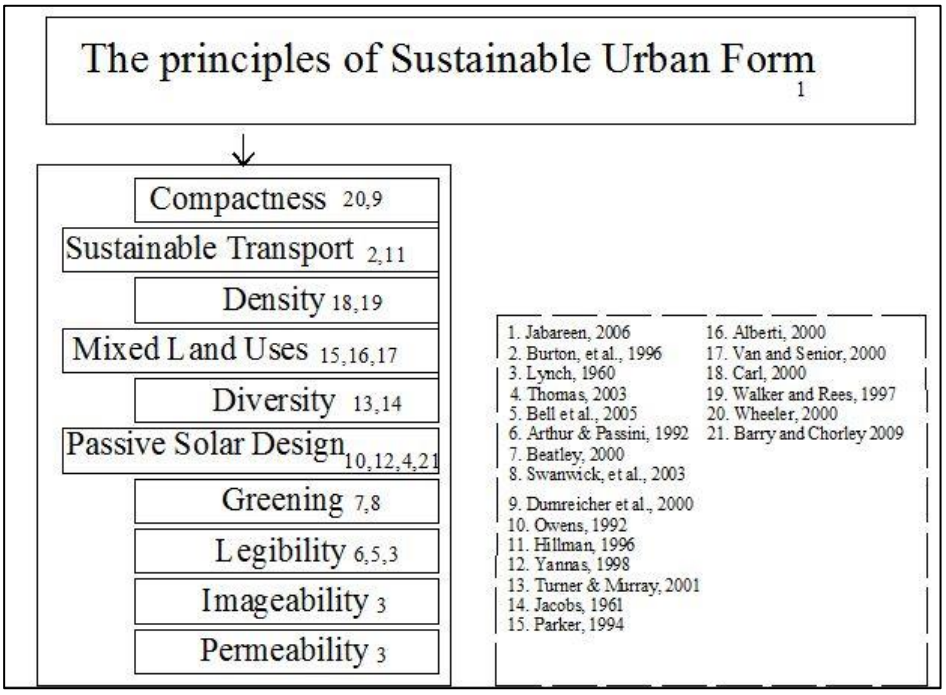

Figure 2.3: The main principles of sustainable urban form (developed by researcher)

The goal is to reduce travel distance, save energy, improve the life quality, optimimum use of the lands, reduce the cost of infrastructure, and so on, which helps the shaping of sustainability in the urban form.

2.5 Sustainable Urban Form Movements

The notion of sustainable urban types has been extensively discussed and is still under discussion. Alternatives include the compact city, decentralized concentration, remote new settlements and multi-centric cities (Owens, 1992). Jabareen (2006), defines four sustainable urban types on the basis of distinct design values in order to achieve sustainable urban development objectives. The sustainable urban types are; 1) Neo-traditional Development; 2) Urban Containment; 3) Compact City; 4) The Eco-City.

2.5.1 Neo-traditional development

Traditional constructed settings have encouraged designers and architects in a movement called "neo-traditional urban design" to pursue stronger spatial types depending on some of

their physical characteristics (Nasar, 2003).The perfect neo-customary town would act naturally contained, firmly grouped, walkable, and designed on the American community before the second world war. It could have mixed land utilizes, just as higher densities; road designs that permit vehicle users and people on foot an assortment of way choices (urging individuals to stroll here and there); customary building characters; and the support of road life through such includes as smaller avenues, entryway patios, and open space (Audirac and Shermyen 1994; Nasar 2003). One of the examples of neo-traditional developments is 'Prince Charles' Model Village' in England. See Figure '2.4'.

Figure 2.4: Model Village'-Neo-traditional development in England(Prince Charles)

2.5.2 Urbancontainment

Nelson et al. (2002) defined urban containment as the deliberate use of state and local government planning, regulatory and fiscal authority to influence development patterns to achieve projected requirements. A few containment strategies do not fulfill planned demands, and urban containment is not all growth management strategies. However, containment program could be classified as a growth management plan for projects and plans for needed growth (Pendall et al., 2002). Smart growth and management is one of the characteristics of urban containment type. The program of management that seek to equilibrium growth when it is meeting environment, society, and economic needs are often referred to as smart programs

of growth. Such programs may include a mix of the above-mentioned programs or could concentrates on a singular path (Gillham, 2002).Qualicum Beach's cartography reveals the urban containment boundary where the city plans to approve urban development under its Official Community Plan (OCP) (in addition to maintaining space for parks, natural area and environmental sensitivity). See Qualicum Beach OCP Map in Figure '2.5'.

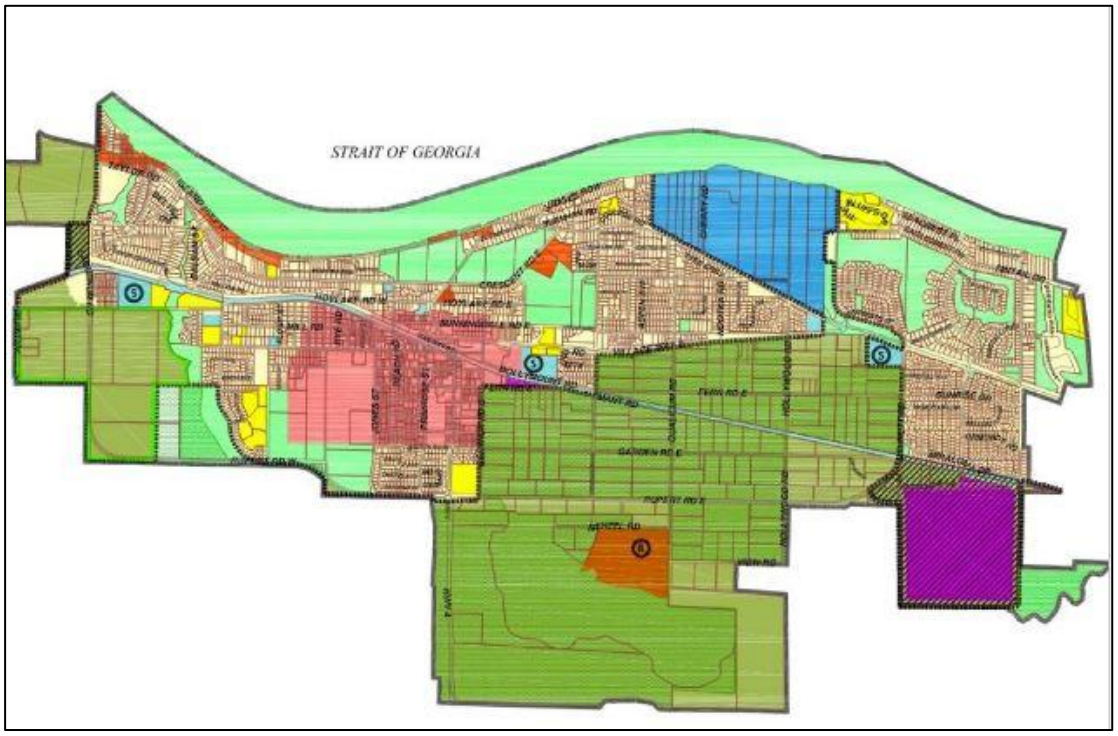

Figure 2.5:the urban containment boundary in Qualicum Beach- Canada (Kveton, 2019)

2.5.3 Compact city

The compact city or town of short distances is a design term for urban planning and economic growth that encourages relatively high density and mixed land use (Dempsey, 2010). The compact city idea comprises a number of strategies that seek to achieve coherence and density that can avoid all design problems in modernist cities, as seen in Figure '2.6'.

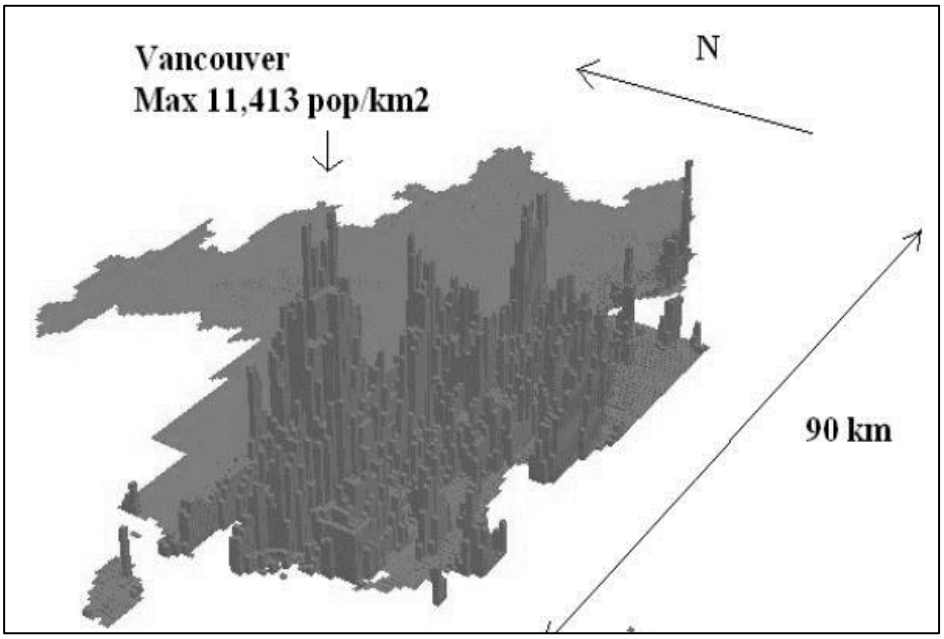

Figure 2.6: Vancouver as example of compactness in the cities.
https://www.oecd.org/regional/greening-cities-regions/compact-city.htm

This was to be done by clearing and erecting blocks of towers, enabling high densities along with broadly opened spaces. Dantzig and Saaty (1973) hadoffered compact cities, taking the concept of radiant city from Le Corbusier's. Their point of view was to to develop the life quality, but not at the account of the "next generation," which is compromise with the principles of sustainabile development for of today. Generally speaking, a compact city principles can includes many strategies (environmental urbanism, efficient land-use, and sustainable transport) (Newman & Kenworthy, 1989; Hillman, 1996). Its' goal is to establish density and compactness that can get ride off city problems throughmodern planning.Main elements of a compact city is demonstrated in Figure '2.7'.

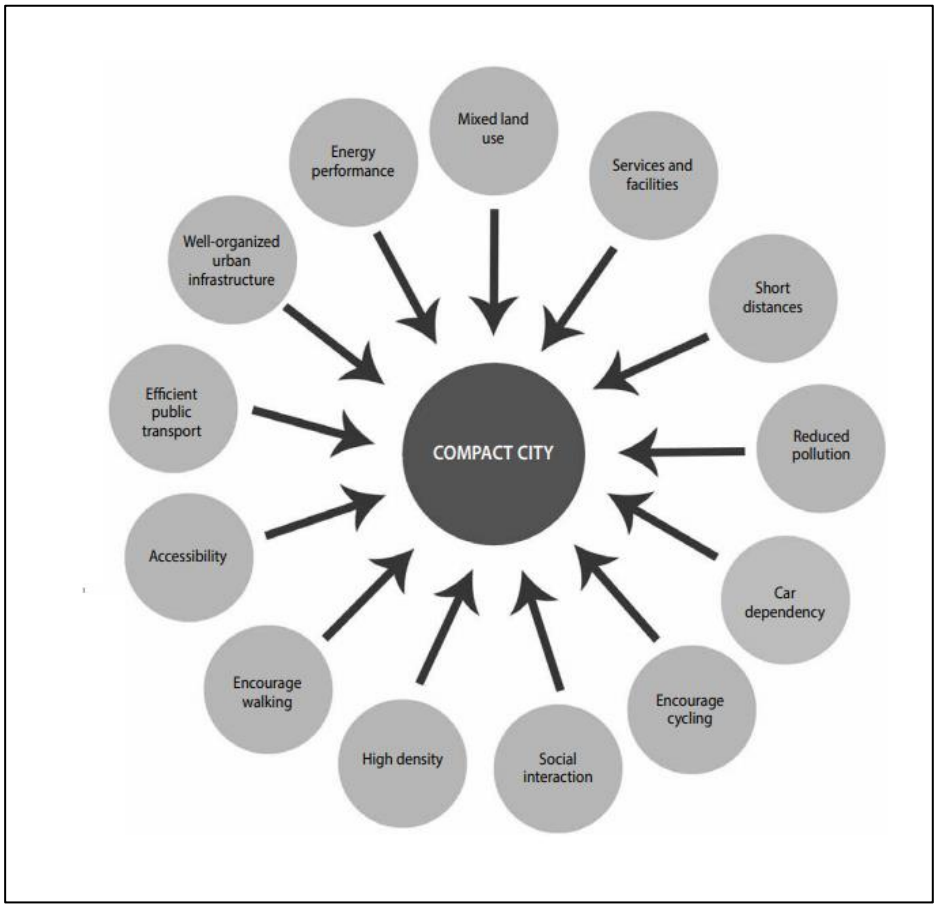

Figure 2.7: Main elements of a compact city (Rogatka and Ribeiro, 2015)

2.5.4 The eco-city

The aim to achieve urban sustainability in an eco-city is an umbrella metaphor that encompasses a wide range of urban-ecological proposals.To attain it, these approaches propose a wide range of environmental, social, and institutional policies and ultimately, they are directed to managing urban spaces.Regarding thickness, density, and different ideas, the eco-city may be imagined as a "formless" city or an eco-amorphous city. There are a few methodologies that underline the uninvolved sun oriented plan, for example, the Eco-village, Solar Village, Cohousing (Roelofs 1999), and Sustainable Housing (Boonstra, 2000). others offer the ideas of green design, like green city and eco-city, or ecological city (Gibbs et al., 1998; Roseland 1997; OECD, 2010). It is exceptional that the center of numerous

methodologies is the management of the city, as opposed to the recommending of a particular urban form; it is accepted that not the physical state of the city and its constructed condition that is significant; it is the means by which the urban culture is sorted out and dealt with that tallies most. So also, Talen and Ellis (2002, p.37) contend, “Social, economic, and cultural variables are far more important in determining the good city than any choice of spatial arrangements."For instance, the outstanding Agenda 21 (UNCED, 1992), proposes incorporated administration in the urban area to guarantee that environment, society, and economy are viewed as bunch in a system for the sustainable city. Figure 2.8 shows an example of eco-cities.

Figure 2.8: Keppel Corporation Eco-City, Singapore, 2008

https://critical-sustainabilities.ucsc.edu/eco-city-branding/

2.6 Approach for Evaluating Sustainable Urban Form

Coppola, et al., (2014), have discussed the relation between sustainable development and urban forms. In order to realize the inter-dependence of main parameters as the way of travel, transport flow, possession amounts, employment, and housing location. hence, a Land Use and Transport Interactions system (LUTI) has been developed and implemented in the Rome Metropolitan Area. The models reflect the actions and reactions of both residents and users of transport to changing conditions. System evaluation indicators were developed to

methodically evaluate and match alternate urban scenarios and to determine how sustainable transport efficiency, social and environmental impacts are accomplished in various sites or density distributions. Many types of research are developed which concentrate on urban effects on mobility behavior in terms of ohysical and social effects (Handy 1996). The compact, polycentric, and sprawl urban forms have been particularly evaluated and analyzed by using various methods and methodologies.In relation to the compact urban form this model promoted as a much more sustainable for urban growth (Naess, 2013; Newman and Kenworthy, 1999), since the EU Green Paper on the Urban Environment (Commission of the European Communities 1990). However, compact planning, on the other hand, can cause extreme traffic congestion, raise lands and housing prices, and establish social isolation (Breheny, 1997).

In addition, dense urban areas, with explicitly adverse health impacts, are also more vulnerable to road noise and local environmental pollution.Furthermore, a high-debate topic in today's urban planning is the Polycentric urban model, which positions activities within and concerning intensive and mixed secondary centers. In the Netherlands a study by Schwanen, et al. (2001), has shown that polycentric urban systems promote the use of cars for whatever reason since public transit net aimed at radial travel.

Few scholars argue “the polycentric designs” are the most likely to decrease car usage and distances of travelling and preserve the ground. Some studies indicate that a polycentric structure helps to minimize travel and transit time (Levinson and Kumar, 1994). Other researchers, on the contrary, disprove this optimistic view of the effect on traveling actions of "Policentricity.", (e.g. Ewing, 1997). Sub-centers situated near the subway station are, according to the theory of TOD, less commuting by car, as shown in other empirical studies (Pivo, 1993).

2.6.1 A Reference model for evaluating land use and transport interactions (LTUI) system

The proposed research model for LTUI involves four main steps:

1. Spatial and transport development scenarios definition;

2. Simulation process;

3. Performance development and evaluation scenarios for sustainability and indicators;

4. Findings' analysis. See Figure ‘2.9’.

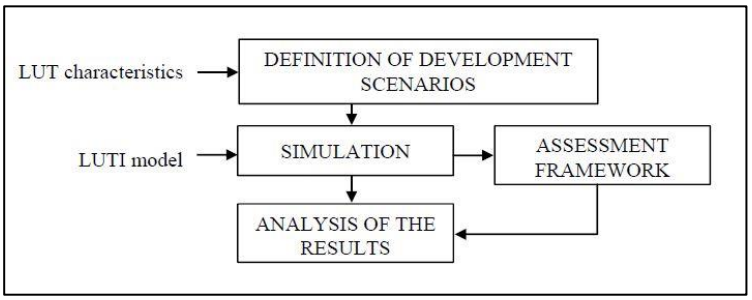

Figure 2.9: Reference model for LUTI assessment(Coppola, et al., 2014)

For the first step, three categories of spatial growth were specified in various distributions of inhabitants and work, but the city-wide total of residents and employment was keeping with the same number. The various choices for development lead to three different urban trends, which contribute to the correct urban (strategic) transport policies: a 'compact' scenario characterized by a new cluster of high-density activities within the city center, and a scenario of transit-oriented development 'TOD' for transit-oriented growth characterized by new rail and subway station activities; The scenario of "sprawl," marked by the dispersion of new activities through market leadership. Two additional scenarios have been developed as criteria for the assessment stage. The "Base Scenario- (BS) for 2011, also the "City Master Plan scenario" scenario involves the new interaction locations and the transport network involvement proposed in the Rome Master Plan (2008). The second step is the simulation of the scenarios, which is carried out with the LUTI modeling method and which simulates residents' and passengers' actions and their reaction to changing circumstances.The third step consists of designing and measuring the main measures of success. The evaluation system discusses the environmental, social, economic, and energy usage factors. The fourth step includes evaluating the results and analyzing the quantitative findings in order to evaluate a city's more efficient mode of transport by land.

2.6.2 Application of LUTI

On behalf of LUTI assessment in metropolitans and urban areas, Rome has been studied. Rome metropolitan areas have approximately 2.8 million residents in 1,285.3 square kilometers and 1.1 million jobs, which lead to approximately 552,000 trips early morning. The city structure is highly mono-centered and can be divided into circulatory rings that approach the city center with increased densities as much as close to the center. See Figure '2.10'.

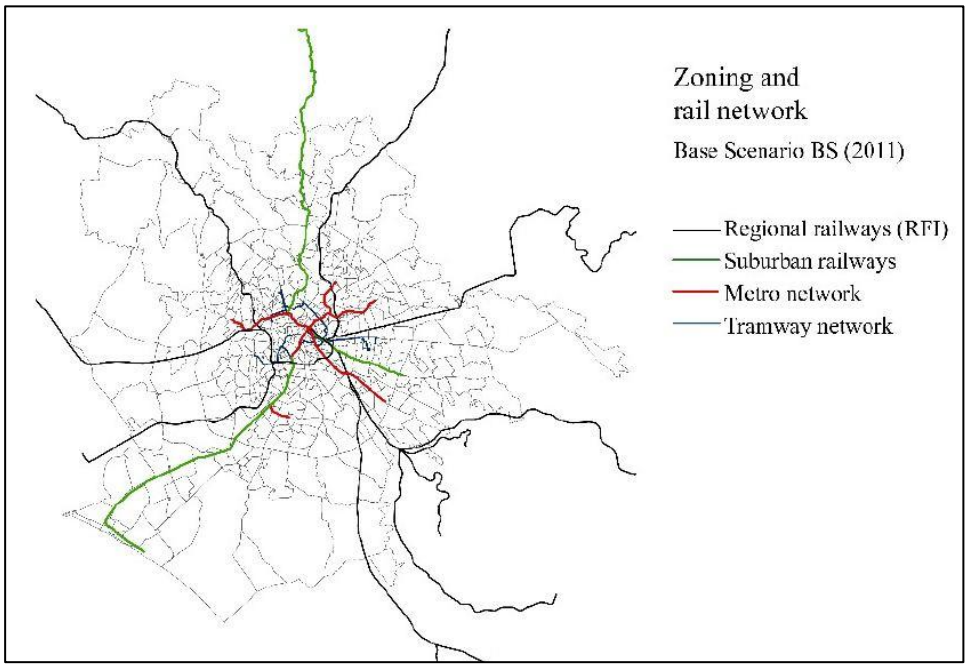

Figure 2.10: The Base Case BS (2011) zoning and urban rail network (Coppola, et al., 2014)

The GRA 'Grande Raccordo Anulare' (the circular highway with a length of about 68 km), is delineating a wide and compact metropolis with an average population density of approximately 70 people/ha, and a jobs density of approximately 75 workers/hectare.The main focus of the population and development is on radial streets from and to core of the city within the GRA. Two metro (and radial) lines stretch 36 kilometers, with just one interconnect in the middle of city (central terminal) being part of the transit network.The seven other territorial railway lines link the city center with the surrounding urban areas. In terms of automobile use, Rome has very high vehicle ownership rates, with the road network extremely congested

(almost 700 per 1,000 people). In a major area of the historical center, access by car is allowed only to the inhabitants(Coppola, et al., 2014).

2.6.3 Spatial planning scenarios descriptionand urban context data collection

Different sources of knowledge and different assumptions involved the set up of scenarios. The following data is aggregated in 463 traffic zones for the base scenario (2011) the study used: 1. XIV Housing and Population Census 2011; 2. XIII Business & Services Survey 2001; 3. XIV Population and Housing 2011 Census and the City of Rome's previous studies and papers.

Schematically, the operating system has been divided into three subsystems: 1. 'People' section segmented by occupational status and condition (i.e. low, medium and high);2. "Economic Operations" subsystems consisting of economic sector workers (e.g., trade, service, industry); 3. "Real Estate" subsystem comprised of building space available with relative property prices in each of the traffic areas of form (dwelling areas, retail, and service). In line with Rome's demographic growth by the Italian National Statistical Institute (ISTAT), estimates for the subsystems "Population" and "Economic activities" achieved in 2013.Regarding the 'Real Estate' subsystem, many presumptions formulated depending on the density of inhabitants, accessibility, and road and rail grid growth.In the scenario of the development (for example, 11.6 million square meters as predicted in the Master Plan), it is supposed the number of additional built-in areas (for example square meters for new housing) remain constant. Different spatial planning scenarios were described based on three urban models and the intervention of master plan.

1. City Master Plan (CMP) to identify new areas under the master plan approved in 2008 by the council of municipality;

2. A scenario of compactness, where the newly built-up areas are located in few zones in central regions;

3. Sprawl scenario, spreading the newly developed areas into the urban periphery zone; described in the density values two different scenarios for the spread (Sprawl P and Sprawl

C);4. The TOD scenario concentrates on the latest growth in many inhabitants regions of built up and proposed rail network stations and is based on the TOD scenario. In particular, TOD P new development is situated near the new railway path in the western section of the urban area, when the TOD C scenario includes putting new scenario in various station areas on the sides of west and east side of the urban area and has been identified by two separate TOD scenarios (TOD P and TOD C).Two main assumptions were made in relation to the creation of the transport network:

a) Complete network (C), which included the initiatives proposed by the city master plan;

b) Partial network (p) which comprised a sub-set of the full net which in line with the existing and funded initiatives, assumed a more "realistic" expectation of transport infrastructure growth. See Figure ‘2.11 & 12’.

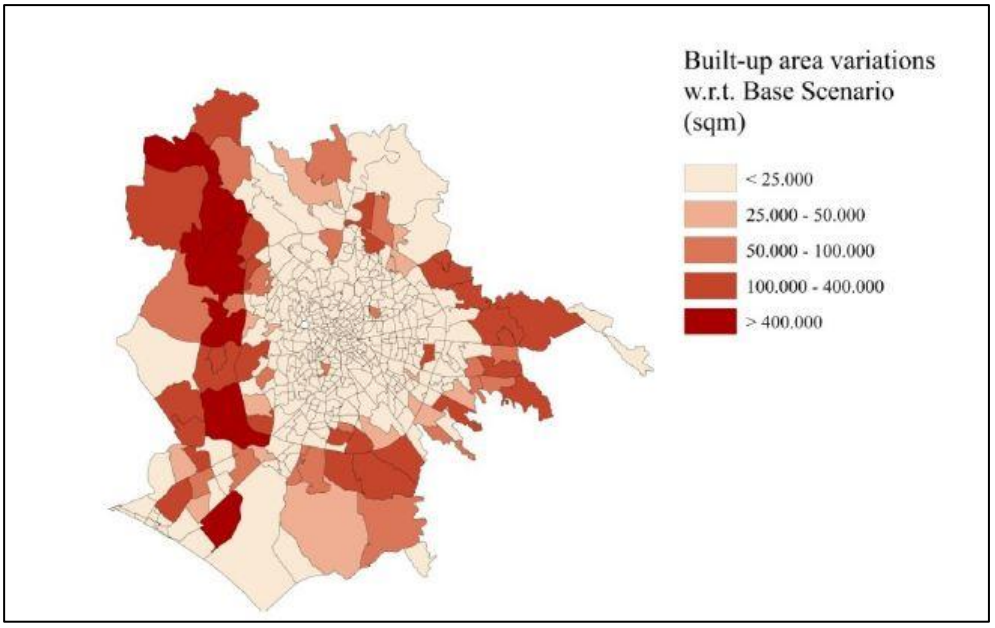

Figure 2.11: Various CMP scenario (Coppola, et al., 2014)

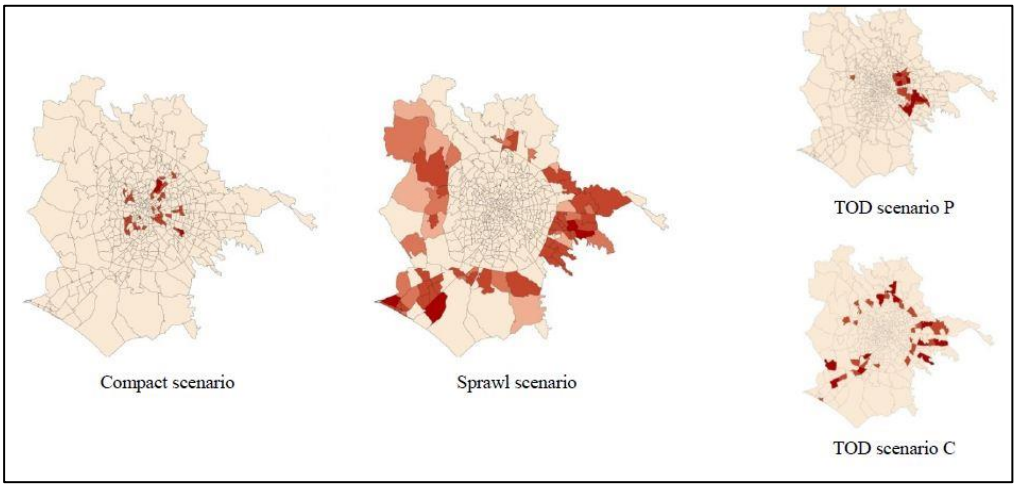

Figure 2.12: Compact, Sprawl, TOD (C &P) (Coppola, et al., 2014)

Ten scenarios for future spatial development have been developed and a database containing data needed for the simulation is built for each of these scenarios from the nexus between the possibilities for land management and transportation systems. See Table '2.3'.

Table 2.2: Scenarios for Spatial development (Coppola, et al., 2014)

		transport network characteristics		
		Base network (2011)	CMP partial network	CMP complete network
land use characteristics	Base scenario (2011)	BS		
	City Master Plan CMP		CMP_P	CMP_C
	Compact		COMPACT_P	COMPACT_C
	Sprawl		SPRAWL_P	SPRAWL_C
	TOD		TOD_P	TOD_C

2.7 Summary

In this chapter the definition of sustainability and its aspects have been illustrated. Moreover, the environmental dimension of sustainability in urbanism have been determined. The relation between sustainability and urbanism and the background has been explained. The overall indicators of sustainable built environment has been demonstrated and the ones which are

related to urban level have been highlited, as seen in table ‘2.1’. Sustainable urban forms elements are the elements which can evaluate all forms in terms of sustainability (Jabareen, 2006). In order to achieve an extensive knowledge about reliability of sustainability in urban form, the principles have been identified, as expressed in section (2.3). The characteristic of each element have been demonstrated. The assessment of the types of sustainability through urban forms have shown based on the sustainable urban forms elements. The conclusions showed that there is solid interaction among these urban forms and sustainable urban form principle, as seen in table ‘2.2’. Furthermore, the approaches for assessing sustainable urban form based on the principles of sustainable urban form, like compactness, transportation, and mix land-use (through travel behavior integrated with land-use and transportation system), depending of the literature in the cities have been highlited. Also, the way of evaluating the sustainability based on the sustainable urban form factors has been introduced.

CHAPTER 3

EVALUATION OF INTERNATIONAL CASES IN TERMS OF SUSTAINABLE URBAN FORM

3.1 Introduction

In the previous chapter, the elements of sustainable urban form have been identified. The characteristic of each element has been demonstrated as; compactness, density, transportation, and mixed-land use. These elements describe how sustainable urban form can be evaluated and influence the design of several important examples.

This chapter examines sustainable urban form assessments in three cities, according previous studies. The international cities as cases are selected to evaluate the sustainable urban form, and they are; Gaziantep in Turkey Lahore in Pakestan, Nagpur in India, and Copenhagen in Denmark. The cities has been selected based on their similarity with Erbil city I different dimensions; they are orient cities and closed to the culture of Erbil as Lahore, Gaziantep and Nagpur, and also they are located in Asia. Moreover, the cities are located in developing countries, which another factor that can add similarity with the level of development in Erbil. Copenhagen has been selected as one of the most developed cities in terms of urbanism in the world level, and based on the size and number of population which is closed to Erbil.

These selected cities as international case. The case studies have be evaluated according to the presence of the indicators of, density, transportation, and mixed-land use. Where, these indicators are tools to evaluate sustainability in urban form. The selected cities have variety in terms of of sustainability in their urban forms, some of them considers high population cities like Lahore, Nagpour, and then Gaziantep, and Copenhagen. The cities have variety in the development point of view, where Copenhagen considers the capital of one of the developed countries that is Denmark, and Gaziantep is located in the developing contry (Turkey), same for Nagpour- India, while Lahore is located in one of the low developed countries that is Packistan. The main factors to evaluate the Sustainability in Urban forms for these case studies are:

1. *Density:* It is an important classification, the proportion of people or a residential portion of a property, and sustainable urban areas are a matter of density in a wider context (Carl, 2000; Walker and Rees, 1997).

2. *Transport*: Transportation is obviousely the single largest matter of specific debates about urban structure (Burton, et al., 2003). Moreover, Hillman (1996) asserts that a feasible urban structure should be a structure and scale appropriate for walking, cycling, etc.

3. *Mixed Land Uses*: It gives the potential for locating harmonious land management in close proximity to one another, thus reducing the movement distance between operations (Parker, 1994). Mixed use of land refers to a diversity of functional land uses like activities related to business, housing, and industrial, or transportation (Alberti, 2000; Van and Senior, 2000).

3.2 Gaziantep in Turkey (1st International Case)

A study by Emekci and Kayasu (2017), has discussed the intersection of the features (considered as prominent features); compact shape, sustainability in transportation, and mixed land use. In this study, Gaziantep have been evaluated through only three design concepts, which considered as three keys for the growth of urban form:

1) Transportation: Extension of road and transit infrastructure; 2) Economic: Greenfield economies or processes of redevelopment; 3) Cultural: The socio-cultural comprehension of urban space" (Kostof, 1991). See Table 3.1.

Table 3.1: Sustainable urban forms and their prominent features (Emekci and Kayasu, 2017)

Sustainable Urban Forms	Prominent features
Neo-Traditional Development	Compactness, Sustainable transportation, Mixed land uses
Urban Containment	Compactness, density
Compact City	Compactness, Density, Mixed land uses, Sustainable transportation
Eco-City	Sustainable transportation, Mixed land uses, Greening, Passive solar design

The main reason why Gaziantep was chosen was that the city has above 1.5 million residents and faces rapid urbanization due to fast economic growth and the government willingly took the initiative to work towards creating an eco-friendly urban policy to reduce the emissions of greenhouse gases GHG. The city is considered a pioneer city of sustainable urban development in Turkey. Gaziantep has historically been a center for the industry of South Anatoly and it is now one of the Anatolia and the Middle East economic gateways. This has, therefore, an important opportunity not only to become a more sustainable city but also a regional innovation center that provides good experience for the other urban area (ECA, 2011). Gaziantep is one of the tenth largest metropolises in the Turkey and also one of sixth largest cities the the country. It was the more rapidly growing city between 1990 and 2010, with 4.25%, as per the Turkish Statistical Institute (ECA, 2011).

3.2.1 Density

Gaziantep is an old urban area in Anatolia, according to Emekci and Kayasu. The growth in population began with rural-to-urban immigration in the 1950s. The city had a population of nearly 120,000 in the seventies, and its population increased to over 1,9 million in 2017, according to data from the Turkish Statistical Institute.

The population growth of Gaziantep began due to Refugees from Syria in 2013. The most important contributing factor to urban sprawl is the growth of the population. The

investigation of Gaziantep historical development leads to find four important master plans. The master plan of Gaziantep has been prepared by Herman, who underestimated the population growth. The second master plan has been developed by Kemal Aru and K. Söylemezoğlu. The traditional urban values of the city and the transport network were highlighted by these two master plans. In the 1950s, with the immigration motivation, Gaziantep has grown quickly. The quick increase has resulted in a demand for dwelling units and working place. Therefore, between 1960 and 1975, the city confronted the emergence of slums. Forty new neighborhoods have been grown in the city, and the majority were out of designed regions.The third master plan was done by Zuhtu C. to serve the new demands of Gaziantep. In the last decade of twentieth century, the population has grown rapidly, and the development of the city into unplanned regions did not stop. (Emekci and Kayasu, 2017).

However, many additional plans have been achieved, especially in 1980, during Afghanian immigration, where, Göllüce Mass Housing Area for Afghani immigrants has been developed, but local people has settled in instead. An additional master plan area has been developed when Bağlarbaşı Mass Housing Area planned for immigrants came from eastern and southeastern Anatolia. Serice Mass Housing Area, also, was another additional master plan that added to the master plan of Gaziantep in 1993 in the south and southwest side of the city. Moreover, in 1998 the additional development has been implemented.

A further master plan in 2002 included the western side of the city and the broad and frequent road patterns connected to the city center and industry. The new and revised Master Plan 2003 ring road provides 10 000 square meters nationalized as a result of the discrepancy between the decisions on two roads. In the same context, other additional master plans have been developed in 2004, 2005 and 2006. The travelling between the communities and the town center can be one of the evaluation ways for compactness. This can be viewed by looking at the evolution of this along time. Therefore, sprawl cities expand more in distance than compact cities. This distance expanded between 1980 and 2006 when additional plans were consider.See Figure 3.1.

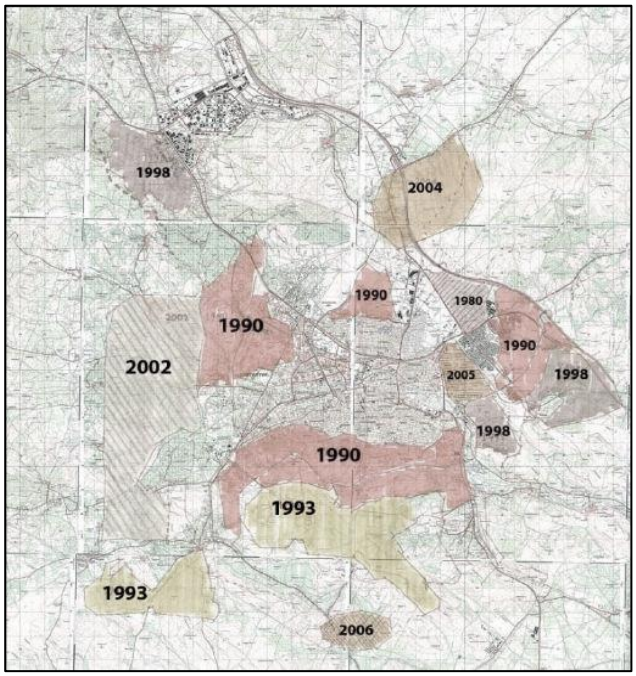

Figure 3.1:The development of Master plan of Gaziantep by additional master plans(Yilmaz, 2014)

New additional areas of development are far from downtown. It increases the reliance on automobiles. Accordingly, though the number of cars were 210,773 in 2005 based on Turkish Statistical Institute in 2005, and it increased to 471,360 cars in 2016 in Gaziantep. These data are proof of urban sprawl. Casual settlements were found in the eastern, and southern-east of the town when the spatial structure of Gaziantep was examined. Only Gaziantep's old town regularly developed towards the west. As Gaziantep was formerly compact, the decision not to recognize the integrity of Gaziantep made it now sprawl (Emekci and Kayasu, 2017).

The development of the urban macroform may be helpful to support such a statement above. The city of Gaziantep began at the castle and its surrounded region known as ‘Turk-tepe’. In time, the city sprawled along with the main line of transportation. Where the city extended along the main road on both sides. See Figure 3.2.

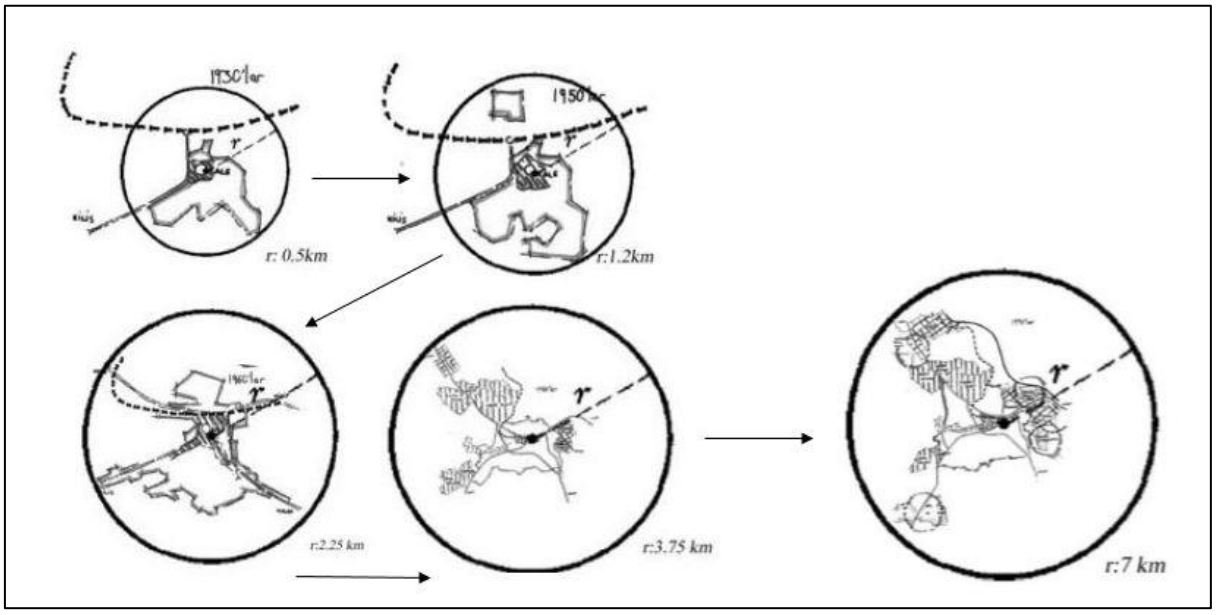

Figure 3.2: The sprawl of Gaziantep city from 1930s to 1990s(Emekci and Kayasu, 2017)

In order to calculate compactness, the layout of the city macro type can be interpreted by changing the diameter of the covered place. The diameter was expanded by around 2 times within two decades after 1930. The development of the outermost regions of the town is reflected in this.Gaziantep was divided into administrative, residential, and industrial regions in the 1980s. Such zoning areas were supported by the plan of 'Oğuz Aldan'. It suggested residential areas away from the industrial area. This began in the 1990s with fragmentation and segregation processes. See Figure '3.3'.

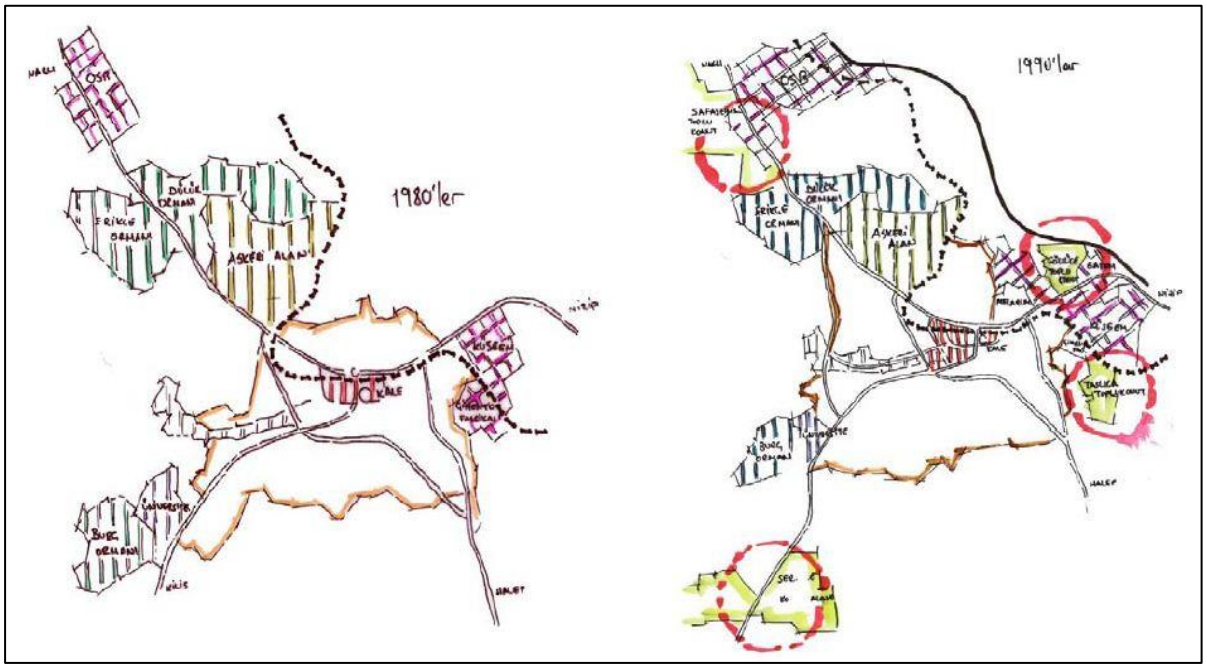

Figure 3.3: Development of Gaziantep city in 1980s and 1990s(Emekci and Kayasu, 2017)

According to the obtained data, the population of Gaziantep city is 1,667,546 [1], and the total area of the city is 622.2 square kelometers[2]. The following Table '3.2' shows the density of the city in different periods.

Table 3.2: Population, area, and density of Gaziantep (Emekci and Kayasu, 2017)

Year	Land use Area	Population of Urban	Population Density
1974	8010 Ha	427.017	53.31
1990	21000 Ha	821.127	39.10
2006	30.000 Ha	1.342.518	43.30

Accordingly, the density of the city core is 43.30 pph, while according to the last estimation of population the density is 26.8 pph.

[1] Since 2013, the population of city cores are calculated based on the city quarters population; in some cases this computation may not be very accurate.
[2] State Institute of Statistics, Republic of Turkey (web). Retrieved from, https://www.citypopulation.de/en/turkey/gaziantep/

3.2.2 Transportation

Gaziantep City has historically been on major trade routes nearly along the Silk Road, linking Anatolia with the fertile Mesopotamian lands. Hence, a transport network plays a significant role in the city's growth (Karakaya, 2012). Three major road connections exist in this region. The first road links Niğde, Mersin, and Şanlıurfa (O-54) motorway. Second, the Silk Road is called (D-400). Lastly, (D-850) connects Syria to Turkey in the north-south direction. The public transport system in Gaziantep is not sufficient and mainly the road transportation system is used, so there have been increased numbers of private cars in the city. The lack of infrastructure contributes to caused emissions in the city because of traffic problems (Ministry of Environment and Urban Planning, 2012, (as cited in Emekci and Kayasu, 2017).

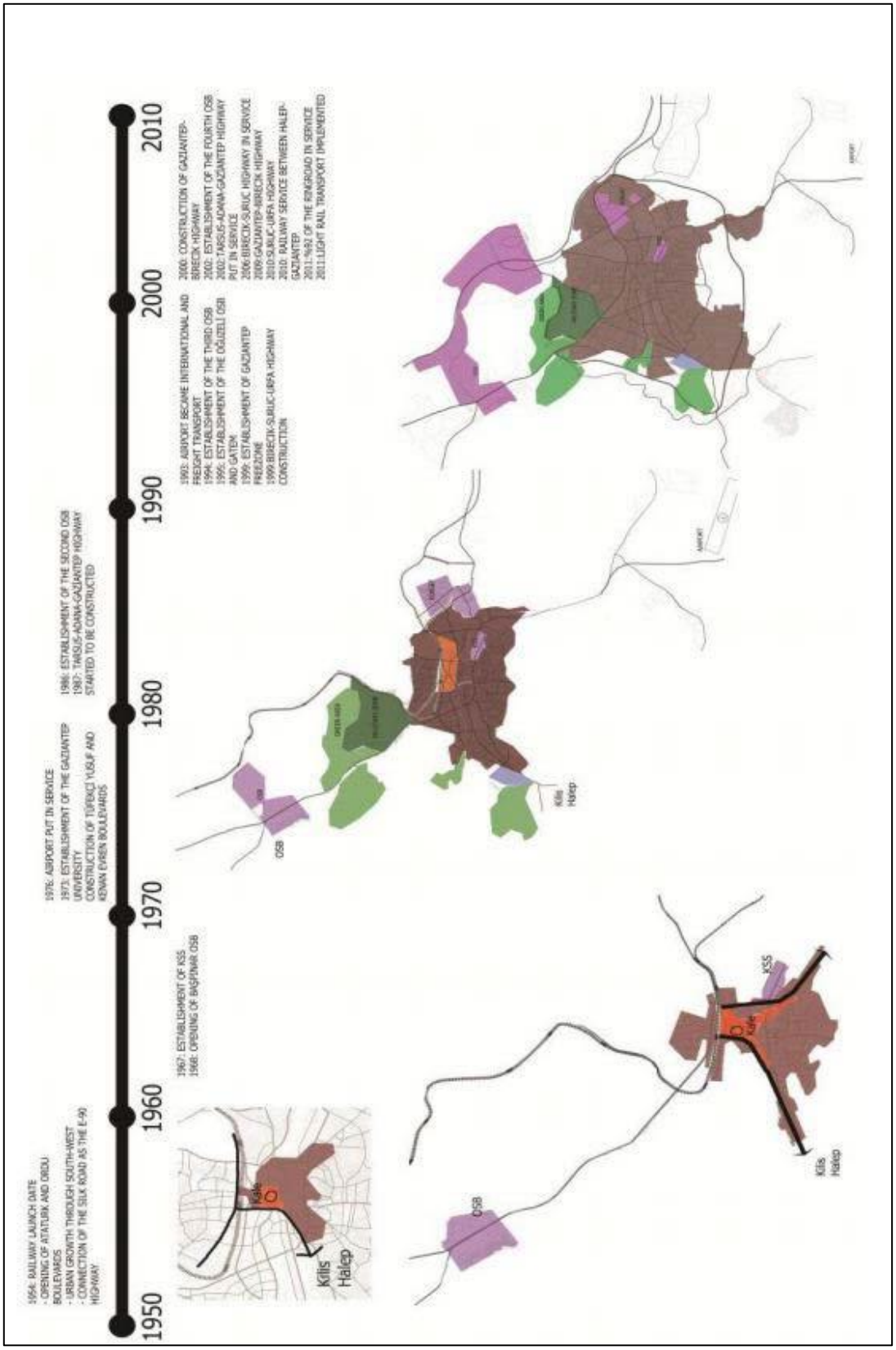

Figure 3. 4: The development of transportation network in Gaziantep city. CRP 401-402 Planning Studio Analyses (2012)

In sustainable development, transport plays a significant role. The transport sector has a high potential for sustainable development in the region. An increasingly growing population and increased car dependence can affect transportation greenhouse gas (GHG) emissions.In the first decade of twenty first century, Gaziantep's population has increased by 62%, in the same time the number of cars increased more than doubled (ECA, 2011). See Figure '3.5'.

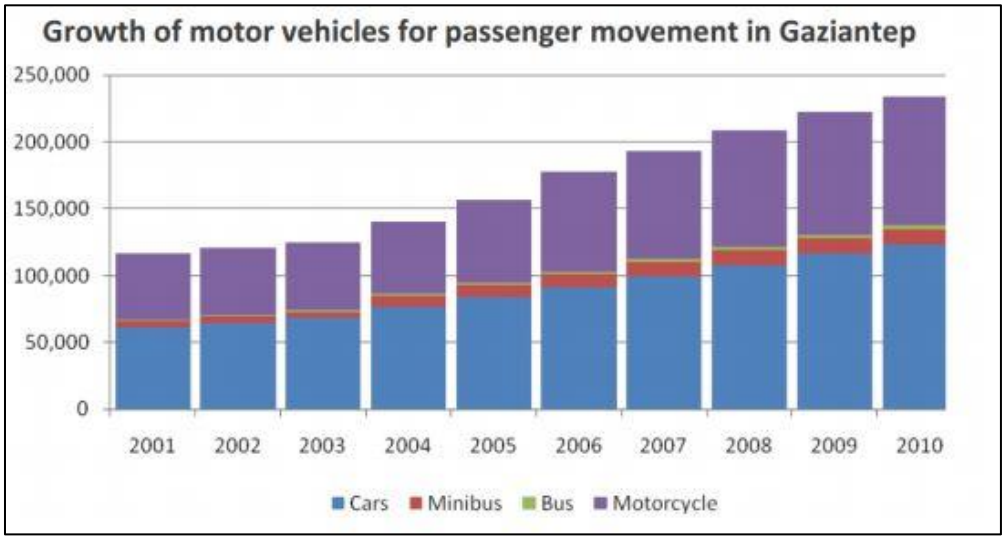

Figure 3.5: The growth of vehicles in Gaziantep (ECA, 2011)

There are 314 km of state highways, 148 km of motorways and 187 km of provincial roads (total 649 km) within the administrative borders of Gaziantep[3]. Therefore the road network density is 0.4 mpp (meters per person), and the road higher density is 1.04 m/ha (meter per hectare).

Gaziantep had 304,344 vehicles by 2010, 225 per 1,000 people, much higher levels than most similar income-based cities with the same size of the population (ECA, 2011). The Most energy is used in the transport sector. The energy efficiency of public transport is higher than private vehicles. For an estimated 960.000.000 MJ of public transport resources used, the private car was almost 2.700.000.000 MJ (ECA, 2011). See Table '3.3'.

[3] Gaziantep Integrated Healthcare Campus Esia/Vol Ii/Annex F. Retrieved from, https://www.miga.org/sites/default/files/archive/Documents/Vol%20II_Annex%20F_Traffic%20Assessment_Sept%202016.pdf

Table 3.3: Energy consumption through vehicles in Gaziantep (Yilmaz, 2014)

Annual Energy Use and Energy Spent on Mobolity in Gaziantap.2010

Mode	Energy Use((MJ)	Energy Spent	Energy Intensify ((MJ/PKM)
Public Transportation	964,257,023	53,775,872	0,32
Private Vehicle	2,770,038,147	1,999,442,747	1,30

The study of Gaziantep's travel characteristics allows understanding that the majority of the travels are between the Industrial zones, the center, and the working primary areas.Based on the master plan for transport in the municipality of Gaziantep 65,000 people are moved to the industrial region of OIZ; 40,000 to Küsget. Transport GHG emissions estimated by 690 kt of carbon dioxide emission, 470 kt of which is CO2, for people's road transport. The number of tons of CO2e / capita is 0.36 (AFD 2011). See Figure ‘3.6’.

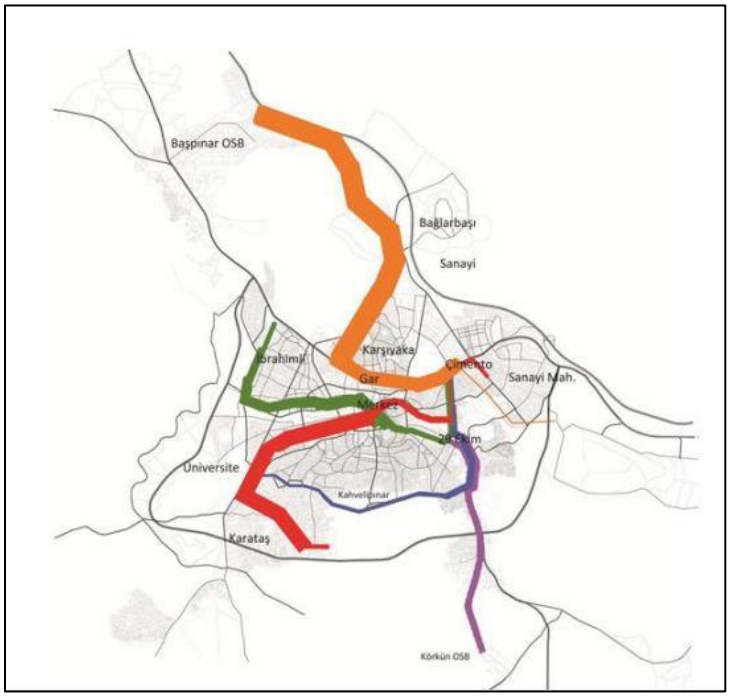

Figure 3.6: The volume of mobility (traffic) in Gaziantep (the thicker lines indicates more volume of traffic) (Yilmaz, 2014)

The total emission amount of CO_2 by traveller transport per person is around 1240 Kilograms annually in the medium and large cities of the model size (50 cities) based on city database samples, located mainly in the developed economy countries. This average is approximately 907 kg in the European cities of the sample (UITP, 2001).However, Gaziantep still generates relatively low levels of transport GHGs compared to developed countries, while car ownership has risen. Preventive steps against increased ownership of private cars must be taken.Light trains are the main drivers of Gaziantep's sustainable urban planning program. Through the use of less electricity and fewer greenhouse emissions, this mobility appliance provides fast and reliable transport. It also reduces the congestion of traffic and air pollution (Emekci and Kayasu, 2017).In the same context, A light rail network will extend by 30 km in Gaziantep. This test yields better results for the environment. Gaziantep, however, is relatively low if compared to other cities in relation to the proportional length of high-capacity transit lines. The bicycle ways are important in achieving sustainability. However, cycling in Gaziantep is still not very popular. It only accounts for 1% of journeys. In Gaziantep there is currently no bicycle path. A 19 km bicycle path will, however, be installed (Yilmaz, 204).

3.2.3 Mixed Land-Uses

Increased distances from home to work would contribute to reliance on automobiles. The transport issue was subsequently traffic congestion. Mixed-use helps to solve this issue by decreasing journeys (motorized) and excursions during the day. Mixed-land is used for better places to live as the critical part. The total area of Gaziantep is 622,200 ha. Most of the land is inclined and rugged. The mountains of Nur (Amanos) make up the city's southern boundaries and the Euphrates river is the northern border. Parallel to the Nur mountains is the mountain range. The city is surrounded by valleys and rivers (Gaziantep Governorship, 2010). Mountains cover large regions. The plains, the plateau, and the upland follow mountainous areas. See Figure ‘3.7’.

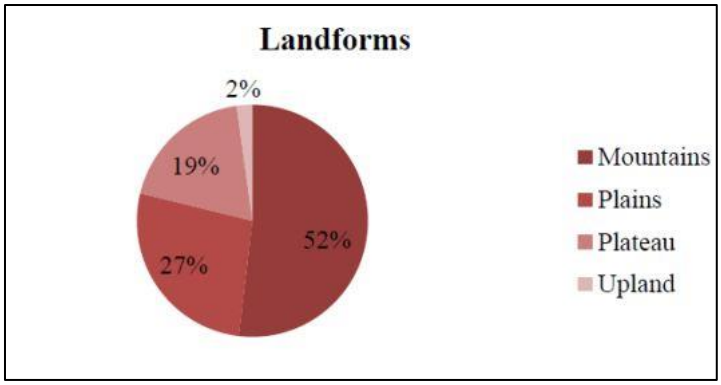

Figure 3.7: Gaziantep landforms (Yilmaz, 2014)

Inhabitation were restricted by mountainous regions. But the urbanism has grown mainly in the inner-lands where growth is ideally suited. The city consists of heavily populated townships. The ratio of built-up to open area in Gaziantep was 2.29 times (Görücü and Yenice, 2019). The urban center comprised areas serving various functions including residential areas, industrial areas, military zones, cemeteries, tourist areas, and solid waste collection areas. See Figure '3.8'.

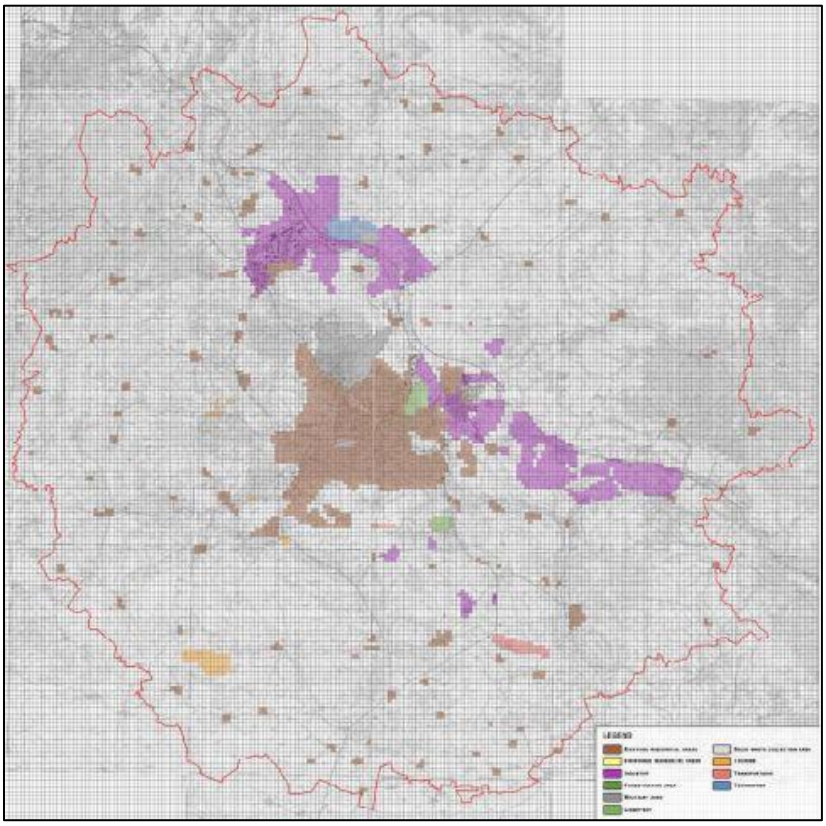

Figure 3.8: The land-use map of Gaziantep (CRP 401-402 Planning Studio Analyses, 2012)

As illustrated in figure ‘3.8’, settlement regions are built at the west and south ends of the city (See brown color) while the north and east comprise developed industrial zones (See violet color). It leads to long walks from houses to workplaces.Therefore, vehicle miles traveled (VMT) and a rise in car traffic. In nearby residential areas, however, the light industrial areas were developed on the eastern side of the city. The direction of the city's development was to the east because of reducing the distance between going /coming to work (Emekci and Kayasu, 2017).On a neighborhood scale, Bey Street, Hanifoğlu Street, and Çamurcu Street, with an average height of 1-2 storeys have good relationships inside and outside. However, on other streets, there is a weak relationship between the inside and outside. They include numerous areas including houses, state-buildings, Turkish baths, cafés, and restaurants as well as mosques for the public and visitors. However, since the lack of pedestrian paths, the lack of parking areas, and traffic congestion, mixed-use will not work there (Yilmaz, 2014). The study found in Gaziantep, a sustainable land-use strategy supports the development of mixing the use of lands involving business and residents regions. Consequently, the city's production of land- uses is fairly mixed at the scale of neighborhood. When studied on an urban scale, the high-value vehicle miles traveled (VMT) caused, when the organized industrial sector placed in the north of the city.The study shows that travel activity and mixed-use planning are closely related. In the development of mix-use walkability and cycling increase (Saelens and Handy, 2008). The average daily rate for vehicles is thus decreased by mixed land-uses. As an assessment method for mixed-use growth, the proportion of trips can be used. See Table ‘3-4’.

Table 3.4: Transportation modes based on masterplan of Gaziantep (Emekci and Kayasu, 2017)

Transportation Mode	Daily Total Trip(%)		Daily Vehicular Trip(%)	
Pedestrian	54,08	54,08	-	-
Para-transit transport	12,57	34,31	27,36	74,71
Bus	8,23		17.92	
Personnel and student service	13,51	9,49	29,42	20.66
Private car(Driver)	7,06		15,38	
Private car(Driver)	2,36		5,14	
Taxi	0,07		0,14	
Bicycle	0,28		0,62	
Motorcycle	1,05	1,34	2,30	2.91
Others	0,79	0,79	1,72	1.72
Total	100	100	100	100

According to Gaziantep's Transport Master Plan, 54.08% of travels are done by walkers. Compared to other cities, the rate is high. The neighborhoods of Gaziantep are assessed to include diverse areas such as sports, business, and residential areas. Accordingly, 54,08 percent of total urban transport is by pedestrians, similar to a comparative and detailed report. Compared with other cities in the world this rate is very high.For instance, in New York City, this rate is 10 percent, which is usually considered mixed-use. According to the study, Gaziantep is also at an average daily rate of 0.49 per person, and the comparison with other cities, the rate is very small.

3.2.4 Conclusion of the 1st International Case

Compactness is the first concept from the point of view of key design principles in connection with sustainable urban forms. Compactness in sustainable urban planning literature is a key element in achieving urban sustainability. Gaziantep is a sprawled city because of the increased size of this city in unplanned ways when considering Gaziantep in terms of compactness. Sustainable transport is the second concept. The biggest issue related to land use patterns is the transport that makes major contributions to climate change. The comparative study’s results of the growth of the mixed-use of lands, the city formed in mixed-use patterns. An assessment of the 3 design principles reveals that the city cannot be considered sustainable when analyzed in the sense of sustainable urban forms in terms of core design principles. However, the city

remains strongly advancing towards more sustainable growth. Gaziantep plans so many areas for development have a strong vision for the future.

3.3 Lahore in Pakestan (2nd International Case)

Liaqat, et al., (2017), have made a study aiming to investigate and quantify compactness in the city of Lahore with different dimensions and related indicators. An assessment of Lahore's urban form has been evaluated using the Lahore Development Authority master plan 2021. This analysis has helped to quantify different land uses of the district of Lahore. Nevertheless, the literature was analyzed to formulate indicators to assess the urban compactness characteristic. Depending on a study of Nagpur, India, a set of indicators have been employed (Kotharkar et al. 2014), to check the compactness in urban sustainability. The evaluation of urban sustainability contained a total of 18 indicators. In order to verify the adequacy of these indicators in the local context, a priority evaluation has been carried out. Hence, planners, architects, engineers as well as economist have been interviewed. Accordingly, a framework of indicators to evaluate sustainability in urban areas through the compactness approach in the city was developed, as seen in Table '3.5'.

Table 3.5: The indicators to measure Density, Transportation, Accessibility, Mix land-use (Liaqat, et al., 2017; Kotharkar et al. 2014)

HIGHEST TO LOWER PRIORITY

LOWER TO HIGHEST PRIORITY

Density	**Gross Pop Density**	**Land Use Split Up**	**Average Density**	**Average Land Consumption Per Person**	
Transportation Network	Average Trip Length	Road Network Density	Walkability Index	Congestion Index	Mode Share
Density Distribution/Dispersion	Density Profile	Population by Distance to Centers of Gravity or CBD			Density Gradient
Accessibility	Public Transport Accessibility			Service Accessibility	
Mixed Use Land Consumption	Land Use Split Up	Ratio of Residential to Non-Residential Use		Ratio of Built-up to Open Area	

The density and the regional distribution is an urban fundemental unit that is commonly used for sprawl evaluation (Knaap et al. 2005) . In order for a better understanding of the total density trend in Lahore, three different patterns of density were employed; (i) the total density of people(ii) average density of the urban area (iii) profile of the density. For evaluation, 1998 census population and reported 2015 Lahore population by the Punjab statistic office were employed (Government of Punjab, 2015). Transport affects urban sustainability through its impacts on environment, economy, and society (Haghshenas, and Vaziri, 2012). It depends on the town's strategy for land use. The empirical calculation formulaes for the mentioned indicators are illustrated in Table '3.6'.

Table 3.6: The indicators characteristics and the calculation ways (Liaqat, et al., 2017)

Urban Form Characteristics	**Indicators**	**Calculation Formula**
Density	• Gross population density • Average Town density • Density profile	Gross Population Density=estimat population/area Average Town Density= Town Population/Area
Transportation & Accessibility	• Average trip length • Road network density • Public transport accessibility	Road Network Density= Road Length(meters)/Population
Mixed Use Land Consumption	• Land use split up • Average and consumption per person • Ratio of residential to non-residential use • Ratio of built up to open area	Ratio of Res.to Non-Res. = Residential Area/Non-Residential Area Avg.Land Con. Per Person= Town Population/Average Land Consumption Area(Sq.m) Ratio of Built-up to open Area= Built-Up Area/Open Area

Related and required data are colledted from governmental bodies (Government of Punjab 2015). While, Master Plan of Lahore, data about land management were got from Development Authority of Lahore, and other authorized qovernmental bodies of Lahore, as well as the Urban Unit Lahore. While, the field survey was approached to obtain the length of strip, and the access to public transport by inhabitants in Lahore. Through convince sampling technique, a total 60 respondents were interviewed face to face.

3.3.1 Density

A mitigation in the density value during the times is calculated as an urban sprawl alert, and the compactness is delineated by the density distribution. Density indicates the trends to development and urban growth. Their distribution, however, can differ across different parts of a region. The growth of Transit-oriented use of lands can be accomplished by the localities of density (Bulkeley, and Betsill, 2005). In addition, the sustainable increase of density will guarantee the prosperity and optimal utilize of natural and man-made resources. Urban developement implicite in higher density, and the globalized condition of urban size, urban syntax, and urban form (Lau et al. 2000). Nevertheless, density is causing some problems as deficiency of privacy, and tensions, also, breakdown of identity, and cause lack of connections. in addition, it helps the rapid population growth, and shortage of land and increase the negative impact on environmental (Zhang 2000). Lahore has been divided into nine administartive towns, as seen in Table '3.7'. Remarkable contrast confirmed regarding density in marginal and cerntral towns of Lahore. This is due to the intensification of a continuous economic activity in central parts of the city like in Samanabad Town, and other towns.

Table 3.7: The density in Lahore (Liaqat, et al., 2017)

Sr. No.	Town	Population 2015 Estimated	Area (aquare Kilometers)	Average Density (Persons per Square Kilometers)
1	Aziz Bhatti Town	623,000	91	6,846
2	Data Ganj Buksh Town	1,070,000	35	30,571
3	Gulberg Town	859,000	34	25,619
4	Allama Iqbal Town	853,000	475	1,796
5	Nishtar Town	1,104,000	532	2,075
6	Ravi Town	1,749,000	64	27,422
7	Samanabad Town	1,086,0009	37	29,495
8	Shalimar Town	585,000	16	37,332
9	Wagha Town	724,000	447	1,621
10	Cantonment	892,000	70	12,674
	Total	9,545,000	1,800	-

The total density of population in Lahore is estimated about 5300 people per sq. kilometer (53 people per hectare) according to Punjab population in 2015. This indicates weakness in the compact shape based on the size of population in Lahore is significantly low when parallel to the United Nations density size of 15,000 people per square kilometers (UN-Habitat 2014). In the evaluation of sustainable urban forms the average land consumption per person, residential to non residential ratios and a ratio of built-up to open spaces were key elements regarding mixed Land-use, (Jabareen 2006).

3.3.2 Transportation

Public transport also contributes to increase density through the traffic density. A shorter moves through the highway grids is therefore expected. The density of the road system is a crucial transport network indicator. Urban growth and construction of road networks are strongly connected. Studies have found that the key main driver for urban growth is the road network, and the total road length in Lahore is estimated by 7826.9 km. The current study came out with that more dense streets net has determined altitude growth. The density of road net is 0.82 m per individual in Lahore, while, in Nagpur is 0.21 meter for individual, Denver is 1.7 m per individual, Sydney is 1.2 m per individual (Kotharkar, et al. 2014). The higher road density (HD) in Lahore found 43.5 m/ha. The access to public transport in Lahore is 1.55 km, whereas it is 0.4 to 0.5 km (UN Development Programme, 2010). Similarly, Lahore has an average travel length of 42.32 km a day while New York and Chicago have an overall distance of 30.42 and 21.73 kilometres.

For sustainable growth, the value for Lahore must be decreased. The cheapest mode of transport is public transport, especially for developing country such as Pakistan. The average interval to the bus station in Lahore is 1.55 km. the major participats, nevertheless, claimed that publics' transit paths are not connected to their end points or major nodes directly. They also indicated that traffic and parking problems were not planned and controlled.

3.3.3 Mixed Land-use

The allocation of land-use illustrates the classification analyzing for the places utility and city speawl (Galster et al., 2001). Average consumed land per individual employed to measure urban land and population density (Fulton et al., 2001). The resident. to non-resident. ratio, and the

built-up to the open area ratio applied for testing of tendancy relations (Ewing 2008) and the pattern of developement (Song and Knaap 2004). In Lahore, a various sorts of land- uses is identified at the macro level as seen in Figure '3.9'. In the city district the areas are divided into farm lands and formulating 48%, the arid land which is disused land has involved 25% of the total residential land. Moreover, mercantile, health, and education are underlying 21% of the whole land. The policy and planning problem of land use lies in the absence of environmental issues which lead to the problem of city governance. It indicates the poor relationship between the urban land - use and transport network. Only the direct action will address the social and environmental issues related to the current model of transportation and land managemnt allocation (Giuliano 1995). In the global level, the development of constructed areas has played a major role in reducing green areas, and gardens that can be resolved by effective legislation (Mosammam et al. 2017).

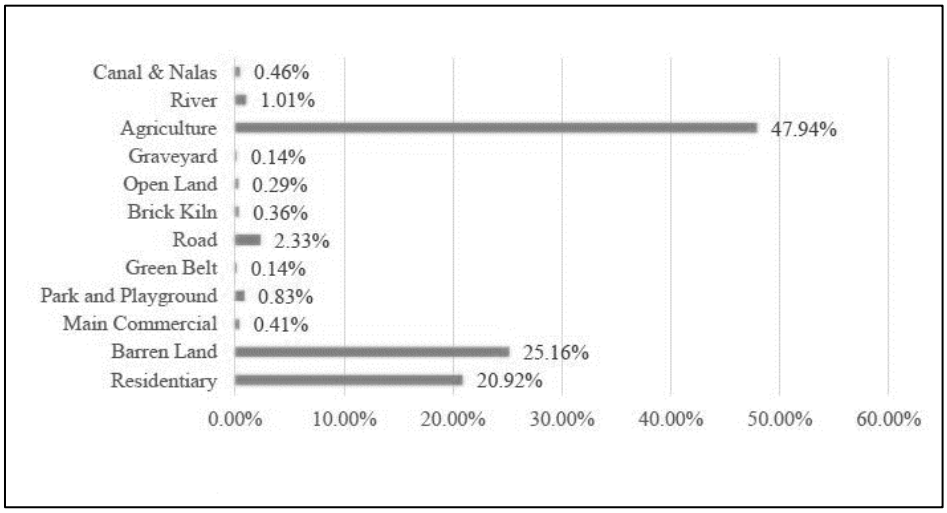

Figure 3.9: Percentage of different Land use – Lahore (Liaqat, et al., 2017)

On the contrary, it was noted that park and playground allocation is very limited which is important for life quality and sustainability. This is partly due to the low priority or less consideration provided by the responsible government authority towards the passive/active recreation facilities. In this city, the mean value of "built up area to open area ratio" was 4.35 which points constructed area in this city is four times bigger than the open spaces. This case is because of the large investments projects like multi-storey buildings, and the new housing developements, in addition to constructing the roads in the Lahore. It has pointed out thae

majority of the land in the region of Lahore is located in the arid zone, which indicates that the zone is appropriate for housing purpose however, it is still empty for unexplained reasons. Land buisness and real estate brokers play a major role in higher land prices. The residential area is higher twice than the other Lahore land-use. For example, Wagha has the lower amount of 0.06 that confirm the lowest residency area. It has remarked that in average residents land is double of non-residential land in this city, and this is goes back to the special land that dealers recognized across the housing development lands investments.

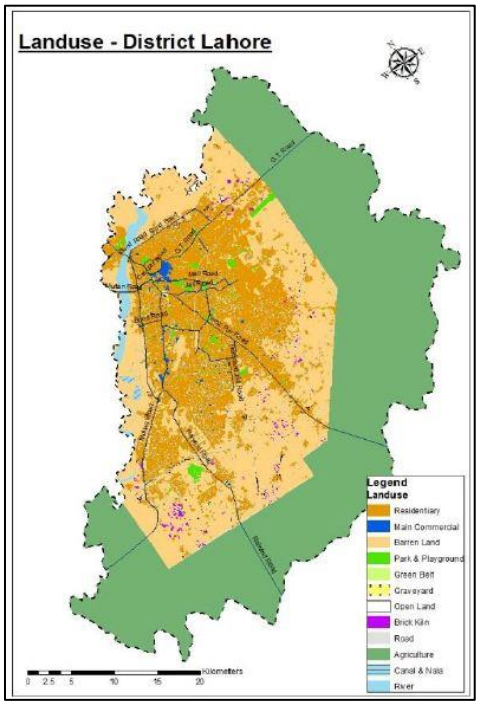

Figure 3.10: Master plan of Lahore (Liaqat, et al., 2017)

Benchmarks can be utterly definitive in the lack of ideal statistics for land use by comparing space use with different uses, and land requirements for cars too. Lahore consumes 455 sq. km from 1,800 sq. km. this indicates that only 25 percent of the total land is consumable in Lahore, and the remaining land does not help the people. As a result of new housing growth in this area, Allama Iqbal city has the highest rating, examples of that are; Bahria Town and LDA Avenue-I, and Jubilee Town.

Nevertheless, the average consumed land per individual is 51square meters. This indicate that one individual consumes on average 51 meter squar in Lahore. The consumed land value is lower if it is compared with Berlin and New York, where the mean value of consumption of

lands per individula is 279 for Berlin and 249 New York (Bertaud 2003). When consumed land average comparing to the required land space for a vehicle to move and it is 40 m2. It is important to mention here that a vehicle consumes almost 80 percent of a plots of individuals, this indicates the car is invasive to individual's spaces in Lahore. The same point occurs in Moscow and Shanghai, where the low mean of consumed land of an individual's land recorded 59 m2 and 33 m2, (Bertaud 2003). The findings suggest that inhabitants' relies on the cars as a shape of transport are increasing and use of public transports are declining.

3.3.4 Conclusion of 2nd international case

Sustainability is a subjective concept in view of its comparison of Lahor's findings with norm and results from the major global cities, the scale has been developed using the expert advice of leading urban planning in the city. A sustainability matrix has been built to show if there is any sustainability in the town of an entity characteristic that has been accessed, as seen in Table '3.8'. Lahore consists of the compact town, but it lacks sustainability

Table 3.8: The Matrix of sustainability in Lahore (Liaqat, et al., 2017)

Indicator	Lahore Result	Standard	Opinion			
			Vibrant	Good	Normal	Poor
Gross Population Density	5300 inhabitants square kilometers	15,000 inhabitants square kilometers			✓	
Average Town Density	17.545 inhabitants per square kilometers	15,000 inhabitants square kilometers (UJN-Habitat 2014)	✓			
Land Use Split up	The value is mutch different				✓	
Avg.Land Consumption per Person	51 square meters	40 square meters(Bertaud 2001)			✓	
Ratio of residential to non-residential area	1.99 times	50 % or 1 time (Military of Housing and Works 1986)		✓		
Ratio of built-up to Open area	4.35 times	75% built up area or 3 times (Military of Housing and Works 1986)			✓	

Avg. Trip Length	42.32 Kilometers	New York 30-40 Kilometers Chicago-21.73 Kilometers (Cortright 2010)	✓
Road network density	0.82 meter per person		✓
Public transport accessibility	1.55 Kilometers	0.4 to 0.5 Kilometers (Wisma etal.2010)	✓

As previously mentioned, density, transport and land- use are crucial considerations for urban development in the compact city model. The findings show that the Lahore population is gross at 5,303 people per km2 and average city at Lahore is 17,545 people / km2, whereas Delhi is 12,591 people / km2 with Nagpur having 562 people per km2 (Kotharkar et al . 2014). It shows that Lahore's density can rise sustainably. Density profil in this city demonstrates that the empty land for living has better living facilities for new residential cities with fast settlements. Although, this growth, increases the average distances between towns and regions. In Lahore, parks and playgrounds are limited. In this sense, Lahore Development Authority urban planners claim that it would help achieve urban sustainability through a compact city strategy if better living facilities have provided within city limits.

Land-use division in Lahore is very different since its uses are increasing rapidly. It must adhere to some of the city's standards and plans. The average residential to non-residential ratio is approximatelytwo-times, which indicates that a residential area is twice as big as another land use neighborhood. The mean amount of the constructed space to the open space ratio is 4.35, which shows that the build-up space is about 4 times to open space. The mean usage of land in Lahore per individual is 51 sqm with significant implications for car use in the future as we see that from the average 42.32 km journey length in Lahore. This value is higher than the main cities in the world, as mentioned above. In addition, greater access to public transport in Lahore is another public issue. The situation requires urgent action from the govenmetal bodies, or, the result will be the control of private transport over public transport and dominate significant part of land usage. The diagram below illustrates Lahore 's rate of sustainability. The lines toward inside show the strong sustainability relation and outside lines demonstrate a weak sustainability in Lahore. see Figure '3.11'.

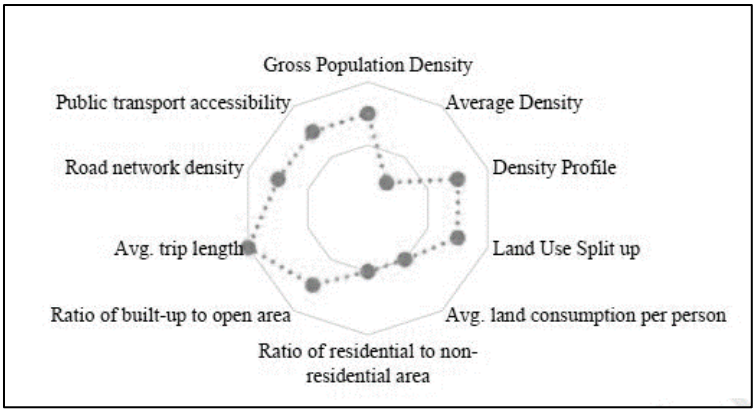

Figure 3.11: Sustainability in the city of Lahore (Liaqat, et al., 2017)

Generally, Lahore is partly condensed with a lack of sustainable development due to uncontrolled and unexpected growth, new houses on the brittle site, absence of organization and priority setting, and less growth and development in the outskirts of the city. It requires a thorough strengthening of sustainable urban planning strategies, services and plans.

3.4 Nagpur City, India as the 3rd international case

The study carried out by Kotharkar, et al., (2014) in Nagpur as one of the significant urban areas in central India within a diameter of 1000 km with remarkable growth and effect on the territory. This is through the assessment of the form to find out the existing compactness behavior. The objective is to examine different urban type measures in the context of a review of the literature. moreovre, identify indicators and to assess if the present urban structure of the city is compacted urban and conducive to sustainability in urban growth. The hypothesis of this research refere to the importance of compactness to achieve sustainability. In the beginning, the literature review extracts a collection of urban type characteristics and indicators. In order to measure and understand the urban type, the urban background of the city of Nagpur is studied through analysis of data collected (by secondary sources). Finally , data analysis and findings evaluate the degree of Nagpur 's compact growth. The results are applied to proposing roadmaps for intervening and reforming the urban shape to implement sustainability in urbanism through the compact form. Nagpur an old city and goes back to 300 years. the urban growth developed from the historic core at the center. Figure ‘3.12’, demonstrates the map of Nagpure city with density distribution within the city.

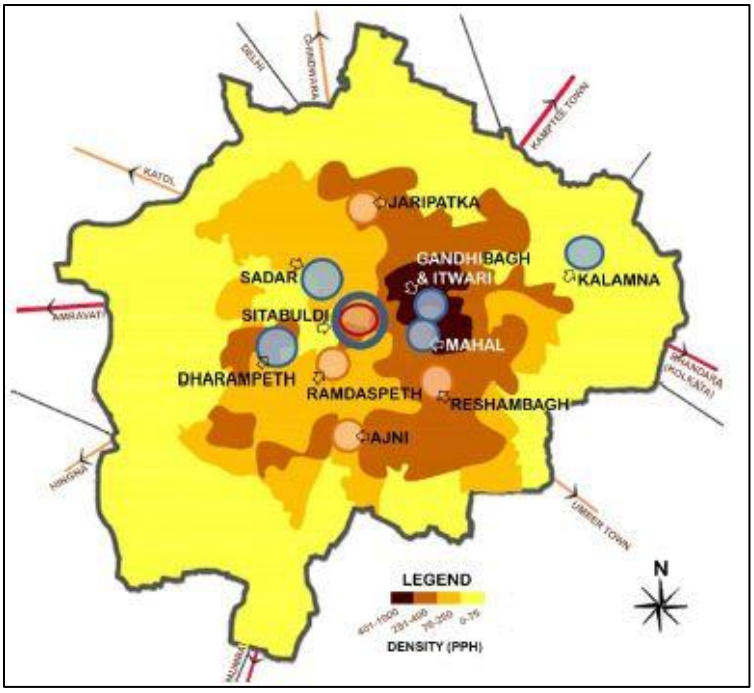

Figure 3.12: Plan of the city of Nagpure (Kotharkar et al., 2014)

Bertaud (2003) addressed a method for investigating the organization of the spaces in an urban area, and it is applied to recognize whether the urban shows a polycentric, mono-centric or a combined model.The spatial structure of an urban region has two overlapping style; the population distribution within the space in the urban area when people settled in their residences, and their distribution during their daily movement. Thus, it considered a acombined model derived for this city, after combining the two models , i.e. population movements and population distribution.

A group of characteristics for urban form have identified and their indicators are obtained based on the literature, as seen in table '3.9'. To assess the form of the city, the series of factors for land composition and mixed-use features (as seen in clause F in Table 3.9) are charted and analyzed at the sector dimension, however they may not be charted at the city dimension. Therefore, based on the concerns of the current study it has been omitted in the discussion.

Table 3.9: The group of indicators for Urban form Characteristics (Kotharkar et al., 2014)

Key Urban Form Characteristics	Indicators	Key Urban Form Characteristics	Indicators
A. Density	• Gross population density • Average (built up area) density • Landuse spilt up • Average land consumption per person	D. Accessibility	• Service Accessibility • Public transport Accessibility
B. Density Distribution/Dispersion	• Density profile • Density gradient • Population by distance to the center of gravity or CBD	E. Shape	• Dispersion Index
C. Transportation Network	• Mode share • Average trip length • Road network density • Congestion index • Walkability index	F. Mixed Use Land Composition	• Land use split up • Ratio of residential to non-residential use • Ratio of built to open area

In order to evaluate the compactness of the city and to assess its adequacy as the potential for Nagpur growth, the urban context of Nagpur is explored. Below are detailed interpretations of the characteristics measurement of the urban form derived in this study.

3.4.1 Density

The calculations of density depending on the developed or constructed spaces, and it excludes large public gardens which are bigger than four Ha, and farm land, airport, unoccupied land, and water surfaces.Three factors have employed to evaluate the density in this urban area: (1) total density of population; (2) mean density of constructed area; (3) land use average per individual. Nagpur Development Plan 2000-2011 has a total area of 235,21 km2 and contains a total of 217 56 and 17,65 square kilometers outside the Nagpur Municipal Corporation's (NMC) boundaries. The NMC region is divided into 10 regions, currently subdivided into 136 regions, for administrative reasons (Town Planning Department, 2001).

a) Total density of population and the mean density of constructed area: It is remarked that in the study area, half of the zones and quarter of total 136 sectors have population density under 100 pph (person per hactre) as seen in figures ‘3.13’. In some marginal sectors density is lower than 32 pph, while central region density is higher than 600–1000 pph. See Figure ‘3.13’.

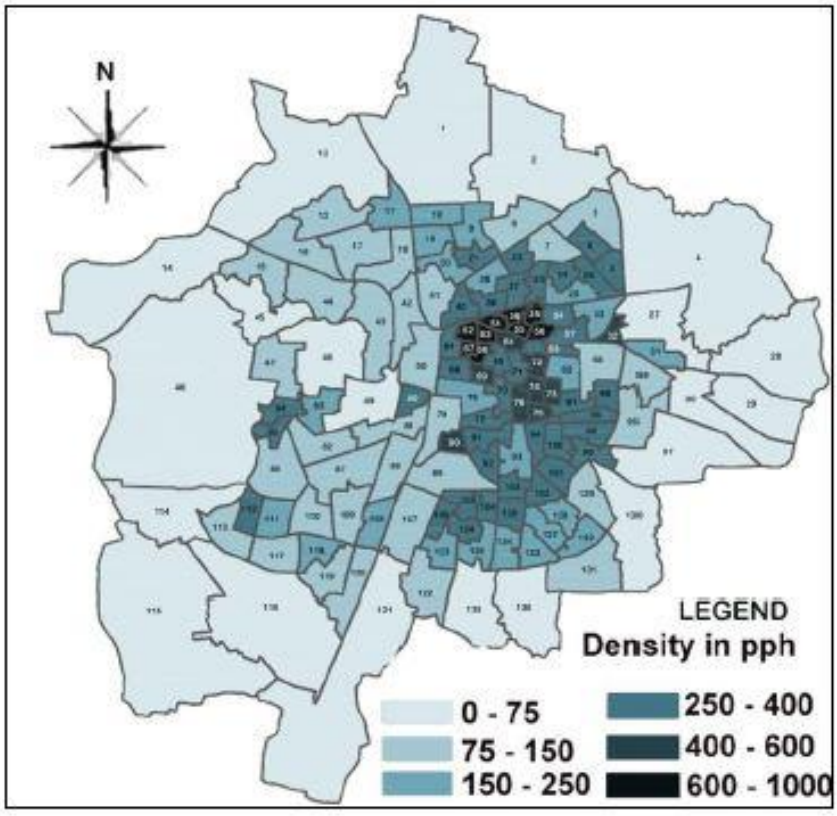

Figure 3.13: Density distribution pph for the city of Nagpure (Kotharkar et al., 2014)

According to the Indian guidelines, the density of developed area is considers 100–150 pph (UDPFI, 1996). Two predominant range of density in this city are: 75–150 and 250–400 pph, and the concentration of the population is majorly found within the radius of 5 km from the center of gravity (CG). The total density grew around triple since 1971, while the average built-up area density raised 50% more, as seen in Table '3.10'.

Table 3.10: The statistical data of Nagpure from 1971 to 2011, Census of India Data (Global Scientific Inc., 2011; Town Planning Department, 2001)

Year	1971	1981	1991	2001	2011
Adm. Area of city (Hectares)	-	21756	21756	21756	21756
Population	864,488	1,219,461	1,650,751	2,051,946	2,405,665
Gross Population Density (pph)	40	56	76	94	111
Developed (built up) Area (Hectares)	7057	8425	9794	12481	13609
Developed Area (built up) Density (pph)	123	145	169	164	178

Accordingly, based on the previous table '3.10', the open area of Nagpur is 8,147 hectar, hence the ratio of built-up to open area is 1.7 times.

Density Distribution/Dispersion

In the metropolitan area, population with altered densities is distributed or scattered. The density distribution scheme in the city can be understood by means of three indicators: (1) The density profile; (2) The population by distance to the CBD or Center of Gravity (CG), and (3) The density gradient.

a) The density Profile: In those cases where more people live near central business district CBD, the average journey period for instance, the distance per individual is less to CBD (Bertaud, 2004). Rather, in positively sloping density curves, longer average journey lengths can occur.The spatial density distribution in an urban area defines the shape efficiency in the mean journey from CG or from CBD. The profile of density provides a calculation of the city's average consumed land and division. Through which, also the root of most trips in a city is also determined (Bertaud, 2003). By analyzing the density dispersion map of the city of Nagpur (Figure 3-13), it is possible to conclude that the density profile of the real spatial density pattern in Figure '3.14' is not a true representation.The south-north railway line split the city into west and east parts.

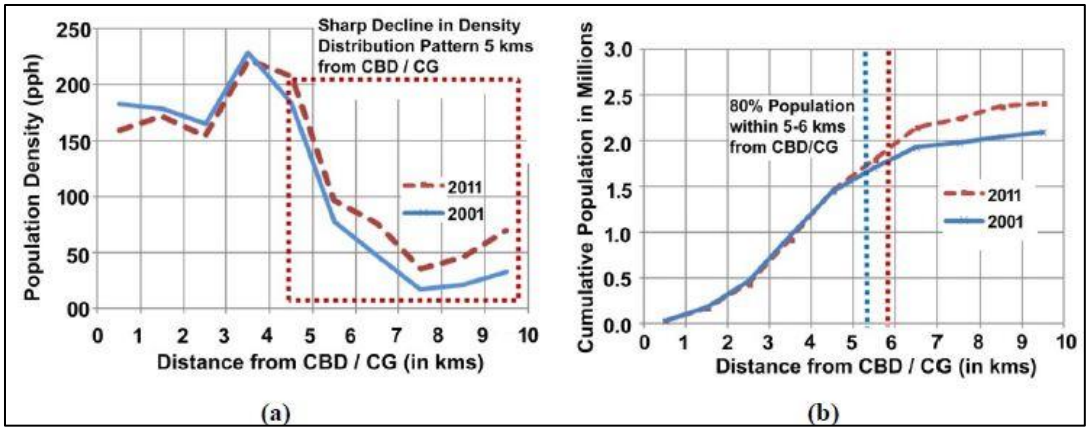

Figure 3.14: (a) the profile of density and spreadance from CG; (b) Aggregative population by the journy from CBD or CG, for the city of Nagpur (year 2001)

These areas have different urban features. Eastern pressure tends to be strong, as all high densities in Eastern portion are concentrated. The density of East and Western Nagpur is therefore determined and parallelled separately to evaluate the current density distribution trend within the region. See figure '3.15'.

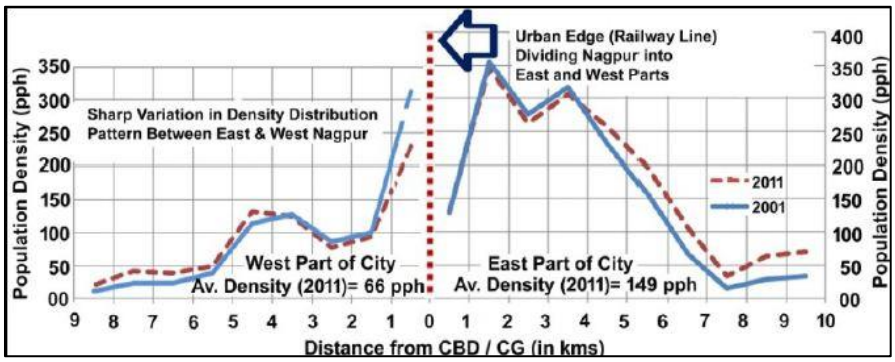

Figure 3.15: West-East Distribution of Density Profile (Kotharkar et al., 2014)

A remarkable variation is thus observed in the structure of density distribution between western and the eastern Nagpur. It shows that the distribution of the population is inequitable. There are a lot of suggestions to raise density in 40% of sectors with densities below 150 pph especially in West part of the city, in accordance with the UDPFI guidelines. A sharper density profile slope indicates greater access to the center (Bertaud, 2003). The density profile of Nager shows that the city centre, as shown in figure 3.14 a, is easier for more people. In terms of access to the city center, Nagpur 's spatial structure offers a firm benefit.

b) Population by distance to CBD/CG:Figure 3.14(b) demonstrates the accumulative population of this city settling within a specific dimension from CBD. For example, above 75% of the city population are living inside 10 km circle far half of this distance from specific center of gravity (CG) which is completely persuasive. This dimension could be short in urban area considerations, where it can be accessible within15–20 min by bicycles, and about 10–15 min by bus or bikes. however, an average travel in the city is around 4.60 km (L&T-Ramboll Consulting Engineers Limited, 2007).This factor is significant because it assess shortest travel for the common individuals land usage in the case study city, however, it is valid for mono-centric urban area (Bertaud, 2003).

c) Density Gradient: According to Clark (1951), in a big city, excluding the central business area with few dense of residency, there are dense inner districts with density gradually falling as much as proceed to the external suburbs. Moreover, density tends to drop in majority of cities over the course of time and is spreading all over the city.

By studying twenty towns he has validated the mentioned relationship. The mathematical relationship between density of residence and dimention from the center of city is demonstrated as:

$$Dx = Do * e^{-gx} \qquad (3\text{-}1)$$

where,

(Dx) is person per unit area (the density of resident population in a sector);

(x) is the distance between the sector and city center;

(Do) is a co-efficient that referes to the (CG) of the city;

(g) Co-efficient, indicates the fall proportion of density. (Clark, 1951)

The density gradient explicitly reflects the urban sprawl, in which a gradient of flattening density suggests the sprawl with rising peripheral densities. In the situation of polycentric cities, this may be an exception because the densities are greater across several centers or nodes, leading to make gradient density flatter.

The density gradient values calculated for the years 1971 to 2011 in this Nagpur analysis indicate a decreasing trend. See Table 3.11.

Table 3.11: Density gradient for Nagpur between 1971 to 2011 (Kotharkar et al., 2014)

Year	1971	1981	1991	2001	2011
"g" value for Nagpur	−0.549	−0.442	−0.429	−0.304	−0.188
"D_0" value for Nagpur	6.735	6.658	6.888	6.415	6.044

It is deduced that the city has a propensity to scatter or dispersion. The densities of the city center have decreased over the past few decades, meaning the inhabitants shifting to the outer skirt of the city, as expected. To know the similarity, the density value of the city is compared with other urban regions around the world.

3.4.2 Transportation

There is a close correlation between transportation grid and form of urban. Better connectivity and usability within the urban environment are a requirement for preserving compact urban forms. The transportation system is therefore an essential urban form features of different ranges of scales. Good connection to transport features and shorter ravelling distances encourage walkability or cycling modes that result in reduced air pollution and a greater residential sense of pride (Johnson, 2007). The main indicators to evaluate transportation network in this study were (1) Mode share; (2) the mean of trip length; (3) the strrets grid density; (4) the index of congestion; (5) the walkability index. The secondary sources for finding data of the factors in this study have been employed (Ministry of Urban Development, 2008).

a) Mode share: In India large number of trips are made by walking, and some data refers that about 16%-58% of trips (Ministry of Urban Development, 2008). Another study regarding to Nagpur figured out non-motorized traffic as 58%, while Car is 1%, PINT is 9%, whereas Bus 5% (L&T-Ramboll Consulting Engineers Limited, 2007). See table '3.12'.

Table 3.12: Trips in Nagpur (L&T-Ramboll Consulting Engineers Limited, 2007; Ministry of Urban Development, 2008)

Transit Mode	% of Trips	% of Trips	Ideal Values (%) for this Category of City (2–4 million)
Non-Motorized mode (Walk)	25.6	20	-
Non-Motorized mode (Cycle Rickshaw and Bicycle)	32.4	28	15–20
Two-wheelers	26.6	35	10–15
Cars	0.9	3	
Bus	4.9	12	60–70
Intermediate Public Transport (IPT)	9.2	2	

Nagpur has a large participation in the formal split and a very smaller shares of cars in the unmotorized mode of transport, if evaluated by comparing to the world's major cities, as seen in figure '3.16'. Nagpur 's share of transit or public transport modes is smaller, possibly because of its medium sized city infrastructure and less investment in public transport.

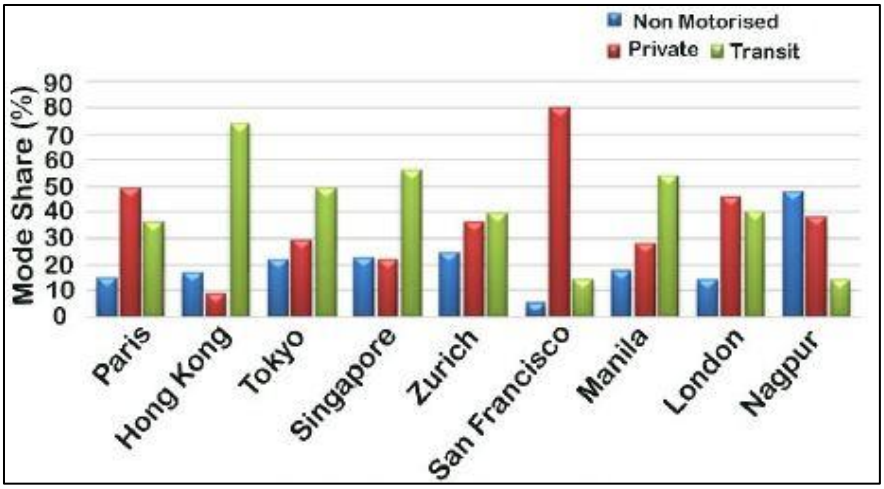

Figure 3.16: Mode types in world cities, compared with Nagpur (Kotharkar et al., 2014)

b) The Length of average Trip:The average travel length is determined by measuring the ratio of the total number of passenger/ kilometres. The length of the trip is connected to the urban area or size of the city, hence, it increases by the increasing the size of the city. The distribution of population density across the urbanized region is also based. In the town of Nagpur, 64,85% of working travels and approximately 74,16% of business travels are limited to 5 km and 69.37% of educational travels and 65.67% of shopping travels are limited to 3 km. The study found that the average trip length in Nagpur is 4.6 km, while the average time of the trip is 18.64 minutes. In the same context, the average trip distance for the work and business is 5.3 kilometers. However,

the length of travel depends on mode of travel, for instance, the mean journey dimension is 6.460 km by bike and 9.920 km by cars (concerning private travel mode),(L&T-Ramboll Consulting Engineers Limited, 2007).Accordingly, it has came out that the mean journey length for the case study city is lesser comparing it with other cities which have comparable population and much shorter comparing it with larger cities in India, and the majority of travels are within Five km.

c) Average Network Density: The density of the road network evaluates the penetration and access to the transportation arteries into cities. This indicator also assesses the capacity of the road urban lands permeability. Figure '3.17', demonstrates Singapore, Seoul, Hong Kong, etc. with extra dependence on public modein transporattion.

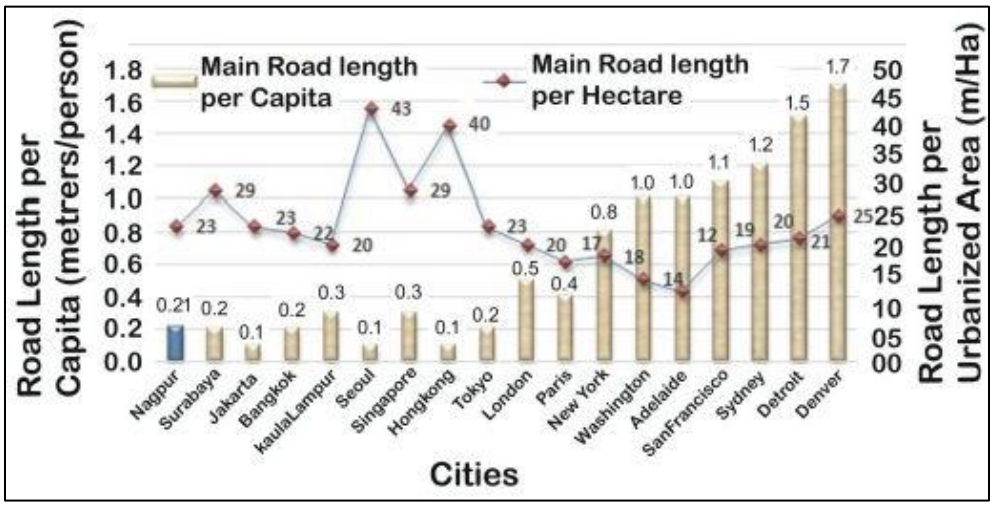

Figure 3.17: Comapring 'Road Network Density' for Nagpur with diff. cities (Kotharkar et al., 2014)

Higher street network density can curb road congestion through more transportation corridors and alternatives to road transport. Minimal length of road per individual refers to more overcrowded levels if the dependance is more on private transportation modes, like cars (Barter, 2000). In the city, the gross lengths of main roads is 500 km, in addition to 1500 kilometers of the secondary roads, The Communities Group International, 2006). The calculation of the total streets grid density found 22.980 m/ha (the length of roads/ built-up of city), while, the built-up area streets grid density is 36.741 m/ha, and the road length per indiviadual is 0.20781 m/person.

d) Congestion Index: Because of the reduction in travel speed, congestion may result in increasing travel time. In other words, increased congestion limits mobility, i.e. how users can

navigate efficiently. nCongestion increases result in reduced protection, a deteriorating environment and restricted economic developement (Ministry of Urban Development, 2008).

The congestion index can be found as follow:

$$\text{Congestion index } = 1 - A(M) \quad (2)$$

Where,

(M) is elegible speed of mean trip on the main street net of the urban area within the peak hour, and it is assumed 30 km/hr.;

(A) is the average speed of the trip spotted on the main corridors of the uraban area within peak hours.

Figure 3.18 displays the index of the 30 Indian cities. A lower index value suggests increased mobility and less congestion. The value calculated of the congestion index for Nagpur is 0.24, which is similar to the average value of the index that represents an typical urban road system. Chandigarh has a very high quality road network index with the lowest congestion (value-0),(Kotharkar et al., 2014).

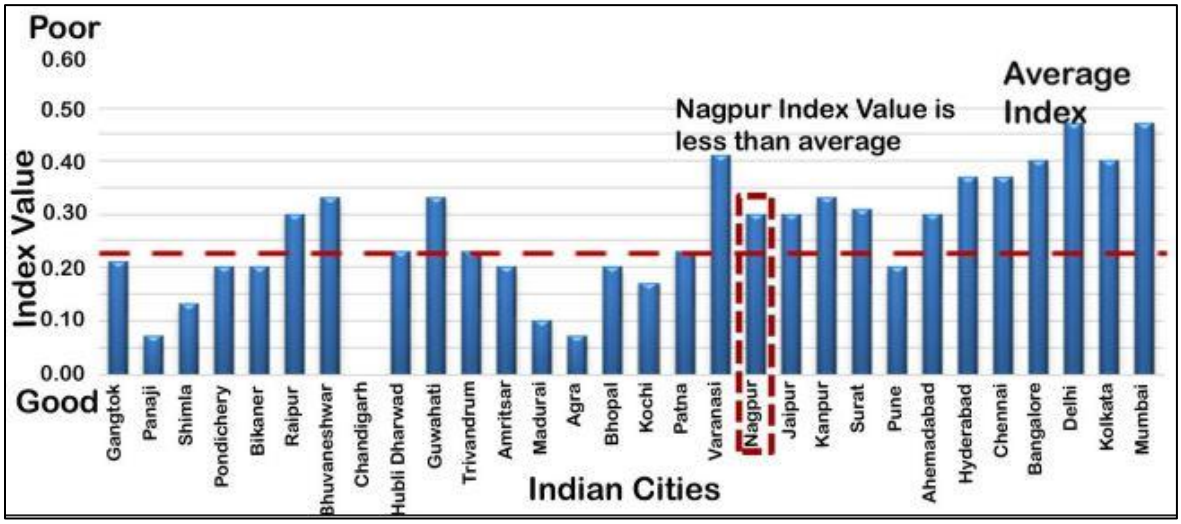

Figure 3.18: Congestion Index for Nagpur and 30 Indian cities (Kotharkar et al., 2014)

e) Walkability Index (WI): Though a majority of trips by foot in Indian cities (16-58 percent), in the Indian cities there are insufficient and neglected pedestrian infrastructure and facilities (Ministry of Urban Development, 2008).

TheWalkability Index evaluation is found by:

$$(WI) = [(W1 \times \text{Availability}) + (W2 \times \text{Facility rating})] \quad (3\text{-}3)$$

Where,

(W1 and W2) are weights (50% for each is assumed),
(Availability) is walking path length/Length of main roads in the urban area, and
(Facility Rating) is considers a score rated according to the opinion on available pedestrian facility (Kotharkar et al., 2014).

Figure 3.19 demonstrates the walkability-index computed for the walkability of 30 cities in india as better pedestrian facilities are indicated at higher index levels. The walkability value calculated for Nagpur is 0.671 which is higher than the mean index value representing the above mean or medium pedestrian capacities in the region. However, it is much lower than the London walkability index, where it found between 1.5 and 1.7 (Ministry of Urban Developement, 2008).

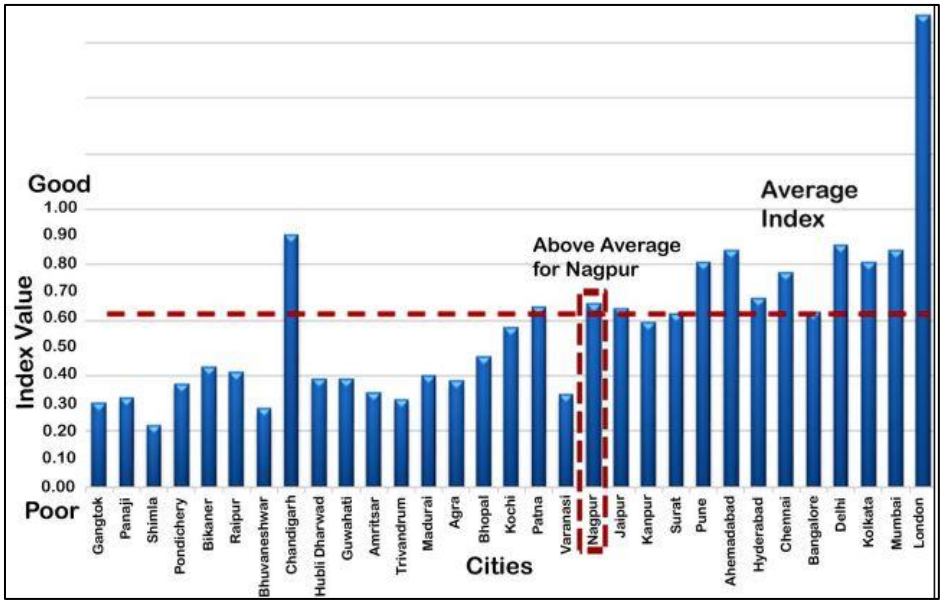

Figure 3.19: Walkability Index for 30 Indian cities including Nagpur (Kotharkar et al., 2014)

3.4.3 Mixed Land-use

It includes the evaluation of two parameters:

a) Land- Use Split up:In accordance with the Nagpur Development Plan 2000–2011, only 8,340 Ha (38 percent) were notified for development of the area of 21,7561 ha. within the limits of the cooperation of municipality. A further 38% was forest lands and agriculture, and 4% watercourses. The land management allocation of construction land (as stated in the development plan), in compliance with (UDPFI) guidelines, complies with the guidelines for residential use. The city is home to large areas of farming , forestry and public open spaces that balance the deficit in recreation fields, which consists of only 2%. More land needs to be used for amenity purposes from the land planned for semi-public and public use. Nearly 660 ha of developing unused land (around 8 per cent) still remains accessible within the administrative limits of the NMC that could be used (Global Scientific Inc., 2011; Town Planning Department, 2001).

b) The mean consumption of the land per capita: The usage of land per capita is straightly obtained from the density through the land consumption per capita in Nagpur demonstrated in Figure '3.20' and previous Table '3.10'. In the absence of perfect estimates for land consumption, the mode of transport is compared, standards can be determined by contrasting the space consumption with other usage. In 2011 Nagpur was 56.57 m2 of developed land per person, so it can be assumed that a car consumes nearly 70 percent of the person's space in Nagpur. In cities with less land use per capita, personal use of the car as transport means would be more disruptive (Bertaud, 2003). In urban areas where per capita land is very low, such as Nagpur or other cities, such as Moscow, Shanghai, and Paris, the car override the proportion of space in people, which is more spatially disruptive in the densely populated city. The policies to promote population dispersal, resulting in low population densities and sizes, also implemented to create more area for vehicles. The choice to limit the use of cars will also retain and encourage compact developments.

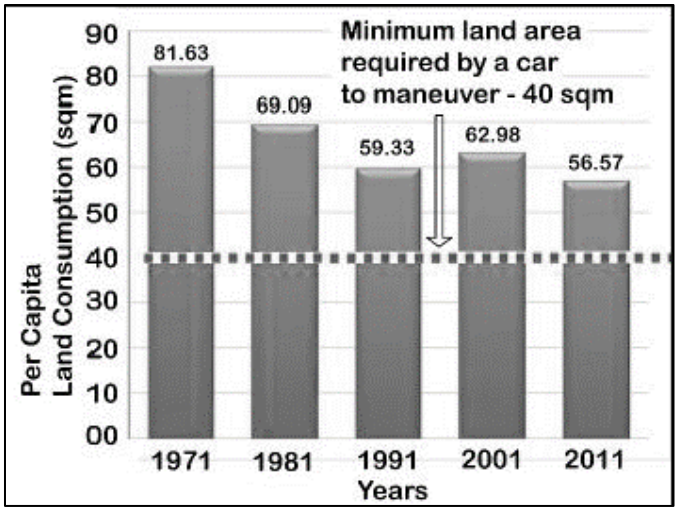

Figure 3.20: Average consumption of land per capita (Kotharkar et al., 2014)

3.4.4 Conclusion of 3rd international case study

The study concluded that urban-form interventions indicate that Nagpur has a compact city in its entirety. The city is small, but it expands steadily. Based on the current study, the compact urban shapes of the city present over the last decades have made it possible to drive shorter distances, the proliferation of mixed land-uses, higher densities of urban fabric with central and medium zones, a high percentage of non-motorized trips modes. In time urban reform action can in the future maintain its comparatively compact urban shape.t is very much possible that obstacles will be at work for sustainable urban growth. The lack of good regulations and appropriate institutional structure to meet a growing requirement for compact , higher density developed areas could lead to overcrowding and deterioration of the environment. Furthermore, the city will face pollution, noise, alienation, identity loss, etc.In developing world cities, the portion of informal growth is big, which prevents compact city policy from succeeding. The heat islands effect and susceptibility to disasters may be enhanced by high density and construction areas.In order to achieve the growth of sustainability in urban area in the sense of the case study area the compact city model can be suggested.

3.5 Copenhagen City, Denmark as the 4th International Case

With a metropolitan population of approximately 2 million people, Copenhagen is Denmark's largest city, a tiny and sparsely populated country (about 5.5 million people) consisting of the mainland – Jutland – and several islands, including Fyn and Zealand. Copenhagen is situated in

the North-East of Zeeland, on the margins of Europe but at the heart of the Øresund area, a transnational region that includes the Danish islands of Zeeland, Lolland, Falster, Møn and Bornholm and the Swedish Skåne region. With the completion of the Øresund Bridge, Zeeland is now linked to the Scandinavian Peninsula by train and rail, and Copenhagen is closed to Malmö, Sweden's third largest city. Among many of the european cities, Copenhagen has the biggest share of jobs in the service industries (86 per cent) and the lowest (13%) in manufacturing. (OECD, 2009). Figure '3.21' demonstrated the map of Copenhagen with the municipalities.

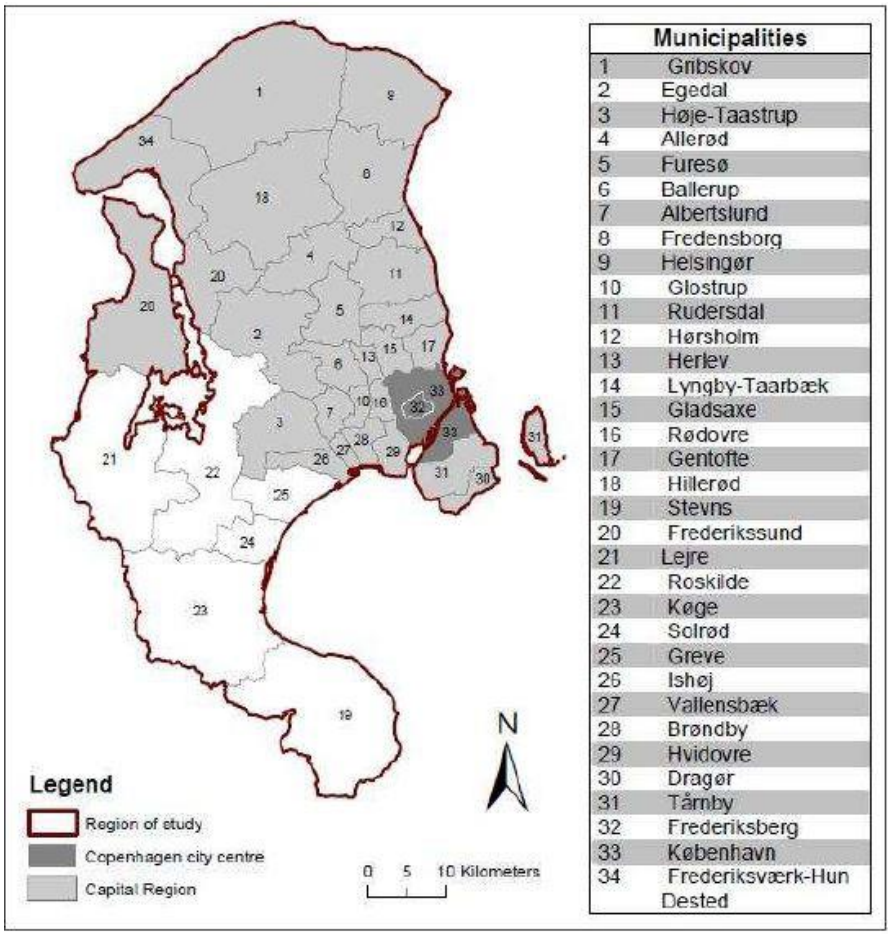

Figure 3.21: The map of Copenhagen Metroplitan Area and Copenhagen center location and its municipality boarder, among other municipalites (Reis, 2009)

3.5.1 Density

The total population of center of Copenhagen is 593,000, spread on the area of 98 square kilometers, while the population in Copenhagen Metropolitan Area (CMA) is 1,800,000, and spread on 30207 square kilometers land. Figure '3.22' shows the population distribution in Copenhagen metropolitan area (pop/km^2).

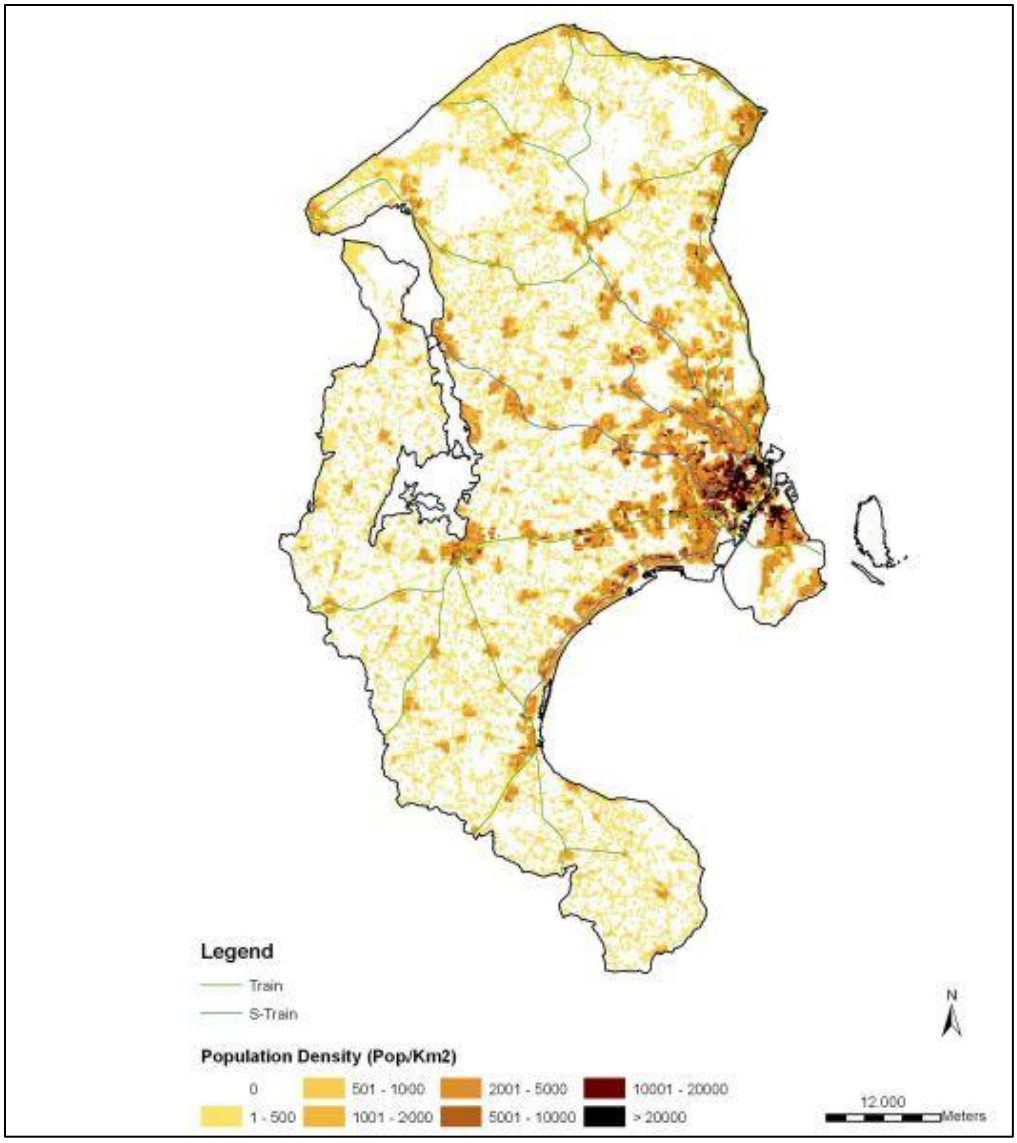

Figure 3. 22: The map of Copenhagen population density (Reis, 2009)

The following Table 3.14 demonstrates the gross population density in different scale in Copenhagen.

Table 3.13: The population and the gross population density in Copenhagen (OECD, 2009; Reis, 2009) (Developed by Researcher)

Region	Population	Area (Km^2)	Gross population Density ($Pop./Km^2$)	Gross population Density (Pop./hectare)
(Copenhagen city centre)- Copenhagen Municipalities and Fredriksberg	593, 000	98	6051	60.5
Copenhagen Metropolitan Area (CMA)	1,800,000	3037	593	0.60

3.5.2 Transporation

The transportation system in the CMA underwent a significant change after 2000, with the opening of the Øresund Bridge, which links the city by road and rail to Sweden. .This link offers not only the connection between Copenhagen and Malmö, Sweden's third-largest city with approximately 300,000 inhabitants but also a link between southern Sweden and Airport of Copenhagen (Reis, 2009). Copenhagen has an extensive transport system, including the roads linking the city to many other areas of Denmark. Approximately half of the city's passengers use the Copenhagen S-Train, the Copenhagen Metro and the regional train systems, while the majority use bus services. See Figure ‘3.23’.

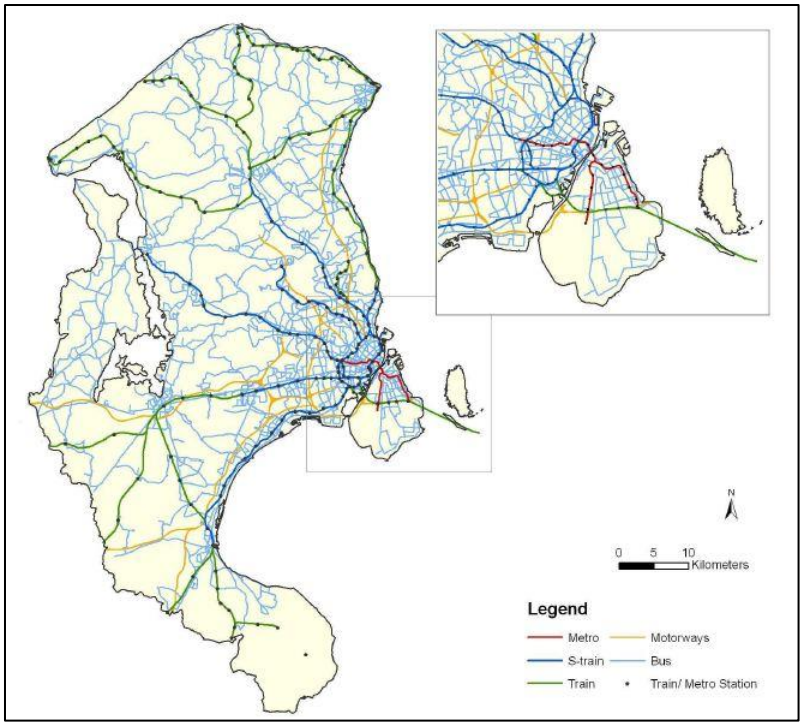

Figure 3.23: The map of road network, metro, train and S-trains in Copenhagen(Reis, 2009)

The total length of roads network in Copenhagen metropolitan area is 1020 km, and S-trains and regional trains lines are 170 Km, and super cycle highway network 746 km, in addition to 21 km metro line in two ways (Halpern, and Orlandi, 2020). This means that the total network in Copenhagen is 1,957,000 meters. Thus, the average network density in the Copenhagen metropolitan area is 1.09 mpp. It should be mentioned that high density (HD) also is 6.44 m/ha.

3.6 Summary

This chapter demonstrated the ways or methods to evaluate sustainability in urban form or the relationship between sustainable urban form and sustainability. The chapter selected three international case studies that analyzed based on the similar indicators of sustainable urban form that formulated initially in the chapter of the literature review. Accordingly, Gaziantep in Turkey, Lahore in Pakistan, Nagpur in India, and Copenhagen in Denmark were selected as examples. The analysis of these four cities has been done by researchers, and the effect of urban form on sustainability in these cities has been tested. The studies demonstrated the importance of compactness and sustainable transportation, as well as mix land-use on sustainability in general and on environmental sustainability as the limit of the current study. Moreover, many other factors such as density, and accessibility are other factors which have significant effects on sustainability in its three aspects (environmental, economic, and social).

CHAPTER 4

EVALUATION OF ERBIL CITY IN TERMS OF URBAN FORM AS CASE STUDY

4.1 Introduction

This chapter is divided into two main parts, the first is describes the methodology adopted and applied in this thesis to fulfill the research objectives and answer the research questions. Thus, it describes the methods used in the thesis to assess sustainability in the urban form in terms of environmental aspects in particular.The second part examines the urban development of Erbil as a case study, through a comprehensive and statistical study regarding the most important components related to selected indicators to evaluate sustainability in Erbil urban form.

4.2 Adopted Research Methodology in the Study

The study approached case study methodology, depending on comparative analysis among international case studies and Erbil as the field study urban area. The comparison has made based on the initial factors formulated from literature to evaluate sustainability in urban form. The factors that have employed in this study were; density, transportation and mixed land-use. Quantitative method has approached in this study to reach the result and answer the questions of the study.

4.3 Evaluation of Erbil City Urban Form

Several indicators have been found to evaluate sustainability in urban form, as addressed through review of the literature, as seen in Figure 2.3. According to the literature review and analysis of the cities of Gaziantep, Lahore, and Nagpur four indicators have been identified to have played substantial and critical roles in the determination of the sustainability of urban areas based on the form, and essential in terms of environmental sustainability. Therefore, the selected framework of indicators to assess sustainability in urban form in Erbil for the current study will be namely; *density, transporatation,* and *mixed land-use*. The assessment of these indicators will be based on the quantitative method illustrated previously in the literature review.

'Density', is calculated based on the gross population density, and average twon density. Furthermore, 'Transportation' as the second main indicator of sustainable urban form in this

study could be assessed by finding road net density, and the higher density. 'Mixed Land-use' is the third indicator, and it calculates by finding residential to non-residential ratio, and average land consumption per person, plus built up to open area ratio. See Figure 4.1.

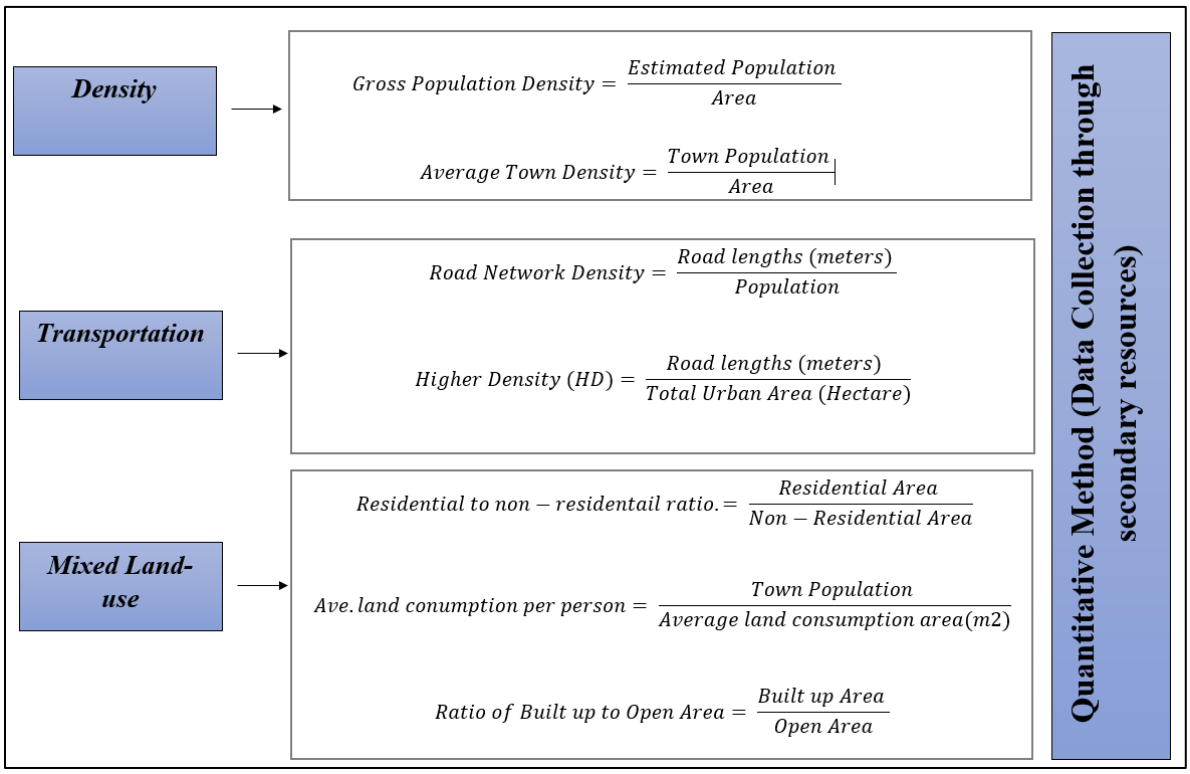

Figure 4.1: The framework assessment methods for the indicators of sustainable urban form (Barter, 2000; Clark, 1951; Kotharkar et al., 2014; Liaqat, et al., 2017) (Developed by researcher)

4.4 Erbil City

The first record dates from Neo-Sumerian times when the Kings of Ur invaded the city of Erbil between 2094 and 2046 and 2046 BC, but he did not succeed to occupy the area. Erbil was one of the famous cities in the old world. The loss of its prestige happened when the invasion of the Mongols, Persians, and Turks took place in the 13th century. Erbil was weakened in the following decades. The population of Erbil increased from 3000 to 6000 people in the 19th century, mainly residing in the ancient castle, which known 'Qala'a' (Sherzad, 1979). Erbil's city is located between the Great Zab and the Lesser Zab rivers, on a tremendous fertile plain of 15870 square km called "Dashti Hawler." (HCECR, 2012). It is found in a relatively plain area and has an average elevation of 453 meters above sea level Erbil is located about 88 kilometers

east of Mosul (Saeed, 2003), as seen in Figure '4.2'. The city of Erbil (36°11′28″N 44°0′33″E) is located in the north-east of Republic of Federal Iraq, and it is the capital of Northern part of Iraq, and one of the large cities in Iraq (Fadhil, 2011).

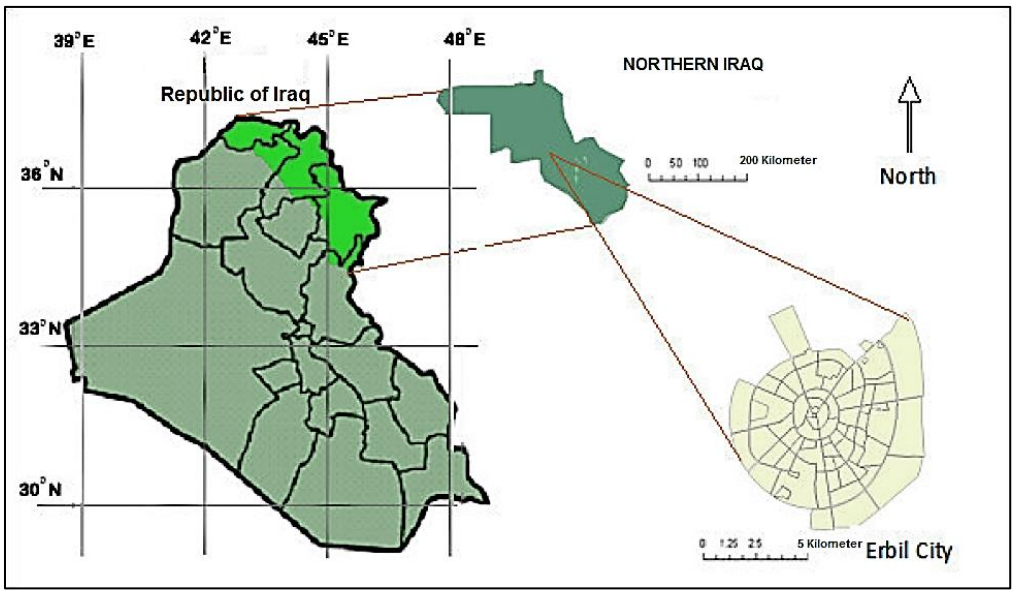

Figure 4.2: The Location of the City of Erbil within Iraq (Khalid, 2014)

Erbil is going through significant changes because of the political, economic, global, cultural, and demographic transformations . Yasin (2011) stated that the city has moved through special periods of history that influenced the present forms of its environment and the identity of the city in the different factors. Economic and political growth and stability have contributed to a flexible, progressive expansion of the city's Master Plan (central-radial). Today Erbil is laid out in a pattern of concentric rings surrounding the old citadel in the city‘s centre. The distance from the centre to the outermost ring (120m Street) is approximately 8 kilometers (5 miles), (Ibrahim, 2016). See Figure 4.3.

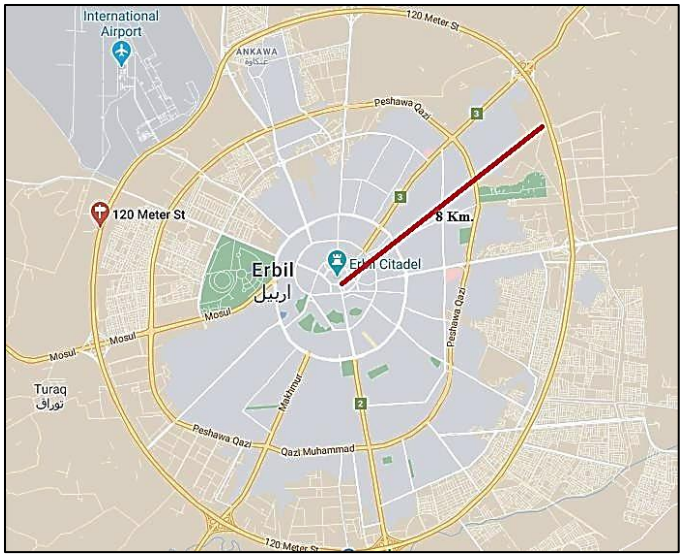

Figure 4.3: The distance between center of the city to the 120 m outer ring-road in Erbil

4.5 Data Collection

The goal from collecting data about the case study 'Erbil city' is to measure the urban form for discovering the potential of sustainability in Erbil urban area if exist. For this purpose, the indicators like; density, transportation, and land-use have been investigated.

4.5.1 Density in Erbil

According to the obtained data, the population of Erbil city is currently 846,000 people as seen in Figure 4.4, and it is increasing periodically as it is predicted.

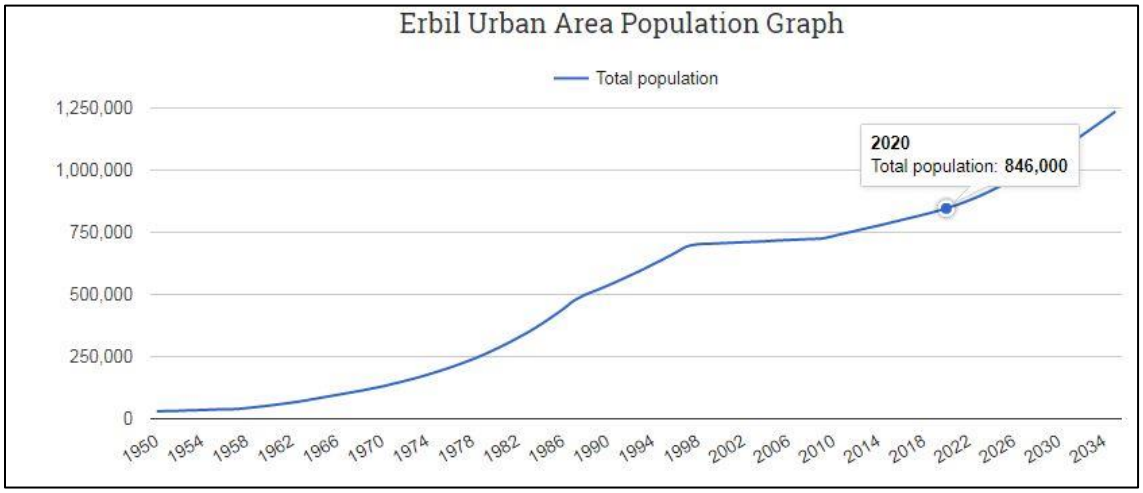

Figure 4.4: The population growth in Erbil from 1950 (World Bank, 2020)

The following table demonstrates the population of Erbil for the last decade.

Table 4.1: The population of Erbil throughout last ten years (World Bank, 2020)

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
746,000	756,000	767,000	777,000	788,000	799,000	810,000	821,000	833,000	846,000

The total area of Erbil city is 115 km^2, (Strategic Development Plan of Erbil Governorate, 2016). The gross population density can be calculated as follow;

$$\text{Gross population density} = \frac{Estimated\ Population}{Total\ area} \quad (4\text{-}1)$$

Where;

Estimated population = 846,000 people,

Total Area= 115 km^2

Thus, the gross population density is 7,356 people per km^2, or 73.6 pph (people per hectare). Acoording to UN-HABITAT's principles to achieve sustainable neighbourhood planning, the gross population density should not exceed 150 pph, (UN-Habitat, 2013).

4.5.2 Transportation in Erbil

The primary and secondary (arterial) networks are the main road network, and are mainly linked intra-urbanly. Road Network Density measures the penetration and access to the transport arteries in urban areas. This measure also assesses roads potential and urban lands permeability. Higher density (HD) of roads in urban area and lower per capita value of road traffic (Average Network Density) suggest sustainability in urban form (Barter, 2000). Roads within Erbil are generally fine, but they face the issue of maintaining up with the continuous and rapid grow of the urban area in Erbil, in addition to the continuously growing number of vehicles. roads have to katch up with the growing requirement to cover the needs of the new residential communities (IHSES, 2012). The total length of paved roads in Erbil is estimated by 5391 Km, and inside the city of Erbil only and upto outer-ring road 120 meters has estimated by 2,156.4 Km (EASO, 2019). Public transport within Erbil and even with other places out of the city is limited. The transportation means are small cars of five passengers, or forteen passengers which vary in their quality and there is weak public means of transportation as buses or mini-buses in the city

(EASO, 2019; Ministry of Municipalities- KRG, 2020). Hence, according the obtained data the road dencity

$$\text{Average Network Density (AND)} = \frac{Road\ length\ (in\ meters)}{Total\ population} \quad (4\text{-}2)$$

Where;

Total length of roads in Erbil within the outer-ring road 120 meter = 2,156,400 meters,

Therefore, AND in Erbil is 2.55 mpp (meter per person). As illustrated bellow

$$\text{Average Network Density (AND)} = \frac{2156400}{846000} = 2.55 \text{ mpp}$$

While;

$$\text{Higher Density (HD)} = \frac{Road\ length\ (in\ meters)}{Total\ urban\ area\ (in\ hectare)} \quad (4\text{-}3)$$

Thus, higher density of network in urban area is 187.5 meters per hectare (m/ha)

Higher Density (HD)= $\mathbf{\frac{2156400}{11500}}$ = 187.5 m/ha.

4.5.3 Mixed Land- use in Erbil

Based on the report of HCECR (2012), Modern Erbil has witnessed several changes and can be categorized by five definitive stages, namely; first stage or the Pre-Industrial city prior to the biginning of 1900s (Ottoman Period); second stage, is the Early Modernity of 1900-40. The third stage is the Post-Modern City and Materialism (1940-80), while the fourth stage is the Autonomous City (1980-2003), as seen in Figure '4.5', and eventually, to the Economic City of Neo-Liberalism (from 2003), (Ibrahim, 2016).

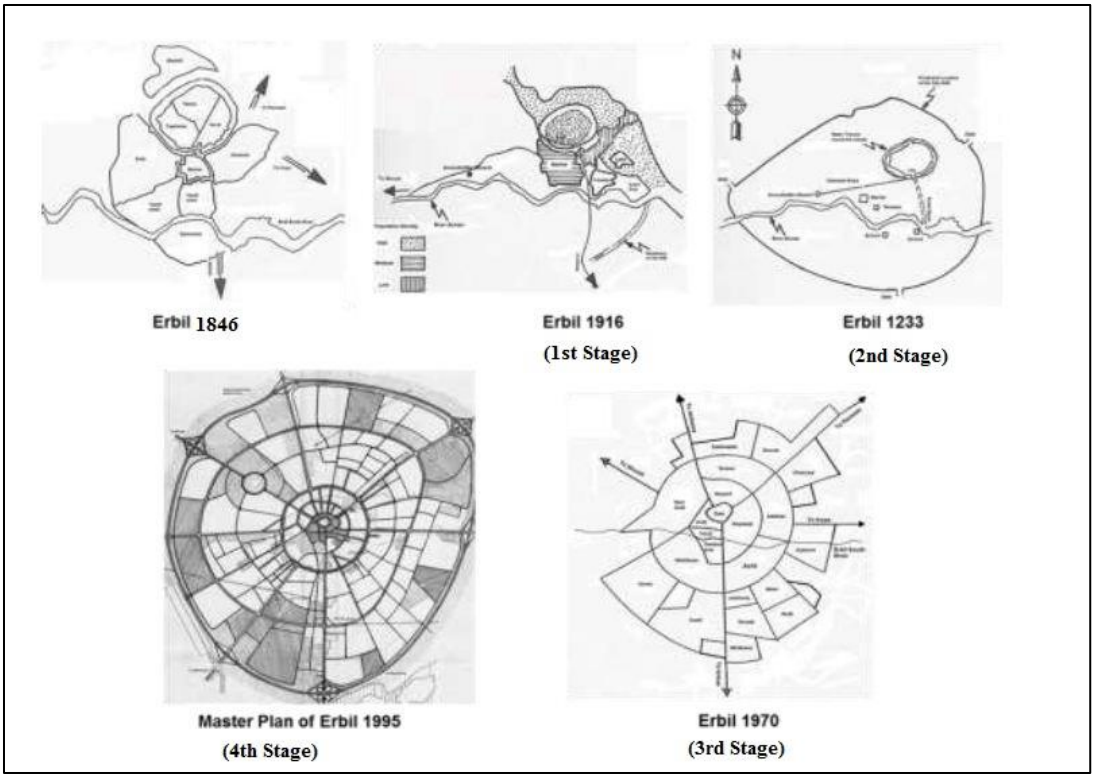

Figure 4.5: The development of Erbil City, the Citadel is represented the center of the city throughout the History (Ibrahim, 2016)

The period after 2003 has witnessed blooming and unprecedented economic and social mobility with wide investments and growing economic revenues. Therefore, the fifth and sixth stage have been added to the city, as seen in Figure '4.6'.

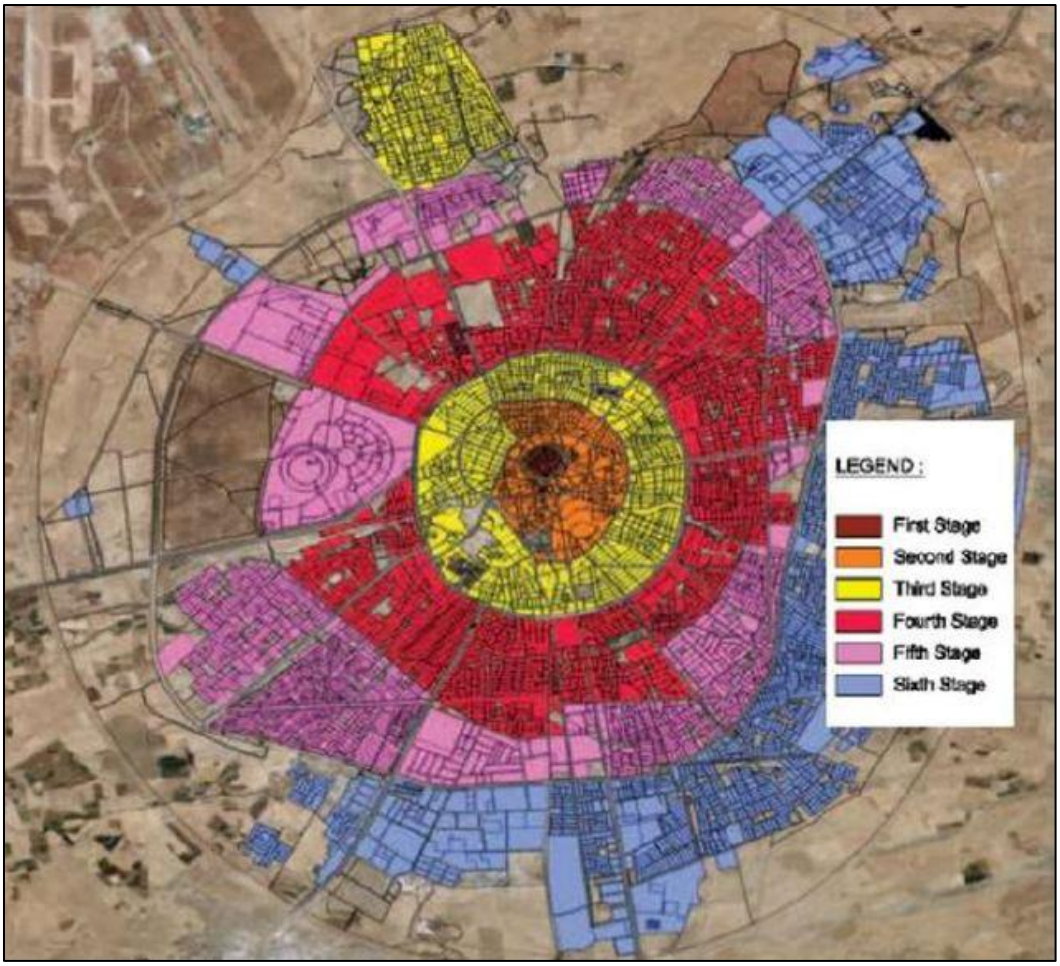

Figure 4.6: The stages of the development of Erbil City until 2007 (Dar Al-handasah, 2007)

To assess the land use in Erbil, two main things should be investigated. First is the ratio of built-up to open area, and the second is residential to non-residential ratio. Currently, the majorities of the families in Erbil owns their residency and formulate (75.4%) and the families. For the remaining percentage of the inhabitants of Erbil, they pay rents or occupy free houses in agreement with the residential unit owner (Strategic Development Plan of Erbil Governorate, 2016). Many changes and development came about in Erbil during the age of the city, especially in residential sectors. The huge development has occurred after 2003, as seen in Figure '4.7'.

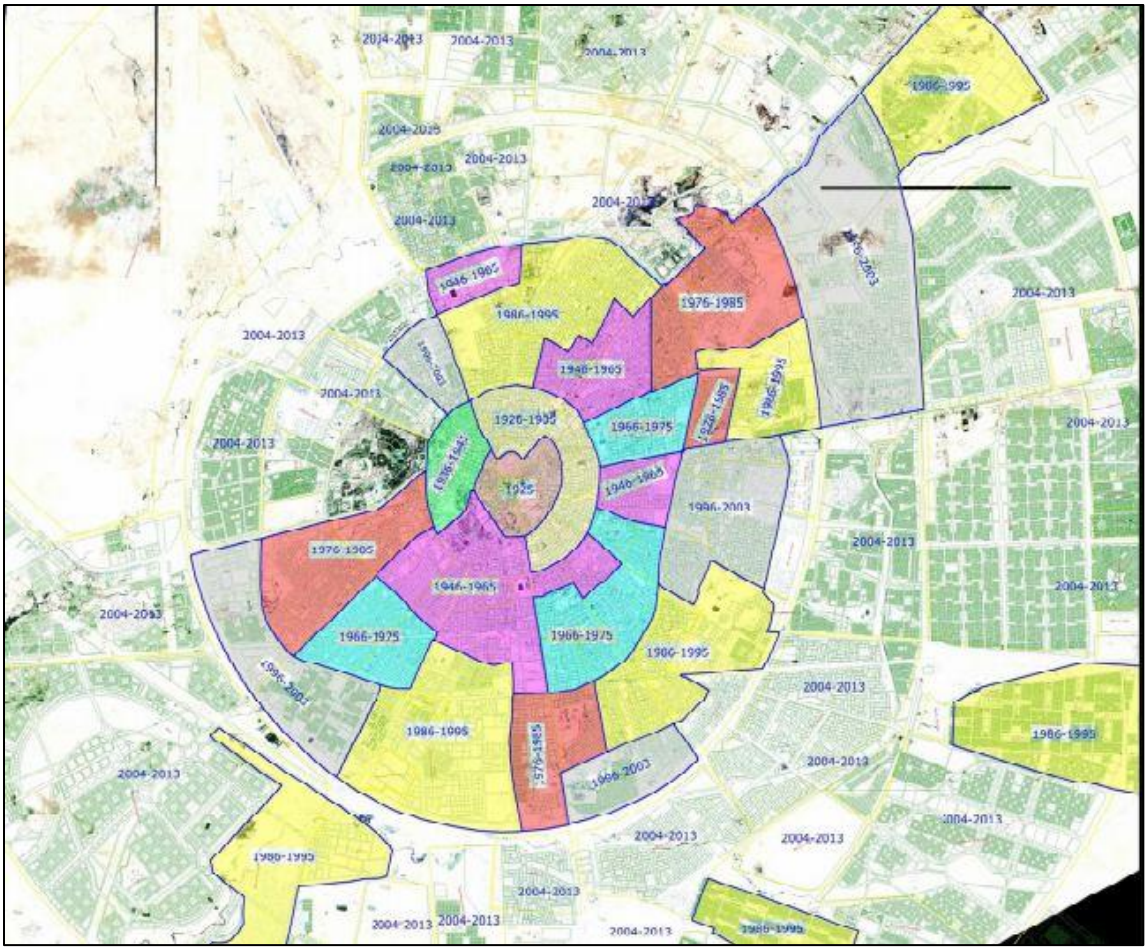

Figure 4.7: The development of Erbil City and the new residential sectors after 2003 (Sabr, 2014)

the data has obtained from Ministry of Municipalities (upto outer-ring road 120 meter), where the data after outer-ring road 120 is not yet documented accurately). The total built-up area is 35.697 km^2, while built-up area without green area, parking, and cemetery is 31.817 Km^2 , therefore the open area is 3.880 Km^2 (Ministry of Municipalities- KRG, 2020).

$$\text{Ratio of Built-up to Open area } = \frac{Built-up\ area}{Open\ area} \quad (4\text{-}4)$$

Where;

Built-up area= 35.697 km^2,

Open Area = 3.88 km^2

The result demonstrate the ratio is 9.2 times.

According to investigations, the residential buildings formulate 70% of the total buildings in Erbil, whereas 30% are used for other purposes, like commercial, governmental, administrative, and industrials (Yaseen, *et al.*, 2014). Acoording the collected data from Ministry of Municipalities in Northern Iraq, the total Built-up area without open areas are 31.817 Km^2 (Ministry of Municipalities- KRG, 2020). The residential area is consist of 70% of this area, which indicate that total residential area in Erbil is 22.272 km^2(31.817 * 70%), while non residential area comprise 9.545 Km^2 (31.817 *30%), therefore;

$$\text{Residential to non- Residential Area Ratio} = \frac{Residential\ area}{Non\ Residential\ Area} \quad (4\text{-}5)$$

Where,

Residential area = 22.272 Km^2, and

Non-residential area = 9.545 Km^2. According to the previous formulae (4-5), the residential to non-residential area raio is found equal 2.33 times.

4.6 Analysis

This chapter presents all the field results regarding the urban form of the Erbil city. First, it clarifies survey results and fieldwork, and the evaluation of the findings according to the international standards in terms of urban sustainability will be done. Second, all the results and data from Erbil urban form will be compared with the information of the selected case study cities and finally, a comprehensive discussion is provided to answer the research questions. The most effective factors on sustainability in urban form which are density, transportation, and mixed land-use for the city of erbil will be compared with other analyzed international cities in chapter three, in addition to international urban standards.

4.6.1 Density

As mentioned previously, 'Density' is a vital factor to evaluate sustainability in urban form. It is the proportion of individuals in specific areas, and sustainable cities are a matter of density in a wider sense (Carl, 2000). The density in Erbil city has found 73.6 pph based on the obtained data. This indicates that the city of Erbil has acceptable density according to the international standards which is 150 pph (UN-Habitate, 2013). However, other international case studies meet the requirements also. It should be mentioned that Gaziantep had lower density (26.8 pph), the second was Lahore city (53.0 pph), the third was Copenhagen (60.5 pph), then Erbil (73.6 pph),

and the higher gross population density found in Nagpur (111 pph). Table '4.2' demonstrates the density in city of Erbil compared with international standards and other international cases that mentioned in this thesis.

Table 4.2: A comparison of sustainable urban form factor (Density) between the UN-HABITAT's principles to achieve sustainable planning with the existingsituation of Erbil and other international cases.

Case study	Erbil	Gaziantep	Lahore	Nagpur	Copenhagen	UN-habitat's principles (UN-Habitat, 2013).
Density-Gross population Density (pph)	73.6	26.8	53.0	111	60.5	Less than 150

Accordingly, the previous table shows that the population density in Erbil is acceptable within the UN-habitat's standards to achieve sustainable urban form. Erbil population density was accepted and within the standards, because the country side of the city, especially between the outer-ring road 100 meter and last outer ring road 120 meter is not crowded as the core of the city.

4.6.2 Transportaion

In sustainable urban principles, the lower value of average network density (road length per person-AND), and higher value of network density (road length per land area-HD) indicates sustainable urban form with respect to transportation parameters. As the city expands with a decreasing population density, the density of the road network will decrease and the length of the road per individual will increase. Less road length per individual may mean higher levels of congestion if there is more dependency on personal modes i.e. cars (Kotharkar et al., 2014).

Accordingly, Lahore has demonstrated low AND, which is (0.82 mpp), while registered high HD which is (43.5 m/ha.). Nagpur also demonstrated the same characteristics, where AND was (0.21 mpp), and HD was (36.74 m/ha.). It should be mentioned that Gaziantep has low AND which is (0.4 mpp), while has low HD too which is (1.04 m/ha.). Copenhagen demonstrated average reading in both, where AND was relatively low (1.09 mpp), and HD was relatively high (6.44 m/ha.). See Table '4.3'.

Table 4.3: The sustainable urban form factors (Transportation) according to UN-HABITAT's principles and comparing them with the existing situation in Erbil and the international case study cities.

Case study	Erbil	Gaziantep	Lahore	Nagpur	Copenhagen	UN-habitat's principles (UN-Habitat, 2013).
Transportaion:						Less meters per person leads to more congestions/ and higher meters per person means city expanding
1. Average Network Density (AND) mpp (meter per person)	2.55	0.4	0.82	0.21	1.09	
2. Higher road Density (HD) (meter per hectare)	187.5	1.04	43.5	36.74	6.44	Min. 180 meter per hectare

4.6.3 Mixed land-use

Mixed Land Use evaluation through, ratio of residential to non-residential and ratio of built-up to open area is essential method for assessment of sustainability in urban forms (Jabareen 2006). Some of the international studies has not approached these indicators to evaluate mixed land use, therefore, the data was not accessible. Accordingly, the evaluations of these two indicators have conducted in the study and found that Erbil has 9.2 times built-up area than open area, which is consideres high density in built-up area. It should be mentioned that residential to non residential area is also high which is recorded 2.33 times, and the ratio of built-up to open area in Gaziantep was 2.29 times. Lahore city demonstrates that the ratio of built-up to open area is slightly high which is 4.36 times, and the residential to non- residential area is high too, and was 1.99 times. On contrary, the ratio of built-up to open area in Nagpure was 1.7 times, and it is lower than the standards which is 3 times according to Cortright (2010). However, the international standards askes for one time ratio for residential to non-residential area in sustainable urban forms (Liaqat et al., 2017).

4.7 Discussion

According to the findings, Erbil city is expanding city, and it should be mentioned that the city population increased almost 13% within ten years between 2011 to 2020. It is observed that the average population density is 73.6 pph, however it is not hemogeneous, where in central areas are higher than the periphery areas. The city according to the UN-Habitat's standards is within the sustainable urban form rules. So far, the density of the population in Erbil city is promising in terms of sustainability in urban form, and it is one of the advantages in achieving sustainability for Erbil.

The measures for understanding the transportation network in Erbil have been approached through AND and HD, and were 2.55 mpp, and 468.8 m/ha, respectively. These findings demonstrate that the city has not potential for congestion because the road length per person is higher than other selected international case study cities. On the other hand, the road length per hectars in Erbil demonstrated very high (187.5 m/ha.), and it is out of the principles of the sustainable urban form standards (180 m/ha.). This indicates the expansion of the city, and it is a negative indicator for sustainability in urban form because it is opposing compactness in the urban areas. The expansion of the city seems to be toward the city periphery. This will raise sprawl and increase the travel distance. The main reason for this expansion is the construction of outer ring-roads surrounding the city, especially the ring-road of 150 meters.

It is observed from the evaluation of the city's land-use, the ratio of built-up area to open area is very high (9.2 times). This indicates that the planned open area is very less if it is compared with the international standards,approximately 3 times. Another factor of mixed land-use that employed in this study is the residential to non-residential area; the findings demonstrate that the residential to non residential area ratio in the city of Erbil is higher than the requirements according to international standards. It should be mentioned that the standards of the residential to non- residential areas ratio should be one time, while in Erbil it is 2.33. The land -use evaluation factors indicate the problem in achieving sustainability in urban form at the city of Erbil.

Therefore with the help of the findings based on the mathematical calculations explained above, an evaluation matrix of sustainability in urban form for the Erbil city is developed. The scale of evaluation is based on the convergence to the international standards. Where, when the value is

within the higher limit or closed to optimum, it will be evaluated ‘Good’, and if it is in the lower limit of the standard, it will be evaluated ‘Moderate’. However, if the results are out of the standards, it will be evaluated ‘Poor’. See Table 4.4

Table 4.4: An evaluation matrix of sustainability in urban form for the existing situation in Erbil

Indicator	**Result of Erbil**	**Scale**			**References**
		Good	**Moderate**	**Poor**	
1. Density					
a- Gross population Density (pph)	73.6	•			(UN-Habitat, 2013)
2. Transportation					
a- Average Network Density (AND) (mpp)	2.55		•		(Kotharkar et al., 2014)
b- High network Density (HD) (m/ha.)	187.5	•			(UN-Habitat, 2013)
3. Mixed Land-use					
a- Ratio of Built-up to open area	9.2			•	(Cortright, 2010)
b- Ratio of residential to non-residential area	2.33			•	(Liaqat et al., 2017)

4.8 Summary

This chapter is devoted to explaining the methodology of the study and the conducted methods to reach the result. Moreover, the chapter examines the urban development of the city of Erbil within the research context. It is consist of the statistical study regarding the most important components related to the employed indicators to evaluate the sustainability of urban form in the city of Erbil. Where, the main effective indicators to evaluate the sustainability of urban form in Erbil has been identified according to the framework of the study which are; density, transportation, and mixed land use, which are evaluating sustainable urban form focuses on the environmental aspects. Moreover, In this part the findings from the quantitative methods are demonstrated and compared with the international case studies of this study. The indicators of density, transportation, and mixed land-use, are the parameters among case study city Erbil, and the international case study cities.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

The main aim of this study was to evaluate sustainable urban form indicators in order to reach a comprehensive understanding within the discourse of urban development. Eventually, it employs these indicators in Erbil city that will enhance urban sustainability and ensure a sustainable urban form. Furthermore, the study attempts to draw up guideline design elements to identify the deficiency in design requirements for sustainability in Erbil urban form. Therefore, the thesis investigated the most important indicators of sustainable urban form that affecting environmental aspect.

Through the literature review approach, the study formulated threeimportantindicators to be assessed to evaluate sustainability in Erbil urban form. These indicators are *density, transportaion,* and *mixed land-us*e. Each of the indicators has been assessed based on mathematical ways (quantitative method) as seen in Figure 4.1. The assessment based on the mentioned three indicators has been approached for indicating whether a subject characteristics accessed have some degree of sustainability in Erbil city. The international standards have been taken as references for the assessment of sustainability level in urban form in Erbil city. Accordingly, the evaluation demonstrates that Erbil does not contain sufficient characteristics of sustainability in terms of urban form. However, it can be mentioned that the city has the opportunity to formulate sustainable urban form in some parts, like the density, and partially in the transportation system.

The previous evaluation matrix shows that the density of population is responding to the sustainability standards in urban form. This is because the city contains a good road network, and the population density is not very high. Hence, the population density is responding to the sustainability principles. The transportation average network density (AND) is partially responding, where it is high to reduce congestions, but at the same time, it indicates expanding city conditions. High density (HD) of network is assessed good, because it is above the required of the international standards, and then the results show that the transportation system in Erbil is partially responding to sustainability standards, and partially not. The main reason is the expanding condition of the city. Mixed land-use of Erbil is very poorly responding to

sustainability standards of urban form. This is through the high ratio of built-up area to open area and the high ratio of residential to non-residential areas. Thus the city shows a deficiency in the land-use side in terms of sustainability in urban form. However, the study demonstrated that the city is facing some recent problems and predicted challenges in the future which is the expansion or sprawl, which considers an obstacle to achieving sustainability.

Therefore, the main recommendations to overcome these problems are; paying more attention to the expansion of the city and avoid the sprawl or unnecessary expansion in the city to overcome the partial deficiency in the transportation system. Development of new regulations retrofitting the land-use through regulating the relationship between built-up and open area. Moreover, the land-use regulations should consider more careful development of residential areas in comparison with non-residential areas for better sustainable development outcomes in the city of Erbil. The conclusion of the current study can help the designers and urban planners to pay attention to the future development of the city.

However, the study suggested that in future studies, other indicators could be employed to evaluate sustainability in the urban form of Erbil, and the results would be compared with the results of this study to understand the similarities or the differences for a more comprehensive understanding. Nevertheless, other cities in Northern Iraq, like Sulaimanyah and Duhok as other big cities of the region to be evaluated based on the same criteria of the current study. This will help the planners and decision-makers to come out with better development of the cities in Northern Iraq.

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APPENDICES

Appendix 1:Similarity Report

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Appendix 2: Ethical Aapproval Document

YAKIN DOĞU ÜNİVERSİTESİ

ETHICAL APROVAL DOCUMENT

Date: 15/12/2020

To the **Graduate School of Applied Sciences**

The thesis titled "*Evaluation of Sustainable Urban Form: A Study in Erbil, Northern Iraq*'' has been evaluated. Since the researcher will not collect primary data from humans, animals, plants or earth, this project does not need to go through the ethics committee.

Title: Assoc. Prof. Dr.

Name Surname: Buket Asilsoy

Signature:

Role in the Thesis: Supervisor