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THE IMPACT OF LIGHT RAIL TRANSIT ON THE URBAN DEVELOPMENT IN DUBAI, UAE

Dhabia Nasser Alhazmi Alefari

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This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science in Architectural Engineering

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Declaration of Original Work

I, Dhabia Nasser Alhazmi Alefari, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*The Impact of Light Rail Transit on the Urban Development in Dubai, UAE*", hereby, solemnly declare that this is the original research work done by me under the supervision of Dr. Mahmoud Haggag. This work has not previously been presented or published or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

Student's Signature:  Date: 01/04/2022

Approval of the Master Thesis

This Master Thesis is approved by the following Examining Committee Members:

1) Advisor (Committee Chair): Mahmoud Haggag

   Title: Associate Professor

   Department of Architecture Engineering

   College of Engineering

   Signature  Date 02/04/2022

2) Member: Khaled Galal Zaghloul

   Title: Associate Professor

   Department of Architecture Engineering

   College of Engineering

   Signature  Date 04/04/2022

3) Member (External Examiner): Dr. John Onyango

   Title: Associate Professor

   School of Architecture

   University of Notre Dame, U.S

   Signature  Date 04/04/2022

   (On behalf of Dr. John Onyango)

This Master Thesis is accepted by:

Acting Dean of the College of Engineering: Professor Mohamed Al-Marzouqi

Signature Mohamed AlMarzouqi Date August 17, 2022

Dean of the College of Graduate Studies: Professor Ali Al-Marzouqi

Signature Ali Hassan Date August 17, 2022

Abstract

The United Arab Emirates (UAE) has seen significant growth in urban development over the past two decades. To overcome the implication of this development, Dubai's Roads and Transport Authority (RTA) has called for sustainable transport development at all levels, including the Light Rail Transit (LRT), which is a friendly mass transit system to satisfy the requirements of urban mobility, environmental sustainability, and green power efficiency. The shift towards sustainable mass transport systems has become the ideal choice to overcome the challenges accompanying the growth and development facing cities such as Dubai and to convert them into sustainable environmentally friendly places. Today, Dubai, as a global city, is seeing an extraordinary development of urban projects with strong emphasis targeting infrastructure and transportation systems. Therefore, the most sustainable transport system used to enhance urban development is the LRT system that plays a major role in shifting the city toward sustainability. Consequently, the Metro and Tramway systems are recognized as optimal provision of public transport modes for high-capacity public transport systems in Dubai. This helps to improve infrastructure by promoting connectivity, economy, and a sustainable environment. The research investigates the impact of Dubai Metro on accelerating Urban Development in Dubai. Urban transformation patterns around the main Metro Stations are analyzed in the study. Population densities, connectivity, and land use patterns were examined. Three main Metro Stations have been selected to study the surrounding urban pattern and population density. These stations namely: Jebel Ali, Al-Barsha, and Business Bay. To achieve the aim of the study, the following objectives are covered: a) to investigate the needs of the sustainable transport system to cope with the urban development requirements. b) examine the population density, connectivity, and accessibility around Metro Stations. c) analyze the impact of Dubai Metro on urban land use. Accordingly, the research approach is using "Case study method" utilizing quantitative and qualitative tools. Conducting an in-depth examination of Dubai Metro case study within a particular context which is land use pattern, population density and connectivity. GIS and Spatial Maps, interviews, case study analysis, and land use investigations have been used to reach the findings of this research. The findings indicate that the Jebel Ali district has the largest proportion of development in terms of residential and commercial land use, at 643% and 542%, respectively. In addition, the Al-Barsha district has seen developments in commercial and green space, while the Business Bay district has seen an increase in commercial space, lakes, and a decrease in green areas. Each of the three districts has

small buildings surrounding Metro stations, indicating that the development occurred recently and as a result of the metro stations.

Keywords: Dubai Metro, Land Use, Light Rail Transit, Sustainable Transportation, Urban Development.

Title and Abstract (in Arabic)

تأثير النقل بالسكك الحديدية الخفيفة على التنمية الحضرية في دبي، الإمارات العربية المتحدة

الملخص

شهدت دولة الإمارات العربية المتحدة نمواً ملحوظاً في التنمية الحضرية على مدى العقدين الماضيين. للتغلب على الآثار المترتبة على هذا التطور، دعت هيئة الطرق والمواصلات في دبي إلى تطوير النقل المستدام على جميع المستويات، بما في ذلك النقل بالسكك الحديدية الخفيفة، وهو نظام نقل جماعي لتلبية متطلبات التنقل الحضري، والاستدامة البيئية وكفاءة الطاقة الخضراء. أصبح التحول نحو أنظمة النقل الجماعي المستدامة الخيار الأمثل للتغلب على التحديات المصاحبة للنمو والتنمية التي تواجه مدن مثل دبي وتحويلها إلى أماكن مستدامة صديقة للبيئة. تقوم دبي بتطوير غير عادي للمشاريع الحضرية واهتمام قوي يستهدف البنية التحتية وأنظمة النقل. لذلك، فإن نظام النقل الأكثر استدامة المستخدم لتعزيز التنمية الحضرية هو نظام السكك الحديدية الخفيفة الذي يلعب دورًا رئيسيًا في تحويل المدينة نحو الاستدامة. وبالتالي، فإن أنظمة المترو والترام معترف بها كأحكام مثالية لوضع النقل العام لأنظمة النقل العام عالية السعة في دبي. هذا يساعد على تحسين البنية التحتية من خلال تعزيز الاتصال والاقتصاد والبيئة المستدامة. يبحث البحث في تأثير مترو دبي في تسريع التنمية العمرانية في دبي. تم التحقيق في نمط التحول الحضري حول محطات المترو الرئيسية في الدراسة. تم فحص الكثافة السكانية والاتصال ونمط استخدام الأراضي. تم اختيار ثلاث محطات مترو رئيسية لدراسة النمط الحضري المحيط والكثافة السكانية. هذه المحطات هي: جبل علي والبرشاء والخليج التجاري. لتحقيق غاية الدراسة، تمت تغطية الأهداف التالية: التحقيق في احتياجات نظام النقل المستدام لمواكبة متطلبات التنمية الحضرية؛ لفحص الكثافة السكانية والاتصال وإمكانية الوصول حول محطات المترو؛ وتحليل تأثير مترو دبي على استخدام الأراضي في المناطق الحضرية. وفقًا لذلك، تركز منهجية البحث على كل من التحليل النوعي والكمي لتأثير نظام النقل بالسكك الحديدية الخفيف. تم استخدام نظم المعلومات الجغرافية والخرائط المكانية والمقابلات وتحليل دراسة الحالة وتحقيقات استخدام الأراضي للوصول إلى نتائج هذا البحث. وتشير النتائج إلى أن منطقة جبل علي بها أكبر نسبة تطوير من حيث استخدامات الأراضي السكنية والتجارية، حيث بلغت 643٪ و542٪ على التوالي. بالإضافة إلى ذلك، شهدت منطقة البرشاء تطورات في المساحات التجارية والخضراء، في حين شهدت منطقة الخليج التجاري زيادة في المساحات التجارية والبحيرات وانخفاض المساحات الخضراء. تحتوي كل منطقة من المناطق الثلاث على مبانٍ صغيرة تحيط بمحطات المترو، مما يشير إلى أن التطور حدث مؤخرًا ونتيجة لمحطات المترو.

مفاهيم البحث الرئيسية: مترو دبي، استخدام الأراضي، النقل بالسكك الحديدية الخفيفة، النقل المستدام، التنمية الحضرية.

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The most deserving and deepest gratitude is expressed to my family for giving me the opportunity to pursue my dream. Finally, I would like to express my warmest thanks to all those who shared the pressure of this work and waited patiently on me during the whole period of the research.

Dedication

This Thesis is dedicated
To my country, the United Arab Emirates, and our leaders, who encourage young people to pursue their passions in all professions. Specially, their continued support for women, their appreciation for her participation in education and work, and engaging her in country's development process and decision-making roles.

To the memory of my father, Nasser Alhazmi, who has been there for me every step of the way and continues to inspire and motivate me on a daily basis.

To my mother and best friend, Shamma, who began this journey with me and has consistently affirmed my academic abilities.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

CBD	Central Business District
CO2	Carbon Dioxide
DSC	Dubai Statistics Center
EDGAR	Emissions Database for Global Atmospheric Research
EEA	European Environment Agency
GHG	Greenhouse Gas
GIS	Geographic Information System
LRMT	Light Rail Metro-Transit
LRT	Light Rail Transit
MRT	Mass Rapid Transit
OSM	Open Street Map
RTA	Roads And Transport Authority
SZR	Sheikh Zayed Road
TOD	Transit-Oriented Development
UAE	United Arab Emirates
UK	United Kingdom
UNFPA	United Nations Population Fund
US	United States
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organization

Chapter 1: Introduction

1.1 Overview

Dubai is one of the seven emirates of the United Arab Emirates (UAE) and a thriving city in the Arabic Gulf region, with a population of over 3 million (Dubai Statistics Center, 2021). Since 1973, following the UAE establishment of the city has received a massive influx of immigrant, whose presence has significantly altered the emerging city's geography. The city's recent economic expansion, fueled by large oil profits, coincided with the demand for immigrant labor. The government has made significant investments in megaprojects aimed at developing the city's transportation infrastructure. This infrastructure development is associated with population growth that led to an increase in urban trips and changes in land use. Dubai invested in the Arabian Peninsula's first Light-Rail Transit (LRT) system in 2009, demonstrating regional interest in sustainability and a sustainable transport system. Dubai's LRT system is one of the world's longest driverless Metro systems.

Dubai city is primarily known for its magnificent architecture and luxurious developments. It has seen a dramatic transformation over the previous two decades to become one of the world's most visited cities and home to the world's busiest airport, the world's eleventh largest port, and highest skyscraper (World Shipping Council, 2020; Kennedy, 2020). These developments attract visitors from all over the world for business and pleasure. The city has a car culture; the vehicle is central to all activities and movements. Short trips are made by car, and accessible parking lots surround most buildings. However, Dubai has many essential drivers of growth, such as transportation, and the LRT provides intermodal connectivity and makes public transport more accessible, convenient, and sustainable. Building LRT in Dubai proved essential due to the diverse needs presented by the infrastructure. The chapter provides a preliminary regarding how the research has been conducted. It provides the context for the research by outlining the study's background,

goals and objectives, methodologies, and conclusion. The background was important since it provided a good perspective on the LRT and its influence on Dubai's urban development. While the questions in Chapter 1 establishes a position that the research findings either confirm or refute, the aim and objectives direct the process. The procedure for doing mixed method research was given to integrate a variety of data collecting and analysis techniques within a single study. Therefore, a wide range of potential transport and economic impacts are associated with this development, including increasing investments opportunities, creating new jobs, quality of life, diversifying energy sources, and fosters economic development and revitalization.

The research explores the impacts between the provision of the Dubai Metro and developing Dubai in terms of three specific factors: land use, population density and connectivity. As a city with a rapidly growing population and interests to improve economic prospects, LRT proved essential for success. Understanding how LRT influences the city from its economic, land and population redistribution, and other factors will provide sufficient insight into such an investment. To further understand this relationship, this research examines the correlation between LRT and urban development around the Dubai Metro using geographical and temporal variables at three stations i.e., Jebel Ali, Al Brash, Business Bay. Such spatial measures of urban development and focus on the LRT will be utilized and assessed using remote sensing techniques and Geographical Information System (GIS) to analyse the transformation pattern of land use and population density.

1.2 Relevant Literature

Sustainable transportation is the capacity of a community to meet its mobility needs in the least environmentally damaging manner possible while not endangering the transportation needs of future generations (Rodrigue, 2020). Transport is critical in establishing the city's physical, social, and economic structure because without an infrastructure base, economic activity cannot take place. The driving force of transport changed land use and influenced growth trends and scale

of economic activity by offering land accessibility (Wang et al., 2019). Transport infrastructure development is associated with urban growth, spatial expansions, and changes in land use. Simultaneously, population development increased in urban journeys, increasing demand for transportation.

The sustainable transportation aims towards providing and meeting these needs: (i) improving the air quality of the city by reducing cumulative emissions from cars and smog-creating pollutants, (ii) decreasing the need to build additional transport infrastructure, the manufacture of new cars and further extract of fuels, which allows for more energy savings and fewer environmental impacts, (iii) connecting the people to businesses and services, thus increasing the economic development of the people as well, (iv) facilitating higher density by moving more people on a single trip while decreasing distance and time taken for people to travel to their destinations (Sekasi & Martens, 2021). One of the sustainable transport modes is the LRT with all these features with the potential for economic growth that helps the city to grow faster.

The implementation of LRT network in urban areas generally operates and uses a rail-based technology to provide public transport to affect economic development and revitalize the core area of the city (Dorina & Stead, 2017).

LRT usually receives its power from an overhead wire. Making it possible to operate light rail on street level and without exclusive road rights (although light rail vehicles (LRVs) can operate on the subway as well.

Rail transit systems are generally classified into three broad categories: Light rail, Commuter rail and Heavy rail, as shown in Table 1. Implementation of the light rail is the focus of this research; it is valuable to notice the characteristic differences among these three categories of rail. Compared to heavy rail and Metro systems, a Light Rail Transit (LRT) system is a mode of urban rail transport that carries a relatively small number of passengers. The term "LRT" refers to a various of public transit systems that operate at a higher speed and efficiency than conventional

heavy rail. Its operating characteristics include the usage of LRV, which are railcars. It is a broad term that refers to streetcar/tram systems that exhibit rapid transit-like characteristics. The phrase was used to differentiate it from heavy rail, which comprises fast transit and heavier regional/intercity rail. Light rail systems can usually manage higher inclines and sharper curves than heavy rail and fit through street crossings (TCRP, 2005). They are often created in urban areas and provide frequent service through multi-unit trains or single cars.

Table 1: Characteristics of Rail Transit System. Adapted from (Matt, 2019).

	Bus Rapid Transit	**Light Rail**	**Light-Metro**	**Heavy Rail**
Passenger Capacity Per Vehicles	70 – Single Decker bus 100 – Double decker bus	450	600	750 – our current 6-car trains 1,500 (9-car trains with metro style seating)
Right of Way	On-street and off-street	On-street and off-street	Off street only	Off street only but can have level crossings at lower frequencies
Geometry requirements (i.e. gradients & curves)	Most flexible but can require significant space to terminate and turn around services	Flexible	Flexible	Least flexible
Speed	Depends on right-of-way and number of stations. Off-street sections can typically run faster than on-street sections.	Depends on right-of-way and number of stations. Off-street sections can typically run faster than on-street sections.	Depends on number of stations and track geometry.	Depends on number of stations and track geometry.
Frequency	On-street sections struggle with over 100 buses an hour and high frequencies prevent use of signal priority.	Higher off-street On-street sections above about 15 trains per hour won't work with signal priority	24-45 trains per hour depending on signalling	CRL allows 24 trains per hour with signalling upgrade.
Corridor capacity (per hour per direction)	10,000	13,500	14,000 to 27,000	36,000 in CRL with 9-car and metro seating
Cost	Generally lowest capital cost, as more flexibility in difficult areas (e.g. shared lanes across Auckland Harbour Bridge) but can require a lot of drivers. Terminating space can be very expensive due to high bus frequencies.	Lower capital cost than other rail-based modes as can run on-street if required. Higher operating costs as street running prevents driverless operation.	Higher capital cost than light-rail due to requirement for tunnelling, viaducts or separate corridor. Lower operating costs if driverless.	Highest capital costs due to requirement for tunnelling, viaducts or separate corridor – as well as demanding geometric requirements requiring gentle gradients & curves.

LRT is the evolution of the tram car system. It can be introduced as a modern, efficient transformation of tram cars. There is a separate lane for the LRT system, and it allows faster transportation with no disturbances. This service is suitable for larger passenger capacity than the buses. A bus can hold 75 passengers, but LRT can hold 450 passengers at once. Normally modern LRT use low-floor articulated trams, and they obtain electrical current from overhead lines.

The rail design portion of LRT is a key focus since it is more comfortable than bus transit. Modern LRT is quiet and has no noise disturbances for the environment, but wheels generate little noise. Light rails are faster than Buses and traditional tram systems. The running speed of LRT is 80-100 Kmph. And LRT is a low-cost, ecologically friendly, electrified system that produces no pollution and produces some noise and vibration. The highest speed of LRV is typically around 100 km/h, while they typically operate at much slower rates, more in line with road vehicles (Fergusson & Skinner, 2002)

Bus Rapid Transit (BRT) is bus-based public transportation that provides speedy, pleasant, and cost-effective urban transportation. BRT is a high-quality, car-competitive mode of transportation reasonably priced. Compared to LRT, BRT requires low-cost capital. Holding 70-100 passengers at once. The differences between BRT and LRT are that BRT systems provide greater track flexibility due to their ability to operate on roads. Whereas LRT systems operate safely on railways, tunnels, and bridges with a longer service life. Secondly, the initial funding required to implement BRT systems is typically less than that required for LRT systems (Lambas et al., 2017).

The Light Metro Rail Transit, commonly known as Metrostar Express (MRT), is considered a 'public good,' as it serves multiple objectives and generates numerous public benefits. Congestion is reduced by improving public transit, such as by introducing MRT. This is because MRT is the quickest mode of transit in the most congested travel corridors, as well as convenient and capable of transporting many passengers. MRT trains can normally transport between 14000 and 27,000 passengers per hour in a single direction. MRT reduces automobile traffic, benefiting transit riders and car occupants on less congested streets. But there is a high capital cost for constructing MRT compared to LRT.

Compared to other modes of the rail transit system, heavy rail transition requires the highest capital cost. But the passenger capacity for one direction is about 36000 which is the highest

capacity of rail transition mode. The LRT ensures that services are delivered quickly, sustainably, reliably, securely, and at a high capacity.

Sustainable transportation is a broad word that refers to Environmentally, socially, and climate-friendly modes of transportation. When considering sustainability, the type of vehicle used for road, water, or air transportation; the source of energy used; and the infrastructure required to allow transportation are all issues to consider (roads, railways, airways, waterways, canals, and terminals).

Due to its ability to adapt to changing urban environments and conditions, the LRT system can be considered sustainable transit. Since one consequences of transportation systems has been a continuous increase in Greenhouse Gas (GHG) emissions, the most significant of which is Carbon Dioxide (CO_2). GHG is released into the atmosphere by nature and humans absorb some of the infrared heat reflected by the earth, making it more difficult for it to escape into space and contributing to the planet's warming. It is expected by 2050, fossil energy use in transportation systems will double (based on 2009 data), further increasing GHG emissions unless mitigating measures are taken (Andrade & D'Agosto, 2016). Establishing a sustainable Light Rail Transit (LRT) system, can help to mitigate these emissions. These systems emit less CO_2 per passenger per kilometre than other modes of transport by reducing the number of journeys that will simultaneously serve a large group of individuals.

In addition, by supporting industrial development and rapid accessibility, which improves living standards, urban rail transit positions are as a powerful lever for the urban economy. Socially, sustainable urban transportation aims to provide enough access to transportation ro reduce social exclusion and enhance an individual's quality of life (Alade et al., 2020). A well-functioning transportation system contributes to sustainable development, as well as all other areas, including energy, manufacturing, health, and construction, rely on transportation for delivery at some point

(Sekasi & Martens, 2021). Thus, public transportation's major objective is to facilitate the effective and efficient movement of commodities and people while simultaneously contributing to economic, social, and environmental sustainability.

The impact of a metro transit network on the urban spatial structure is largely determined by the station locations. In addition, the more accessible a metro station is, the more passengers it attracts and the more valuable the area it surrounds (see e.g., Abutaleb et al., 2020; Hurst, 2011; Furlan & Sipe, 2017; Abdulla et al., 2020; AlQuhtani & Anjomani, 2021).

In return, increased passenger traffic and demand can strengthen the functionality of a metro station and its surrounding land, further improving the urban spatial structure, which influences the characteristics of human activities near metro stations and results in agglomeration economies. A survey conducted by Abutaleb et al. (2020), confirmed that a large number of respondents confirmed their intention to use metro stations located near a shopping center. This high percentage is due to the station's proximity to the mall (Abutaleb et al., 2020). Metro stations are not only the gateways to the public transportation system; they are also critical nodes that connect the Metro network's links.

Hust researched to determine the impact of the Hiawatha (LRT) line on land-use change in Minneapolis. The study concluded that the LRT had little effect on land use within a 90-foot radius of low-density residential areas. Some land-use changes happened within 150 feet of high density and commercial properties. Vacant land had the greatest effect, while industrial land changed, though not always in response to distance from stations. There is conflicting evidence indicating the effects are less pronounced in high-income communities. A spatial association between neighborhood median income, race, and land-use change appears to exist. Regression analysis verifies this finding when other variables are considered (Hurst, 2011).

Thus, for an urban area primarily served by a metro transit system, access to the urban area is contingent upon the accessibility of the metro stations. Accessibility evaluates the ease of

connecting to a metro system by multiple means of travel, which can be used to determine whether a transit system's users' needs are met.

There is a lack of research and studies on the functional relationships between urban development and Dubai's LRT System. Understanding public transport and urban dynamics is the main issue covered in the literature review is a necessity to avoid significant environmental and ecological risks from occurring. The findings will be discussed with consideration given to three primary issues: land use patterns, population density, and the degree of interaction with the Dubai Metro systems.

The three districts are represented in Figure 1, Jebel Ali, Al Barsha, and Business Bay, as well as their surrounding urban areas, were chosen for the following reasons:

1) Jebel Ali District is in the south-western region of Dubai and is a significant part of the city due to the Jebel Ali Free Zone, the Jebel Ali Port, the Jebel Ali industrial zones, and the Palm Jebel Ali development. Therefore, the Dubai Metro connects the central business district to the outer edge of a city.

2) Al-Barsha District is one of Dubai's most affluent residential areas. It used to be primarily a huge sandy area with a few residential developments and a sparse road network, but the neighborhood has developed into a mixed-use district. The area has one of the main access points to the Mall of the Emirates, defined as most a densely Metro station where passengers primarily travel for shopping and leisure. And the district is connected by a transportation network that extends from the central Metro station to a range of public transportation options. There are pedestrian, cyclist, and vehicular access points to the area.

3) Business Bay District is a global economic hub, financial, and new business district center of Dubai. Business Bay station is located southwest of Dubai's historic district, near the Sheikh Zayed Road (SZR) and 35th Street intersection. As its name implies, the station serves the

massive Business Bay, which borders Downtown Dubai. Al Wasl is a neighborhood located to the station's west.

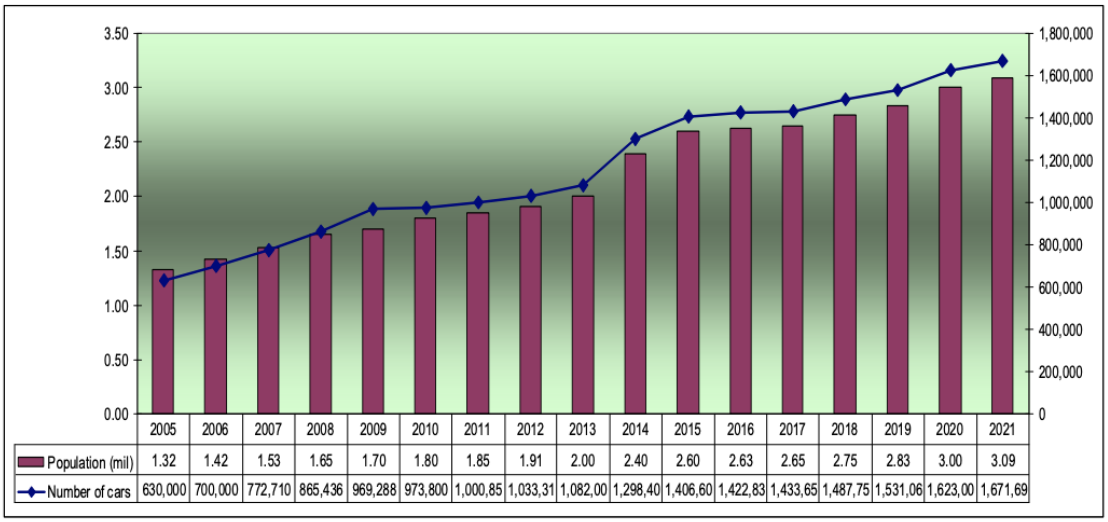
Figure 1: Dubai metro stations with three selected districts. Adapted from (MapaPlan, 2013).

1.3 Statement of the Problem

Increased population development in urban areas is one of the most important transportation challenges in developing countries, compounded by high energy consumption and the demands of urban environments. Rapid and unplanned population grown in major cities and developing countries is Matter of con-cern in relation to increased transport mobility demand. In addition, there is a linked trand to rise in the ownership of private cars. Effective city planning will be critical in addressing these and other issues as the world's urban areas expand.

With the growth of Dubai's population, car ownership has surged. The automobile ownership rate in Dubai is 6.2 people per car (Al Ali et al., 2015). Car ownership among the Dubai population depends on the type of individuals' occupational status. The majority of journeys are made to and from work as part of Dubai commercial operations. The link between travel and socioeconomic level is critical in determining the extent of automobile use and its consequences for the community.

The increased use of private automobiles has resulted in congestion on Dubai's major thoroughfares, particularly in the Central Business District (CBD). Congestion is one of the environmental challenges in Dubai's urbanized area. This relates to individuals driving their own vehicles rather than taking public transportation. As shown in these sections, the problem is directly connected to the large volume of traffic on the road. High traffic levels undoubtedly contribute to air and noise pollution. The majority of people drive their own automobiles, followed by public transportation (buses).



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Population (mil)	1.32	1.42	1.53	1.65	1.70	1.80	1.85	1.91	2.00	2.40	2.60	2.63	2.65	2.75	2.83	3.00	3.09
Number of cars	630,000	700,000	772,710	865,436	969,288	973,800	1,000,85	1,033,31	1,082,00	1,298,40	1,406,60	1,422,83	1,433,65	1,487,75	1,531,06	1,623,00	1,671,69

Figure 2: Dubai's population growth rate with vehicles growth rate. Adapted from (Al Ali et al., 2015).

Dubai roads are habitat to about 1.6 million vehicles as shown in Figure 2. Vehicles and light trucks account for the largest share of the numbers (Al Ali et al., 2015). According to a

Dubai police report, 123 people died in road traffic incidents in 2019, with the majority of accidents occurring on Sheikh Mohammed Bin Zayed Road (13%) known as SMBZ Road parallel to Sheikh Zayed Road (E11) (Dubai Police, 2019). Most fatalities occurred among motorists and pedestrians, with approximately five fatalities per 100,000 persons. However, road death has decreased dramatically since 2007, when there were over 17 deaths per 100,000 people. The WHO has set a target of three deaths per 100.000 people for Dubai. The report noted that the global fatality rate from roads traffic accidents has continued to rise, while it has remained relatively stable compared to population growth.

Each year, 1.35 million people die on the world's roads, equating to nearly 3,700 deaths every day. Road vehicular accidents are the greatest cause of death for children and adolescents globally and the eighth biggest cause of death for persons of all ages (WHO, 2019).

This section describes the important transportation issues facing Dubai's development in terms of air pollution and the potential of injury or death from traffic collisions or road accidents.

1.3.1 Greenhouse Gas (GHG) Emissions in UAE

In the UAE, the primary source of GHG emissions is the combustion of fossil fuels for electricity, heat, and transportation. According to Emission Database for Global Atmospheric Research (EDGAR), a worldwide database of global GHG emissions and air pollution is multifunctional and independent. EDGAR uses worldwide statistics and a uniform Intergovernmental Panel on Climate Change (IPCC) methodology to give independent emission estimates compared to those provided by European Union Member States or United Nations Framework Convention on Climate Change Parties (UNFCCC). Using annual, monthly, and up to hourly data, EDGAR provides emissions as country totals and grid maps at 0.1 x 0.1-degree resolution at the global level. The UAE ranked 28th in the world in terms of CO_2 emissions in 2016 with 218.8 million tons. The monitoring of air quality in the UAE has been investigated and assessed by the levels in

various industrial and heavily inhabited areas. Figure 3 shows the CO_2 emissions increased by 4.43% year over year when CO_2 emissions were 209.5 million tons. If researchers investigate further into the issue, the primary source of GHG is the transportation sector, including burning fossil fuels for automobiles, trucks, ships, trains, and planes

(Worldometers, 2016).

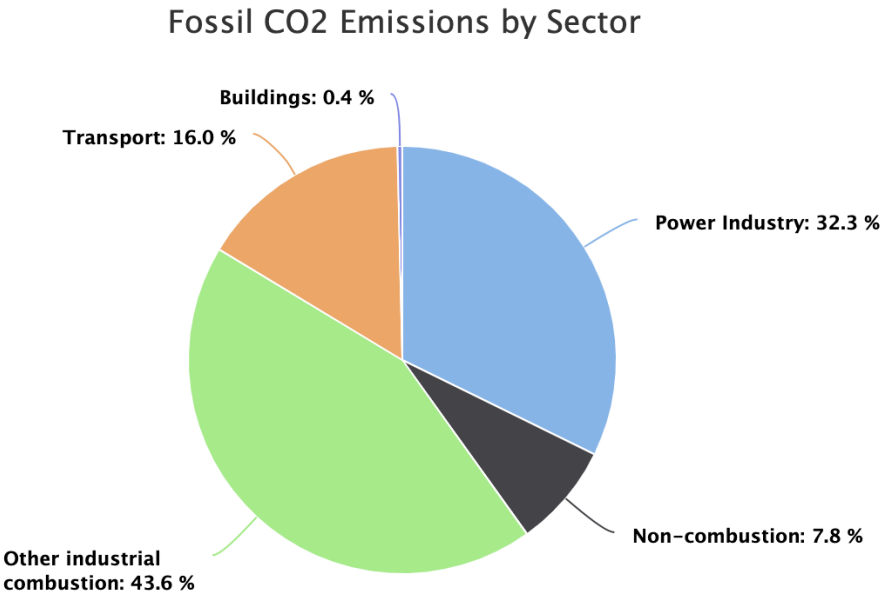


Figure 3: United Arab Emirates CO_2 emissions in 2016. Adapted from CO_2 Emissions from Fuel Combustion – Worldometer.

1.3.2 Car Accidents

Road traffic injuries (RTIs) are the tenth biggest cause of death globally, accounting for 22% of all deaths. Approximately 1.3 million people die on the world roadways every year, with another 20 to 50 million suffering nonfatal injuries (ASIRT, 2021). If current trends continue, RTIs will become the fourth greatest cause of death, contributing to 36% of overall mortality in the next 20 years. The UAE's expanding road traffic accident problem may be explained by these new high levels of motorization, as well as the existence of a large resident population. Similar

findings were made about Saudi Arabia by Ofosu, Abouammoh, and Bener (1988), who argued that variations in cultures, habits, and attitudes might lead to road safety issues, as Saudi Arabia has similar geographical and urban environment to Dubai and cultural norms of both countries are also overlapping to a great extent (Ministry of Interior Annual Statistical Abtracts, 1995 - 1999). Road accidents in the UAE are caused by human errors such as irresponsible driving, exceeding speed limits, and ignorance of traffic laws and regulations rated number one (Abdalla, 2002). Compared to high-income countries, where traffic fatality rates have decreased significantly, developing countries are facing a decline in their situation. Dubai's motor vehicle-related fatalities routinely exceed those of North America and Europe's industrialized nations. Traffic accidents are the second leading cause of death in the UAE, behind respiratory disorders, according to official sources (Ministry of Health Annual Statistical Abstracts) and (Abdalla, 2002). One of the most important factors of RTIs is location. The 10 key highways in Dubai were found to have the highest traffic accidents in this survey. The SZR was ranked first in terms of accidents (AlSerkal, 2018).

Throughout the research period, Emirates Road came in second. Both routes, which are freeways with high-speed restrictions, were rated first in terms of injuries and fatalities from road traffic accidents. Heavy cars and trucks are key contributors to the rise in traffic accidents on Emirates Road, which has the highest number of injuries (Al Marzooqi et al., 2010). Compared to 2015, there was a 20% decrease in road traffic fatalities in the same year. The reason for decline in 2020 is mostly the pandemic and transportation strictness due to the pandemic. The reduction in fatalities in 2020 was even more pronounced, dropping by 30% from 2015; this may be ascribed to the adoption of severe traffic laws and regulations, as well as the installation of the "black points" system (Chaudhry, 2012; DSC, 2020). At first, just a few cars use the transportation link, thus the chances of an accident are low. As the number of vehicles grows, so does the number of

deaths. Countries spend between 1% and 2% of their gross domestic product on traffic accidents. The reduction of traffic congestion and the number of road deaths are two opposing goals.

Governmental measures aimed at reducing congestion, such as expanding road capacity, may accidentally increase the number of traffic deaths (Figure 4). Similarly, policies that result in the greatest reduction in traffic accidents are not always the best or most socially acceptable policies. The policy with the greatest net social benefits is the most effective. When a program's marginal social cost matches its marginal social benefit, it has achieved its optimum level. Every intervention policy has both direct and indirect consequences (Shefer,1994).

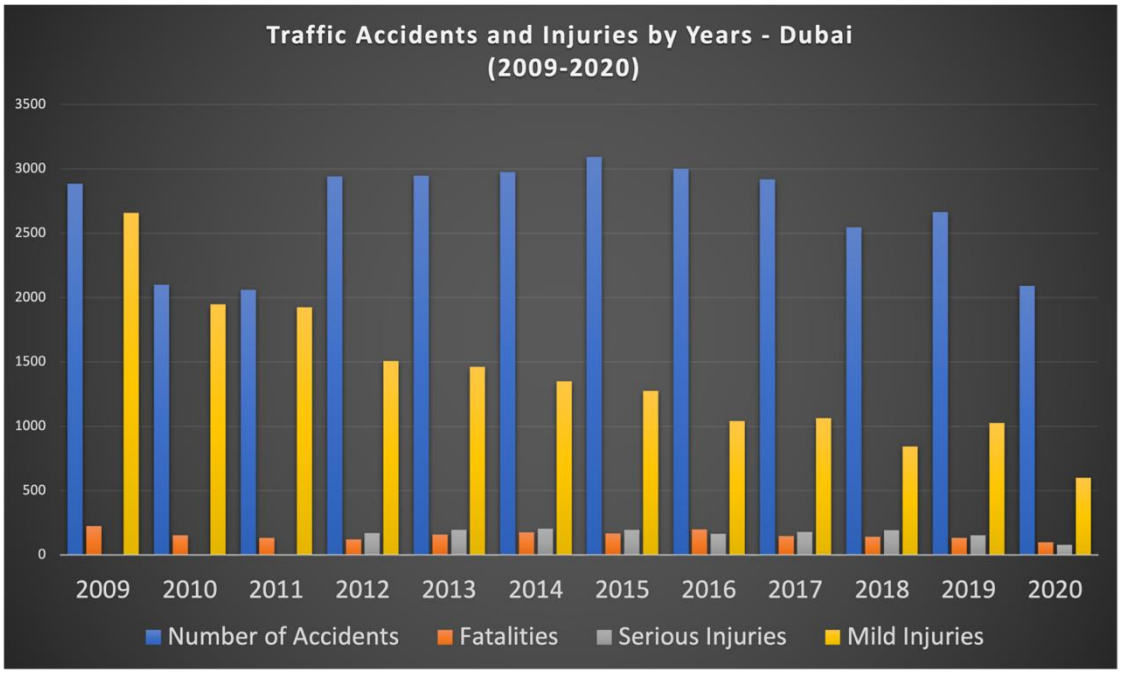


Figure 4: The number of traffic accidents, injuries, and fatalities in Dubai (2015 - 2020). Adapted from (Dubai Statistics Center, 2020)

The research problem emphasizes the importance of a light rail transit system due to the growing demand for transportation mobility in Dubai when compared to other modes of transport. It will exacerbate the problems related to the presence of cars in urban areas (congestion, pollution, and parking). Simultaneously, this will result in additional public space being dedicated to

car parking in the city, or we can option which is the LRT. That can transport a much greater number of people in a smaller space than existing public transport options, thereby reducing CO_2 emissions and gallon fuel consumption.

Dubai experienced significant urbanization expansion, particularly following the 2008 financial crisis. As the population of Dubai is expected to exceed 5 million by 2030, the development of the city was a difficult challenge. With rapid expansion, traffic congestion has become a serious concern in Dubai, with the daily increase in development, road traffic has become a serious issue. Specifically, in three districts: Jebel Ali, Al-Barsha, and Business Bay, it is an optimal case study for examining the impact of LRT Systems on land use. The rail infrastructure becomes important because it connects suburban housing with metropolitan employment opportunities. The LRT system is critical for transporting employees from the urban core to the economic development zone of the new CBD, thereby meeting the population relocation objectives. As a result, rail transit passengers will have better access and convenience by integrating transportation infrastructure with the surrounding land uses and facilities.

Therefore, the Dubai government integrated Trams and Metros to steer transportation development toward a more sustainable mode of transport. However, what effect does the LRT have on surrounding urban development, and what impact does the Dubai Metro have on urban land use redistribution and population density. All these concerns have received little attention from scholars and researchers. Therefore, the primary research problems are to determine the impact of the Dubai Metro on urban development, and the study evaluates the impact between in 2009 and 2020. Thus, by considering these fundamental difficulties, the study's primary purpose is to investigate the requirements for a sustainable transportation system capable of meeting the requirements of urban expansion, which is a significant issue.

1.4 Actions Taken by the Government to Overcome Transport Problems

The public transportation networks and infrastructure in Dubai, played a critical role in changing demand away from private car ownership and toward more efficient means of transportation, and reducing congestion in traffic networks. With increased and improved public transportation, Dubai mitigates traffic congestion, promotes social inclusion, and minimizes pollution. The Dubai transportation system is a connected network consisting of Metro, Tram, Bus, Marine, and Shared Mobility "E-hailing and Shared Vehicles" transport that serve the city's roughly 2.2 million residents and visitors.

The Dubai Metro, the world's largest automated driverless train system, is also the most intelligent system, reliably delivering on its promises. The Dubai Metro got people engaged with public transportation by incorporating innovative technology such as Wi-Fi, smart malls, and easy accessibility for disabled passengers, as well as excellent connectivity to other public transportation such as buses and taxis, making it one of the most popular, convenient, and affordable modes of transportation. The Dubai Metro was built to satisfy the significant environmental sustainability requirements such as energy management, emission management, and green economy. It contributes considerably to the green environment by decreasing CO_2 emissions.

According to the sustainability report, the Dubai Metro reduces carbon emissions resulting from the use of private vehicles, by motivating the population to use mass transportation, as the number of transportation users has reached or 16% of the total flights in Dubai. This means a reduction in total carbon emissions by 330,000 tons, and the total reduction in carbon emissions achieved by initiatives in 2016 and 424 tons of clean energy and green economy was 35,000, which is 9% higher than the target set (RTA, 2016). When compared to an automobile, the Metro system's architecture has the least impact on the environment.

The term "Transit-Oriented Development" (TOD) developed by Peter Calthorpe in 1980s and is becoming more popular in urban rail-transit planning and design research. TOD refers to the temporally and geographically integrated integration of various (but desirable) mixed use development with transport to increase transit usage and promote attractive land uses around station locations. There has been a surge in interest in building light-rail transit (LRT) systems in North American communities to improve mobility during the previous decade. LRT stations appear to be good locations for TOD programs due to their operation compatibility scale (Khasnabis, 2010). There are a number of transit initiatives in the Dubai Metropolitan region that may have a substantial impact on the country's transportation features.

1.5 Preconceptions for the Study

The Metro lines in Dubai and the subsequent increase in population density, development of new industrial, residential and commercial centers, attracting the population and services in Metro areas of the city are directly linked. The city has seen a dramatic makeover from desert to gardens and skyscrapers with development of urban transportation services and well-connected area. Therefore, the Metro lines and increased population density in certain places are related to changing land use patterns.

This means the Dubai Metro has important redistributive effects and influence where and how development occurs in an urban area. The research assumes that with the ingoing transport development, more changes due to the improvement of the infrastructure will further attract the population on the one hand and affect the distribution pattern of urban land use on the other hand. By anticipating an increase in population and the need for proper infrastructure and sustainable transportation, the study will investigate the redistribution pattern of land use and population density after the construction of the Dubai Metro as a sustainable LRT system.

However, a large range of social science research, including construction management, use questionnaire surveys, interviews, participant observations, etc., to gather information from the subject or issue under investigation. However, the questionnaire has been shown to be the most employed method of data collecting by many researchers to answer research questions (Fellows & Liu, 2009). To gain insight into the thoughts, feelings, and opinions of the interviewee, Fellow, and Liu (2009) recommended using questionnaires. A face-to-face interview was conducted to get to know about perceptions of people living around the Dubai Metro and using the Metro for their different purposes. The face-to-face interview aimed to determine the possible impacts of the Dubai Metro on users, the direct and indirect effects of this mode of transport on urban residents' daily activities, as well as to identify the research gap that needed to be addressed.

The Author conducted to con-duct face-to-face interviews rather than filling out surveys to engage with respondents and establish their perspectives or anything the research missed due to a lack of knowledge about using the Met-ro. The interviews took place at the Jebel Ali energy station, the Ibn Battuta station, and the business bay station. These stations were chosen because the case study for the research is easily ac-accessible from the city and has a large passenger capacity. Face-to-face interviews were used to recruit 33 participants with 18 questions, see Appendix A. While participants were chosen randomly, care was taken to ensure that they represented the study's various dimensions in terms of age, gender, professional status, and income level. The findings act as a base and orientation for further investigation, and for identifying opportunities and stressors to be investigated in greater detail in a potential complete analysis. The face-to-face interview was created on the following two interconnected research questions:

- Do residents prefer living near a Metro station and take the Metro daily?
- How does the presence of an LRT affect the development of urban areas with the land use and population density?

In a face-to-face interview, most residents lived near Metro stations or nearby areas. Very few are locals (Emirates) were using the Metro. The research had to conduct phone interviews with locals to discover the cause for this. They were previously using the Metro, but now they are avoiding busy areas out of fear of contracting the Coronavirus.

Most respondents were males in the survey. A small number of females ride in the Metro. As Dubai has a high proportion of male workers, the majority of individuals uses the Metro are men.

Through participant observation and interviews, this questionnaire discovered that women place a larger priority on personal security than men do. Most well-educated people use the Metro as the mode of transport as the high number of respondents were bachelor's degree holders. Very few people had extra high education that bachelor and about two-person was PhD holder and used the Metro once a week.

Most employed people use the Metro to go to their offices and other businesses. Very few unemployed people are females who use for their personal uses (shopping, entertainment, etc.). Almost 6 persons are students and the same ratio of housewives who use the Metro for shopping and their other domestic purposes. Interestingly, no one was dissatisfied with Metro growth, according to the survey. Almost everyone was satisfied, although more individuals were delighted with the Metro's progress in Dubai region. Some were comparing the Dubai Metro with other countries they visited before, such as Turkey, claiming that it is significantly superior in terms of design, accessibility, ticket price, capacity, and organization during the Corona pandemic. There were only two people there who were satisfied with the Metro, and the reason was that they took buses more frequently. It is an essential part of building urban rail transit to get a high satisfaction level for passengers. By constructing the Metro in Dubai, the Dubai development has brought prosperity and comfortability for Dubai residents.

The face-to-face interview finds that almost 22 who are employed are using the Metro daily preferred living near Metro stations and will choose hotels are close a Metro line. Some

working individuals commute to their offices using the Metro and earn more AED +15,000 AED/Month. This reflect that even the Metro is accessible to all groups of people regardless of their social status. Which demonstrates the role of demographic shift in influencing the economy's underlying growth rate, structural productivity growth, living standards, consumption, and development. It has the potential to impact market forces that drive housing trends and also shaping the land use patterns.

1.6 Research Questions

The study's research questions focus on areas of the research topic and data that will influence the research outcomes. The research questions include:

1. How does the LRT affect Dubai’s urban development?
2. What are the main factors affecting land use patterns after the development of LRT?
3. What are the main impacts of LRT on urban development in terms of land use, population density and road network connectivity?

1.7 Aim and Objectives

The urban area of Dubai faced apparent challenges that the study sought to solve. Like any other advanced city, Dubai experienced a growing population that needed proper amenities and a strong transportation system for urban land expansion. For example, if a Metro is to be built in a metropolitan like Dubai, it has to be sustainable in its land use and consider the connectivity of all major parts of the city in the best effective way possible.

The primary aim of the research is to investigate the impact of the Dubai Metro on urban development in Dubai. Population density and urban land use patterns have been studied using GIS and spatial maps. Hence, the following research objectives were set :

a) To investigate the needs of sustainable transport system capable of meeting the demands of urban development;
b) To investigate the role of the Light Rail Transit in urban development; and
c) To assess the impact of Dubai Metro on the redistribution pattern of urban land use, and population density in relation to connectivity.

1.8 Research Structure

The research structure is represented in Figure 5, and it consists of five chapters that explain the research process and address questions of research approach. Each chapter comprises a variety of components that contribute to the overall design of the research. The research uses a mixed methods approach to help in determining the research objectives and addressing the research questions.

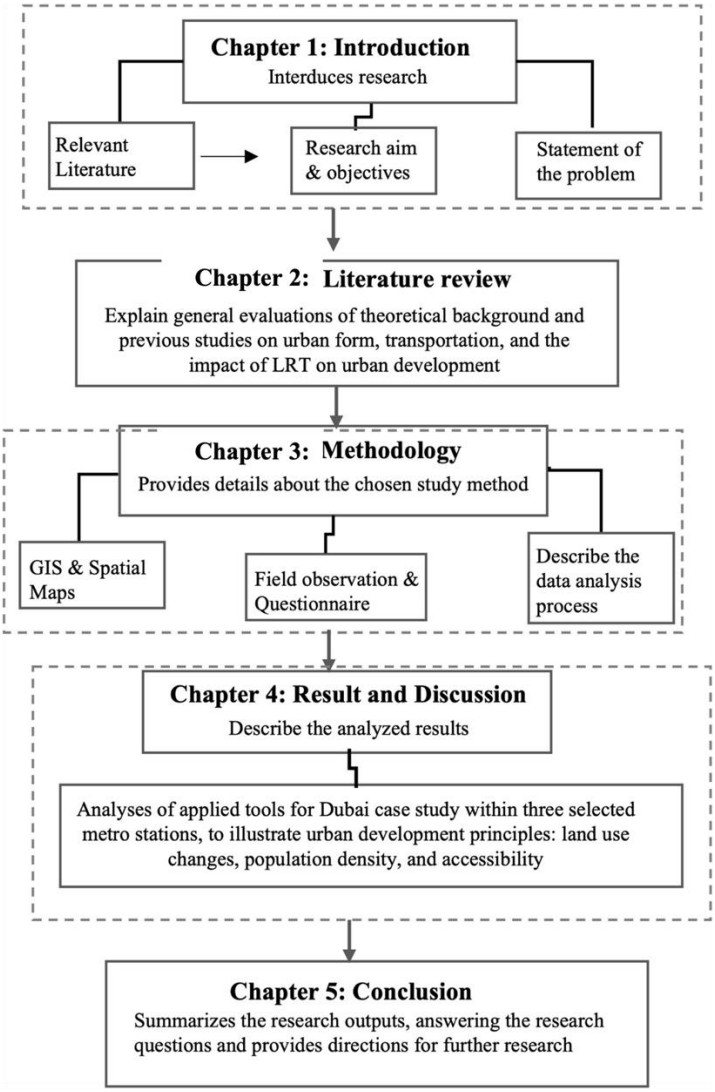


Figure 5: Research structure

1.9 Conclusion

Dubai has many of the important drivers of development growth (transport sector, industry and manufacturing, foreign investment, and travel and tourism) and the LRT provide intermodal connectivity and make public transport more accessible, convenient, and sustainable. The enhanced access offered by the Metro affected the growth of the surrounding parts of the city. The Dubai Metro provides daily commuters with a feasible, cheap, and fast commute system. The study included an in-depth examination of urban and demographic growth in the Metro-impacted area. Having a growing and large population proved essential for the UAE and city growth.

The LRT acted as a strategy that would improve the environment, economic, and social significance of Dubai. Therefore, considering these developments, the study analyses the impacts of Dubai Metro on the distribution pattern of land uses and population density around three Metro stations: Jebel Ali, Al-Barsha, and Business Bay districts. These stations were selected to cover different districts in nature; industrial district, business district, and residential/commercial district.

Chapter 2: Literature Review

This chapter establishes the study's theoretical foundations and literature review. It contains information about urban development, urban form, and urban transportation systems. More emphasis is placed on land use, with the LRT system being considered as a model of sustainable transportation.

2.1 Urban Development

Cities have evolved over time, with numerous concepts adapted to characterize the nature of the forms and growth that occurred to meet the diverse necessities of society and nation. Similar to any organism, cities evolve/change with time, defined by interdependence (between human-made, natural, and social capital) and synergy, which increase the resilience capacity (Saad et al., 2014). Statistically, urbanization represents a rising of the living population's percentage in urban settlements (UNFPA, 2007). Also, it is one of the dominant contemporary paradigms as an increasing share of the world's urban population. 70% of the population will be living in cities by 2050. which is sixty-four billion urban inhabitants (United Nations Population Division, 2018). Urbanization has been influenced by transport networks, such as highways, rail systems, or walking paths. There is huge, complicated transport in urban areas due to the involved methods, the abundance of sources destinations, volume of the traffic, and the diversity. Urban transportation was centered on passenger traffic because cities were considered as the hub of social collaboration, with a complex network of traffic connecting travel, commercial communications, cultural activities, and leisure.

There are fundamental changes that have been seen by urbanization in the demographic environment of human actions. A dynamic combination of financial, demographic, and technical factors drives urbanization. The key driver of urbanization is the growth of GDP per capita, but it

is facilitated by the equivalent development of transport systems and the spread of air conditioning that enables people to settle in high-temperature areas such as the Near East (e.g., Dubai). Urbanization results in new jobs, economic growth, and lifestyle (Rodrigue, 2020).

2.2 Transportation and Urban Form

Urbanization occurs in lockstep with the expansion of urban transportation systems, particularly as regards their ability and performance. The more revolutionary the change, the more altered the urban form. The two characteristics of cities that decide how people communicate with each other are the urban shape, the pattern and density of land use and transport systems — the means of moving within Metropolitan areas (Jacobs, 1961). Historically, urban movements were confined to walking, rendering mass transit impractical and time consuming. Therefore, there was a tendency to aggregate operation nodes and urban forms dense with other uses. Under these conditions, most developed cities have assumed an urban posture, although this type no longer prevails. On the extra hand, the separate urban types of the current constructed Australian, Canadian, and American cities encourage car dependence and are connected to motility levels (Saurabh, 2003).

The development of new core areas that express new urban activities and new links between elements of the urban structure is among the most profound changes. Many cities expect a polycentric type of change associated with new patterns of mobility. New manufacturing, retail, and management practices have transformed the Central Business District (CBD) that was a key goal for travelers served publicized transport. While conventional manufacturing relying on centralized workplaces and transportation, modern industry was made more versatile by technological and transport growth. The urban spatial structure has changed its centrality to a multichannel, suggesting recent urban kinds and current possible links with zonal and worldwide productive criteria (Rodrigue, 2020).

When cities grew, they demonstrated growing complexity over time. Many cities are port with trade, which plan an enduring role, not only for economic vitality, but also in the urban spatial structure.

It is necessary to understand how urban areas are structured, the research will look at three models of urban spatial structure: the concentric zone model, the sector model, and the multiple nuclei model. These three theories of urban structure concentrate on the development and functional distribution patterns of a community and the residential location versus socio-economic characteristics for an urban area (Settlement Geography, 2020).

2.2.1 Concentric Zone Model

The concentric zone model was derived from a study by Ernest Burgess in Chicago in the 1920s (Figure 6). This model was developed at a time when the full effect of the Industrial Revolution on the American City was evident. In the Chicago example, Burgess defined five different zones with separate spatial functions (Langenfeld & Writer, 2017).

The CBD is located within the central loop in zone 1. The transition zone (2) characterized by a deterioration in residential properties and a bias to industrial and light development. The zone of independent homes (3) was predominantly occupied by labor force bluecollar (wage-earners, manual laborers). The area of better residences (4) was primarily middle-class. Finally, the suburban ring was the commuters' zone (5), mainly of white-collar employees who could afford to live farther from the CBD. That model is dynamic. As the city expanded, the outer zones encroached.

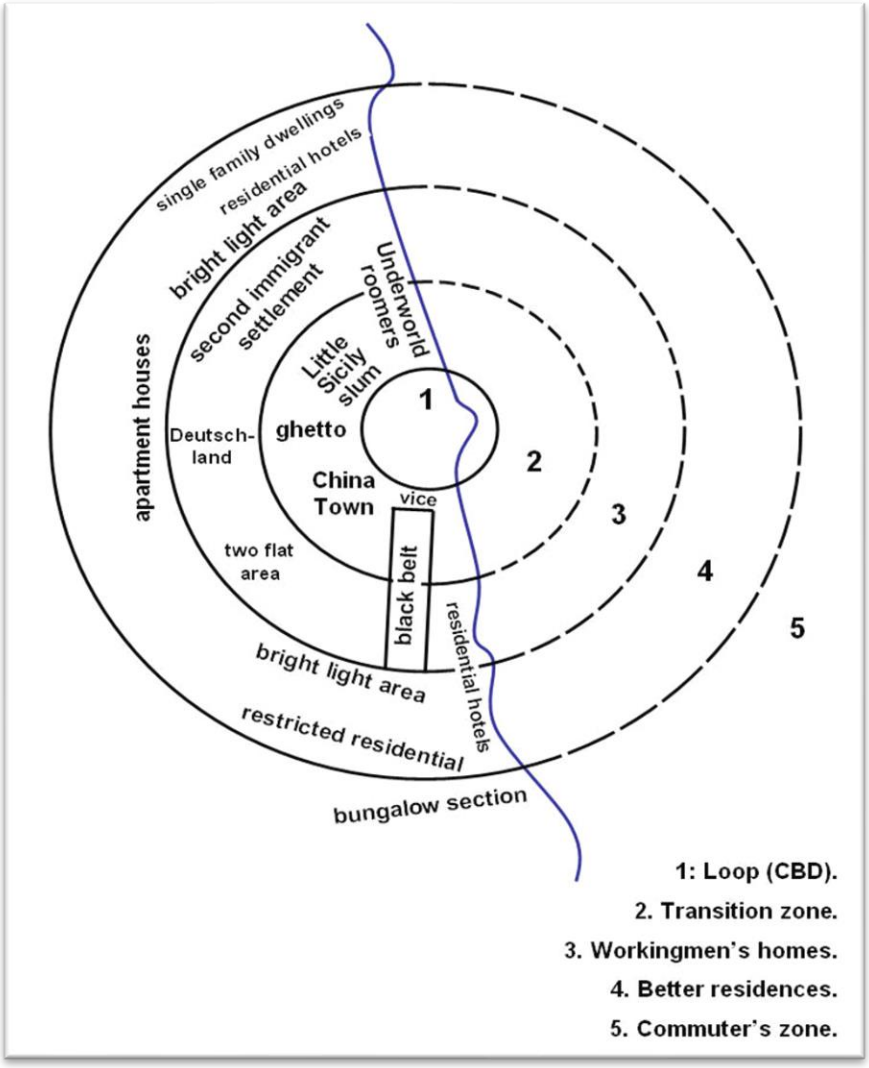


Figure 6: Concentric zone model, 1925. Adapted from (Settlement Geography, 2020).

The concentric zone concept identifies four zones located in rings around a city's core, decreasing linearly in socioeconomic class toward a catch-all 'commuter zone' on the city's outskirts (Delmelle, 2019). The concentric zone model shows the human ecology model that views cities as a set of circular zones or human ecology zones: a functional perspective that examines the relationship between people and their built and natural environment (Brown, 2002).

The rapid population spread in the early postwar period (1950s) in the external suburbs caused distant nuclei but also decreased contact volumes and levels between the central city and these new suburban towns. By the 1970's, outer cities became more and more separate from the

CBD in which these former suburbs were once closely associated. With time and technological advancement, the cities become more widespread due to the proliferation of cars. Suburban neighborhoods now play a variety of functions in the CBD, and their significance has waned.

Today, there are urban realms, components of giant urban areas which operate separately in some ways but are connected in a larger Metropolitan area. Production and distribution are central activities. In the suburban sector, regional shopping centers (e.g., malls) are the new external core CBDs. With shopping centers and offices outside the CBD, it creates realms that can be autonomous (Godfrey, 2013). In 1964, geographer James E. Vance Jr. proposed the urban-realms model to strengthen the multiple nuclei model. With this model, Vance analyzed urban ecology in San Francisco and summarized economic processes into a robust model. The model suggests that towns consist of small "realms," autonomous urban areas with independent focuses. The definition of these realms is explored by five criteria (Langenfeld & Writer, 2017):

- Area topology, including water barriers and mountains.
- The scale of the whole Metropolis.
- The volume and the intensity of economic activity in each region.
- The internal accessibility of each area in relation to it is key economic feature.
- The inter-accessibility of each suburban area.

2.2.2 Sector Model

The second model is sector model (also known as Hoyt Model and Hoyt Sector Model), a spatial pattern of activities in an urban area which describes the relationships of the various activities in the area. The sector theory was built based on the urban structure of 142 cities, it is structure pattern of residential areas (Briassoulis, 2020). The model explains how cities expanded and how activities spread as the cities grew. As shown in Figure 7, Hoyt noted the elevations of residential areas with high social status residents. In comparison, Hoyt found that high poverty areas

had lower elevations and were less likely to have the resources required to accommodate potential growth.

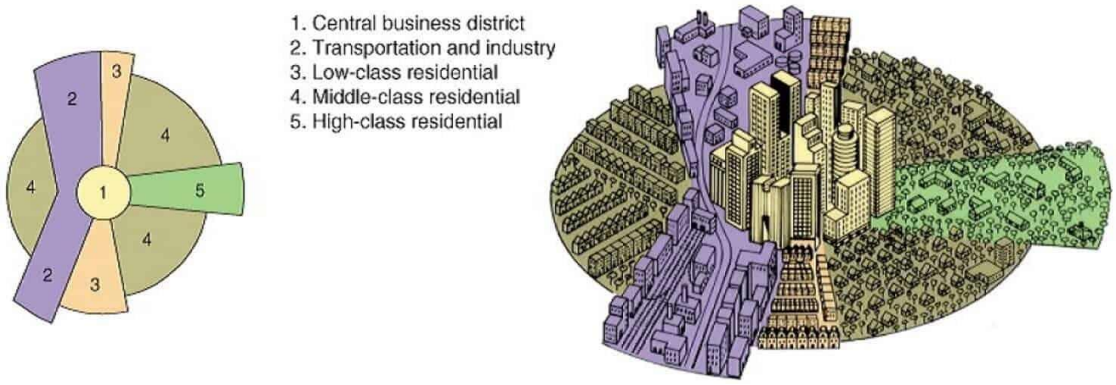


Figure 7: Hoyt sector model. Adapted from (The Albert Team, 2020)

Hoyt argued that cities evolve in several distinct ways, not just circles and particularly significant to Hoyt was the social status and geographic distribution of the residents in the various sectors. Activities in a sector often follow the same general pattern, whether they have the same role or serve the same purpose. Land use for each sector must stay the same since they attract each other. The high-class sector would remain high-class because only the wealthy would live there, leaving out the majority of the population. The manufacturing sector will remain in it is current state as the site will have access to transportation and industrial zones. These industries include housing, transportation, etc. These sectors are housing, manufacturing operations, etc. They are situated near rail lines, highways, and rivers (Faridi, 2020).

Any city has a large number of economic activities and where they are located is analyzed by land use models. The Hoyt model consists of the following components:

i. Central Business District – as with all classic models of urban land use, the Hoyt Sector Model includes the central business district as it is heart (CBD) (The Albert Team, 2020).

Sectors and partial rings of land use divisions are listed. This area is also known as downtown, and it includes high-rise buildings. It represents the history of growth and development of many centuries, and the influence of cultural and customs of men, tourists who inhabited the region. The layers of the city grow one upon another. The synthesis of these layers and the way they are held together in the city gives the urban environment much of it is visual appeal from it is socio-cultural heritage (Admin, 2020).

ii. The Industrial Sector – Industries are depicted as a field radiating out from a central point. These forms sector because of the existence of a transport channel, or transportation link, along which economic activity was conducted. The noise and pollution from these zones have pushed everyone else away. Therefore, everybody rents in these places. Chicago is a major industrial corridor, extending from it is CBD outward along railroad and industrial canals (The Albert Team, 2020).

iii. Residential Sectors – Hoyt's model assumes that people want to live in cities based on the amount of income they earn. Because desirable land (near lakes, hills, places away from the smells of the factories) was more costly, the elite class communities were developed in zones segregated from lower, working-class zones. it classifies the phases of residential construction according to the incomes of the residents. The first group is low-income groups, such as the urban communities with narrow roads, high population density, small houses with poor ventilation. Roads are narrow and relatively few, which make them easily accessible. It is proximity to industries that lowers travel costs thereby attracting industrial workers. Pollution and other unhealthy living conditions are directly linked to close proximity to industrial areas. The second group is the middle-class who can afford to move more but still want to live in better conditions. It is more closely related to CBD, as it also has linkages with other industries. This is the most densely populated area. Third group is high-class residential, this is the farthest place from downtown in the city. This is

a neighborhood with less noise, less traffic, and has nice big homes. The corridor from the CBD to the edge of the city has the best accommodation.

2.2.3 Multiple Nuclei Model

The main benefit of the concentric theory is that it is very simple, but land usage is much more nuanced, varied, and extreme than originals proposed by Burgess or Hoyt. The majority of city issues are complicated that they can't be described by simple, general statements. As a result, the Multiple Nuclei Theory offers a more versatile model that can be applied to a variety of urban conditions. According to this theory, land use trends in most of the major cities evolve around a variety of discrete centers rather than one central area. Cities have a cellular structure in which distinctive types of land use formed within certain growth centers recognized as ‘nuclei' (Mohsin & Anwar, 2015). The number of a city nucleus depends on two factors: historical development and location powers of the city.

The theory of multiple nucleus does not generate a clear urban model like the previous models that applicable to all cities but suggesting a number of principles to cover the important issues for land use pattern of cities. According to Harris and Ullman, these principles are relevant to land-use and zoning of cities, [Figure 8].

The grouping of specialized land uses around these nuclei has been clarified by using factors:

i. Certain activities include specialized facilities such as a CBD or shopping district situated in the most easily accessible location in any particular area.
ii. Certain activities combine in order to benefit from common interests or commonality. Furthermore, in industrial areas many roles occur are adjacent or in the vicinity of the industrial area e.g., retail trade zone, the financial and office buildings due to the facility of transportation and communication needs.

iii. Certain activities that are damage one another cannot occur at the same time. Such as the heavy manufacturing and high scale residential areas aren't always clustered close together.

iv. Certain activities that are unable to pay the high rents of the most desirable places e.g., less costly housing or bulk storage sites.

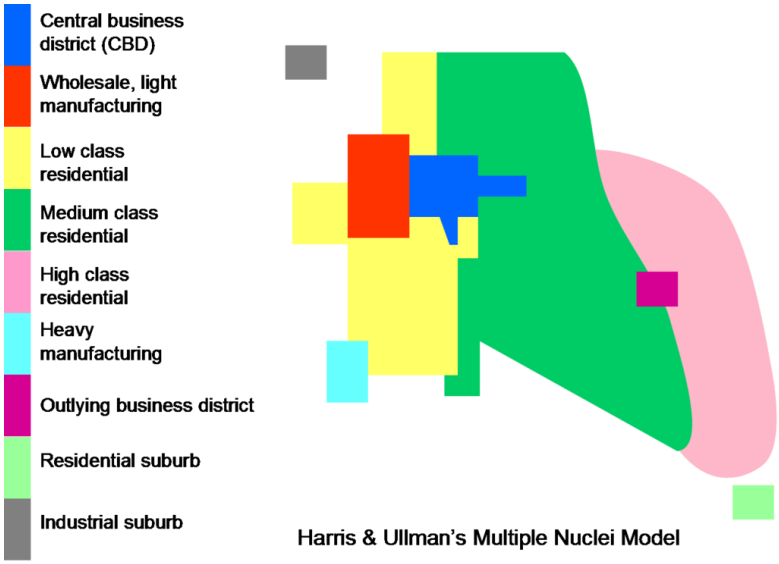


Figure 8: Multiple nuclei model. Adapted from (The Albert Team, 2020)

The multiple-nuclei model shows that even though an urban center might have been built with a CBD, there are other smaller CBDs develop on the outskirts of the city rising near the more costly housing. This helps make longer commutes more tolerable in the suburbs.

This phenomenon produces a cluster of economic activity in other parts of the city other than the CBD, thereby giving rise to the name multiple nuclei model.

As the nuclei grow, transportation hubs are developed, which enable industries to be formed with reduced shipping costs. The TOD model developed in which mixed-use communities are developed around transit hubs to enable sustainable living. Where transport lines intersect, land value is at it is highest. While the hotels close to airports because passengers would prefer to

be close to the source of travel. Housing usually grows in various parts and becomes increasingly more costly as it gets further away from the CBD (Chen & Hao, 2008).

Burgess's, Hoyet's and Harris's models are considered the pioneering works of urban land use and the classical or simple models of urban land use. But specifically, these models have been developed for the urban environment of the United States and Western Europe, for instance; Burgess' concentric model is especially designed for such urban environments as Chicago. Similarly, the Hoyt sector model and the Harris and Ullman model are not entirely applicable to real world cities due to some inherent shortcomings. But many land use planners use and stick to classical models as they look at the development trends of cities in developed nations. Hence, they are known as the ‘classical models of land use' and useful for urban land use planners to figure out the configuration of the cities as they are easy to understand and distinguishable between various classes of land use. Moreover, the multiple nuclei model propose that different land-use trends can emerge based on the locality. Therefore, it more accurately represents the nature of urban land use.

Urban form refers to an urban transit system spatial influence as well as corresponding physical facilities. The urban spatial structure is a term that is frequently used to describe and address the distribution of activities within a Metropolitan area.

2.2.4 Morphological Pattern of Dubai

Cities undergo a variety of transformations as they grow, and urban development takes place. In the case of Dubai, it is more suitable to the Multiple Nuclei Model, it is described as a city that begins with a CBD and other smaller centers develop on the borders of the city near the valued residential areas to allow shorter travel from the peripheries of the city. The urban growth in Dubai is characterized by a sprawling and expansive city, rich with diversity and a diverse range of unique traits. The city expanded because of vehicle transportation, resulting in increased

urbanization. It begins in Deira and Bur Dubai, which are Dubai's Downtown, then expanded to other nuclei around the city. Today Dubai has five Central Business Districts.

Figure 9: Identity of new CBDs in Dubai. Adapted from (Al Masar, 2021)

Deira and Bur Dubai are considered the city's historic CBDs, as they are still functioning urban hubs that serve as a reminder of the city's history and heritage. For historic satellite images of the two sectors, see Appendix B.

With reference to Figure 9, 1) Deira / Bur Dubai, 2) Downtown / Business Bay, 3) Dubai Marina / JBR, 4) EXPO 2020, 5) Dubai Silicon Oasis. The second business district is the city's commercial and financial core, encompassing Downtown and Business Bay. The third one is the Dubai Marina and Jumeirah Beach Residence (JBR) encompasses a hospitality and leisure hub that serves as an international tourism and leisure destination. Then there are two new centers, EXPO 2020 Center, an economic and growth hotspot with affordable housing and a main focus for the exhibitions, tourism, and logistics industries; and the Dubai Silicon Oasis Center, a scientific, technology, and knowledge hub that promotes innovation, the development of the digital economy, and the cultivation of talent (RTA, 2020).

2.3 Transportation and Urban Land Use

Urban areas are distinguished by social, cultural, and economic activities at separate locations in which an activity structure is created. Some are routine, since they occur on a daily basis and are thus predictable, such as shopping and travel. Such activities are typically connected to passenger mobility. There are also manufacturing and distribution activities, the connections of which may be local, regional, or global. As activities have a different location their separation is a generator of transport-supporting passenger and freight movement. The location and interaction form of urban activities therefore interrelate transportation and land use.

Land-use and transportation interaction is a complex process involving changes in spatial and temporal aspects between the two systems. Changes in systems of land use will alter the patterns of travel demand and cause changes in transport systems (Shaw & Xin, 2003).

City planners and transportation engineers have developed numerous methods and models for predicting urban travel demand. This is because the forecasting of travel demand is the key to designing transport facilities and creating urban planning policies and regulations.

Many studies on travel demand have shown that the spatial arrangement is strongly connected to land use forms and its activities of Daily life (Escamilla et al., 2016), number of job opportunities, Trade Activities, Commercial Activates, Administrative activities, Transit and Major Infrastructure Provisions, distribution of land uses. Previous studies have recognized the need for region-specific land use data and modelling rates (Akin & Alasalvar, 2020; Alonso et al., 2017; George & Kattor, 2013; Sperry et al., 2016).

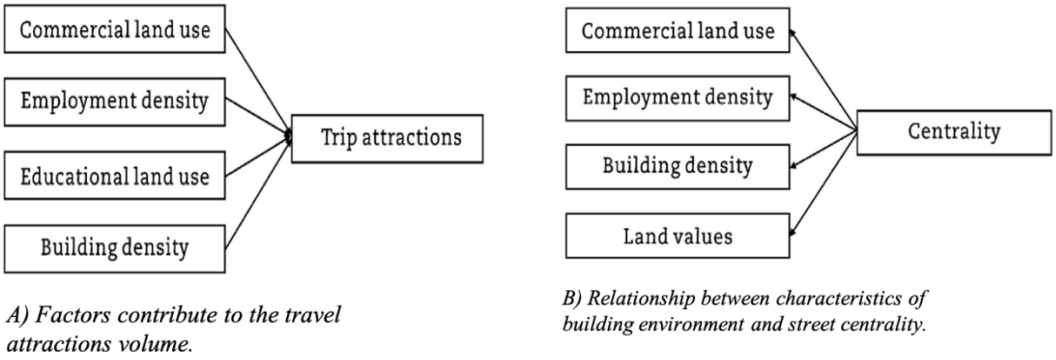


Figure 10: Factors contribute to travel attractions volume and relationship to street centrality. Adapted from (Jayasinghe et al., 2017)

According to Jayasinghe et al., (2017) the travel attraction volume and relationship to street centrality was connected factors. The commercial land uses, employment activates, educational land uses, building density was major factors to vary the trip attraction and trip generation. As well, centrality also depend on commercial land uses, employment density, building density and land values. The factors are shown in Figure 10, are makes variations and dependence to transit profile of the urban areas. However, the connectivity measurement of network configuration was major phenomenon which impacts to the urban transit models.

Saurabh (2003) identified that urban land use is mostly concerned with the levels and nature of the accumulation of spatial activities. In contrast, urban forms are concerned with the formation of spatial structure links and node patterns in cities. Production, consumption, and distribution of function occur within the activity systems that contribute to land uses through the location and spatial accumulation. The land use is categorized into two representations depending on the people's, institution, and firm behavioral pattern on land use. Formal land use representation deals with the qualitative features of space. The second representation is the functional land use that mostly deals with the spatial accumulation levels of various economic activities (Rodrigue, 2020).

Characteristics of land use also influence patterns of service, such as zoning patterns and legislation, land access, public services, and telecommunications infrastructure. The changes in passenger and freight generation, which are affected by economic and demographic changes, are of particular importance. Obviously, population growth is a catalyst for additional demand for transport, also for higher income level. As accessibility varies, this attribute affects land use such as the location, expansion, or densification of new activities.

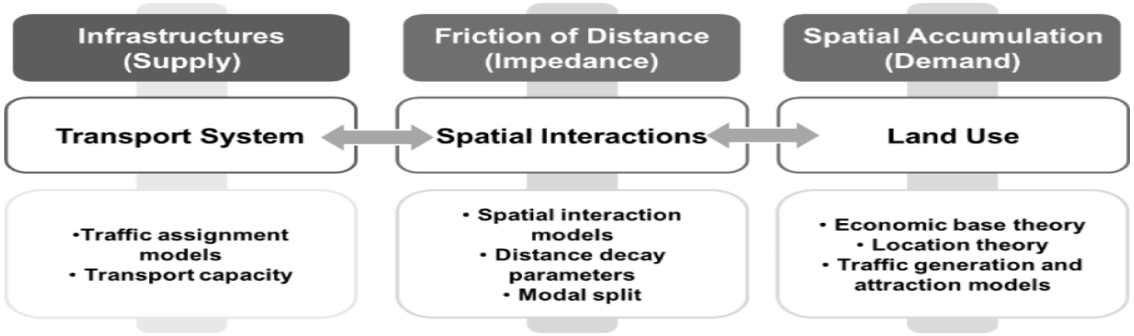


Figure 11: Transportation and land use relationships. Adapted from (Rodrigue, 2020)

The transport system is referring with accessibility and how far it is connected to the locality. The level of transportation system with mobility factor and accessibility factor. The spatial interaction demonstrates how the distance, spatial interaction and models rely on distance decay parameter. Land use of transport system represent that the spatial accumulation and level of spatial agglomeration. There is a wide base of spatial economic models estimating transport demand, mainly through the generation and attraction of traffic by different types of land use. In addition, land use and transportation interaction are a dynamic process that involves changes over spatial and temporal dimensions between the two systems. Changes in land use systems can modify the travel demand patterns and induce changes in transportation systems. The interests of individuals, organizations and corporations have a land use imprint in terms of their place preference. The representation of this imprint includes a land use typology that can be formal or functional.

Rodrigue also explained that a set of relationship is implied by the land use in both formal and informal representation. For instance, land used for commercial purpose results in the emergence of customer and supplier relationships. The supplier relationship involves the movement of freights, whereas the customer relationship involves the movement of passengers. Every type of land use has specific mobility needs, and as a result, transportation serves as an activity location factor. The effective investigation of transit analysis and land use dynamics will provide a better understanding of the urban entities. Numerous interfaces exist between the system and the transportation system, as well as changes in land use, connectivity, and spatial configurations. The transport system involves the transport infrastructure that supports the movement of freight and people in the urban areas (Saurabh, 2003). The origins, destinations, nature and extent of the passengers' and goods movement are considered in the spatial interactions. Spatial interaction also considers the transport system attributes and the factors of land use responsible for movement generation and attraction.

2.4 Urban Transportation Systems

The urban transit systems involve the mobility of major vehicular movement of various mode of transportation. In instances where the transit share road areas, efficiency is impaired. In urban areas, transportation systems depict and have direct impact on quality of life as well as the development opportunities. There are some unique challenges of planning with respect of environment and social commitments. The public transport facilities are not only the fulfilment of need but also act as an accelerator for more impartial and more sustainable society. There are four basic aspects on which the contribution of public transport towards the quality of life can be analyzed. These aspects include culture, economic condition, environment, and society.

Public transport system is beneficial for society as it provides an equitable access to all the opportunities and fulfil the demands and expectations of the people. It allows people to continue their routine activities eliminating the effect of uncertainty.

Public transit system is also the reason behind the establishment of distinctive and worth visiting places and it reduce the requirement of an extensive infrastructure and road network as well as allows limited the automobile usage (Diab & Geneidy, 2015). The evolution of human settlement and contiguity of transportation facilities are not only strongly corelated to each other but also plays an important part in the development of human civilization. The quality of transportation facilities is linked with the living standards of the people to meet the demands and expectations of people. A comprehensive transportation system should be analyzed such a way that it is socially credible, practically, acceptable, predictable, financially variable, safer, time saving ecofriendly and with sustainable solution.

2.4.1 The Main Functions of Transportation

Transport is important because it enables people to communicate, trade, and engage in other forms of exchange, which results in the development of civilizations. Therefore, transportation is critical to economic development and urban development. With reference to Mathew & Rao in 2007, to make the transportation system more viable and diverse, the main functions are listed below:

1. Multi-Modal: the system should be covering all the modes of transportation i.e. Air, land, and Water for passenger as well as freight.
2. Multi-Sector: it should be encompassing the needs, expectations as well as problems and considerations of government, public and private industry.
3. Multi-Problem: the system should incorporate and cover all the national and international policies and procedures, keeping in view the planning of regional system. It

should also come up with the location and design of specific facilities, carrier management stance, regulatory affairs, financial and institutional policies.

4. Multi-objective: an extensive system must keep the national and regional economic development in consideration. Also, the aspect of urbanization, environmental and social quality as well the financial and economic feasibility of the service provided to the users.
5. Multi-disciplinary: the transportation system must be drawn based on engineering designs, economic viability, research about operations, political and psychological aspect, social and natural sciences, legislations, and management.

The strong relation and interaction between transportation and urbanization, specifically in today's fast changing world, is essential for a transportation planner. Among these, four important dimensions of transportation system transformation can be recognized, which serve as a foundation for developing the proper viewpoint:

1. Change in need: with the change in population growth, income, and land-use, the pattern of transportation facility demand also changes. The amount and spatial distribution are considered.
2. Technological change: from cables, steam, and horse-powered predecessors to underground rapid transit lines to metropolitan electric railways, which competed with steam trains between cities as newly called Light Rail Transit (LRT). Urban transportation needs are updating very rapidly in case of technology, for instance in past few years, only bus transit and rail transit systems were considered but now updated systems like LRT, MRT system, etc. offer a variety of alternatives.
3. Change in operational policy: the policy changes and options in policies are considered to improve the efficiency, such as car-pooling and incentives, bus fare, road tolls etc.

4. Change in values of the public: in early years, all the users of a system were considered as customers monolithically. Nowadays, no single system can be effective to all users, therefore during the planning process, it is necessary to identify target groups such as work trip, rich, poor, young, leisure etc.

According to a review of statistics from the Federal Transit Administration and other academic, government, and industry sources, public transportation can help reduce GHG emissions by providing a low-emission alternative to driving, enabling compact land usage, hence minimizing the need for long distance transport and reducing transit operations' and construction's carbon footprint.

2.5 Sustainable Urban Transport

A good working definition of sustainability as it applies to cities was written by the Brundtland Commission of the United Nations in 1987 “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” This means the production and consumption of these and urban infrastructure which contains network of water, sewer, roads are all managed well to meet our needs without compromising the ability of next generation.

The elements often present in 'sustainability' conceptual models include representation of (three pillars: environmental, economic, and social models), as shown in 2. To decide whether your project is sustainable, you must not only examine the three-pillars issues that referred to as people, planet, and profits but also the intersections of these issues:

Table 2: Sustainable Transport Goals. Adapted from (Bakker, 2019)

Environmental	Social	Economic
Energy / resource consumption	Accessibility	Development of the economy, including access to jobs
Climate change	Safety	Transport industry development
Air quality	Jobs and working conditions in transport	Financial sustainability of transport providers
Noise	Universal access (e.g. for the elderly and physically impaired)	Energy security and oil import dependency
Land grab / land use	Health and physical activity	Congestion
Biodiversity	Choice of transport modes	Logistics efficiency
Agricultural productivity	Equity and transport justice	Infrastructure investment and maintenance costs
	Quality of life	Technological innovation and competitiveness
	Gender	Infrastructure resilience to climate change
	Service quality and passenger rights	Transport costs for households and businesses

Source: adapted from various sources including the SDGs, VPTI Online TDM Encyclopaedia, Clean Air Asia, UNFCCC

There is a need for sustainable urban transport systems. Nearly 55% of the world's population live in urban areas, which is projected to rise to 68% by 2050, according to the United Nation (2018). Therefore, there is a need for a transport system which can meet requirements for economic development and care for the environment and human quality of life. The urban development is also synonymous with local economic growth considered necessary for improved public welfare (Bartik, 2005).

Its most sustainable solutions are those that focus on the long term and prevent migration while meeting the population's fundamental requirements, such as a sustainable light railway system. Most research has questioned the main decrease in the overall traffic of improved public transit systems (Rubin et al., 1999; Small & Verhoef, 2007). The priority given to public transport has been shown to minimize deaths from traffic resulting in enhanced road safety and public policy effectiveness in urban areas.

Ahmedabad, India, and Bogota, Colombia, accident rates are 50 times lower for rail than for road transport.

Transport has been a big concern on the sustainability agenda (see documents such as EEA, 2002; WBCSD, 2001; World Bank, 1996) which listed three major risks of unsustainable growth in motor transport:

a) local and global ecosystem degradation; b) use of non-renewable resources that appear important to future generations' quality of life; and c) structural deficiencies that compound the two previous problems.

2.6 LRT as Sustainable Transport System

A group of dedicated planners have put in the effort in explaining the hidden connections between transport and land use. In Figure 13, it is pointed out that from the transport side, accessibility is defined first as the ease with which activity destinations are reached from a given location through a particular transport system. It is estimated in the distance, regardless of whether linear (Euclidean distance) or network-based (determined utilizing the road/way links). Studies show the importance of accessibility and proximity in urban areas through their effects on variables relating to production, housing, employment, and services in urban areas (Geurs & Ritsema, 2001; Kasraian et al., 2017; & Bae et al., 2003).

Accessibility

Accessibility is defined as the capacity of a location to be reached in relation to another location. Accessibility is used in this context to refer to the ease with which places can be reached. Accessibility considered to be a critical component of enhancing social sustainability. People seek to live, work, and engage in recreational and cultural activities without traveling excessively far (Huasheng & Edwin, 2000). Che Musa (2000) identified that residents desire to live in areas that offer work opportunities and amenities for family members and friends. Individuals who live in

more accessible places will be able to reach activities and destinations more quickly than those who live in inaccessible areas. On the other hand, will be unable to reach the same number of destinations in the same length of time (Rosenberg, 2018). Every person, regardless of age or physical condition, should have appropriate and convenient access to locations in their everyday lives. Residents that live close to services and amenities in their area have a healthier lifestyle and prefer to travel on foot rather than driving (Pitarch-Garrido, 2018). Therefore, accessibility is considered as a fundamental human right which allow for social equity.

Spatial accessibility emphasizes on one or both of the following two factors: spatial impedance between demand and supply and service availability (i.e., the amount of supply that is available to a population group) (Tao et al., 2018). It can be used to quantify differences in access to healthcare services between different demographic groups or areas.

According to Barton (2000) by improving accessibility to and use of public transportation, the amount of land necessary for roadways is reduced. Moreover, encouraging the use of alternate modes of travel to the automobile, which can result in a decrease in transportation-related energy consumption and emissions. Denser development consumes less land and offers a larger potential for energy efficiency. Increased availability to public transportation may result in a reduction in the quantity of land and resources required for roads if it motivates individuals to leave their vehicles. Reduced parking space necessitates the use of less land and construction materials. The loss of locally accessible facilities and their replacement by more distant facilities built for easy access by car limits the options available to everyone, hence limiting choice.

Centrality

Accodring to Galster et al. (2001), centrality is "The degree to which observations of a certain urban land use are located near the urban area's central business district." The centrality is the measurement of nodes and nodal connections. Centrality concepts were first developed in social network analysis, and many of the terms used to measure centrality reflect their sociological

origin. The nodal connection of a roads refers the access and ability to movement. The centrality was referring with land utilizations and land use dynamics. If there are a low dynamical land uses the transport system will have low number of nodes and road connections. There for it will reduce the centrality value. The centrality has nodal centrality with closeness centrality and between centralities as shown in Figure 12.

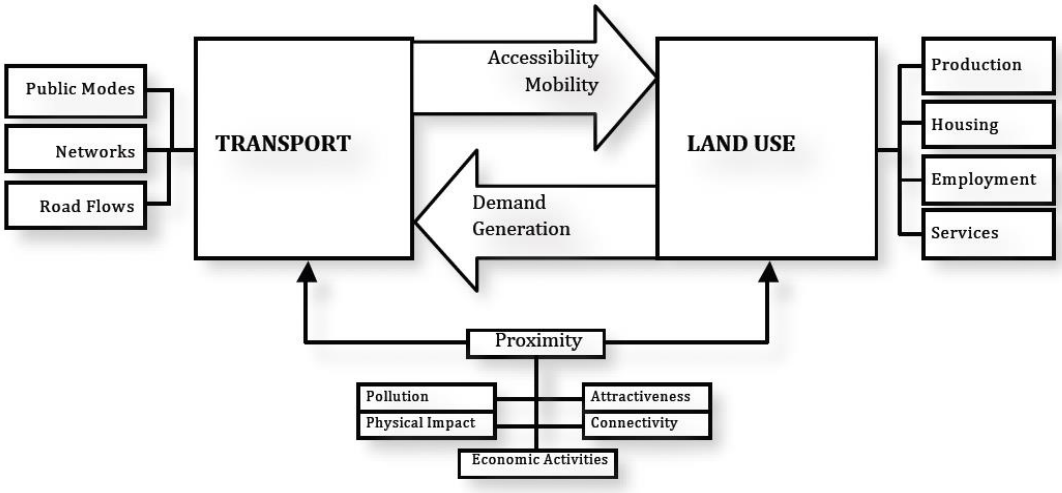


Figure 12: The relationship between transportation and land use. Adapted from (Raguz, 2010)

The LRT systems are urban rail transportation solutions that use electrically powered coaches, rolling stock, and they are used to move customers between fixed stations. The LRMT describes a broader range of transit or, instead, mass public transportation. LRMT covers; light rail trains, electric commuter rails, and grade-separated medium-capacity –light Metros (Mandri-Perrott, 2010). Mass transit modes are also classified by whether they share the public space or are segregated from it. Although they operate on different rights of way on parts of their routes; trams (streetcars), light rail, trolleybuses, and interurbans, they tend to share space with other transport modes. Electric railways and Metros are part of segregated systems.

As vehicles became the dominant form of transportation following World War II and the middle class shifted to suburban areas. This mobility had an effect on the stability of public transportation facilities. Driving became the important part of life to go to the work and complete the

daily routine task, as the driving increases a lot of traffic problem also increases like the air pollution, congestion of traffic, energy consumption increases and occurrence of accidents on the roads. To solve all these problems the Cities made plans and invested in the public transits such as light rails.

2.6.1 Accelerate the Urban Mobility

According to 2013 data, LRT has been adopted in 436 cities worldwide (includes 39 under construction and 30 under planning). There are important cities in countries throughout the world, including Algeria, Argentina, Armenia, and Australia (LRTA, 2021). International experience with 436 LRT systems demonstrates that LRT is the most successful mode of transport for medium-capacity passengers, with almost a century of development behind it.

Topography, transportation, and population expansion are all biophysical and socioeconomic factors that influence urban development. Institutional and policy variables that vary with urban growth can have an impact. Transportation infrastructure is one of these socioeconomic and institutional factors that has a significant impact on urban growth.

Depending on its design, planning, building, and operation, transportation infrastructure has varied effects in shaping urban land use, however measuring, and assessing the effects of land use change caused by transportation system development can take a long period. In order to encourage increased residential density and link downtown and suburbs, public transportation lines have been employed as corridors in urban spatial design. Many big cities prefer urban LRT above other forms of transportation because of its speed, accessibility, and closeness. Future urban development will be substantially influenced by LRT, perhaps leading to a shift in development modes from car-oriented to LRT-oriented corridor patterns (Wang et al., 2020).

LRT proponents claim that it decreases reliance on car and emissions while also encouraging land use change and urban redevelopment. LRT reduces transportation expenses in regions

adjacent to stations by giving a travel option, incentivizing families to settle near stations. Businesses relocate to these denser locations to serve newly moved families, and developers respond by developing multi-family housing. Therefore, it has social effect as it changes the social standing of low-income family in terms of transportation as a new, more comfortable, and safer method of mobility (Alade et al., 2020). Rail service, on the other hand, lowers the cost of commuting for those who live farther from the city center, which should encourage development and population flow to first-ring suburbs (Hurst & West, 2014).

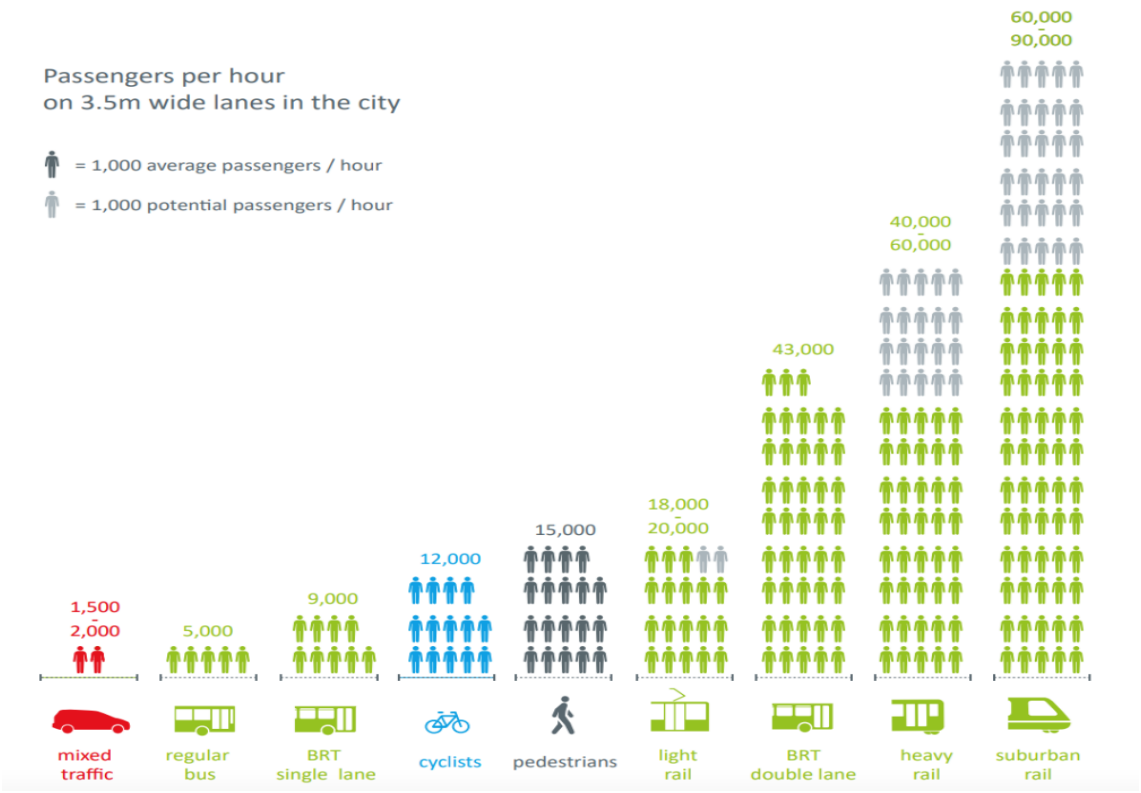


Figure 13: Comparison for carrying capacity of LRT with different mode. Adapted from (TUMI, 2018)

Compared with Metro rail - the LRT is difference from Metro in the trail length and right of way, road level crossings and controls. LRT is relatively low speed than Metro. If it comes to

flexibility and accessibility, the LRT is less convenient than the bus. Also, capacity of transportation, comfort and convenience is relatively high in LRT system. Finally, when compared to BRT ways LRT is exactly similar to BRT and both need relevant need of road system. Moreover, BRT consume more land than LRT and it is emphasizing individual contribution of buses, see Figure 13.

More alternative forms of sustainable transportation systems are one of the key goals for future cities and their architecture. By helping cities reduce auto-centric (oil-dependent) behavior, improve accessibility, and link locations, urban rail has demonstrated it is ability to be the axis around sustainable urban growth. Since the previous decade, big cities have been aggressively developing urban rail projects (Sharma et al., 2015). Even if the infrastructure has grown obsolete, LRT can counteract the unsustainable development trajectories produced by fast motorization.

2.6.2 Road Safety and Use of Resources

In underdeveloped nations, the influence of traffic accidents on economic performance is less well recognized. Several accident-related empirical research in these nations is hampered by a lack of data and inconsistent database updates. Nonetheless, the socio-economic consequences of road accidents are becoming a major source of worry across the world since road accidents are viewed as a major public health issue that affects people all over the world. According to the World Health Organization, 1.25 million people die in traffic accidents each year, and between 20 and 50 million people suffer non-fatal injuries, the majority of which result in disability. LRT can help in reduction in automobile accidents, by reducing human error and number of automobiles on road (Bhavan, 2019).

The transportation sector, like the building industry, are responsible for a significant proportion of worldwide resource usage and waste emissions, as well as playing an essential role in

socioeconomic development and quality of life. Creating a sustainable Metro system is undoubtedly the first step in integrating the complex interrelationships of sustainability concerns that arise in real life (Li et al., 2012). However, while assessing the sector's effect, it is important to use a holistic perspective. Different means of transportation require different levels of construction and maintenance; some modes may be very material and energy expensive, while others may be comparatively low. Consumption of materials and energy at various phases of a public transportation project like LRT are comparatively lower than the other modes of transportation. As a result, the provision of LRT can reduce the need for continuing road building to accommodate future population growth.

2.6.3 The Impact of LRT: Case Studies

Two studies can be used to analyze the impact of LRT. The first study, conducted in Yizhuang, Beijing, found that LRT assisted in simulating development and promoted high density mixed land uses. The method included analyzing land use within a one-kilometre radius of three rail stations and monitoring changes in land use over time (Xia et al., 2017). In 2008, due to activating the preparation of Olympic the light rail dramatically expanded in Beijing from the length of 51.4 Km and 2 lines to a very well-established system of 574 Km with 19 lines and 288 stations. As the new town of Yizhuang was designed to serve as a suburban job center, and as the town's light rail system is unique. It was originally a small village before being developed as a national development economic zone, a light rail system was planned for employees to provide an essential mode of transportation. In Figure 14, all commercial buildings are built outside the inner circle of stations, while residential and office buildings are located outside the circle along the streets. Ensuring that rail users have greater facilities and accessibility. By observing the land use changes in the study that land which is commercial is critical for the transit oriented develop-

ment (TOD) is a type of urban development that maximizes the amount of residential, business and leisure space within walking distance of public transport) as these station. Thus, the land use around the three observed stations creates a multifunctional center, a manufacturing center, and a semi-employment or residential area, demonstrating that even with similar urban rail transit, the impact of land use changes can be significantly different, indicating that with better planning and design, more facilities can be added to increase the neighborhood area's vitality and livability.

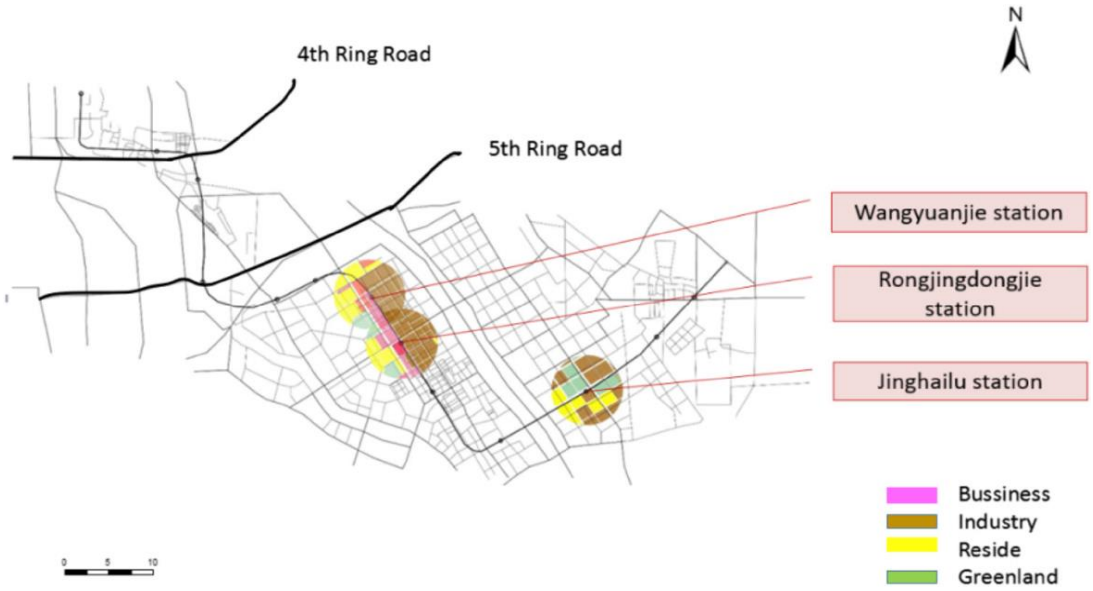


Figure 14: The location and research area for the one-kilometer land use zone. Adapted from (Xia et al., 2017)

Due to the large amount of low-density industrial land along the light rail line in Yizhuang that was not considered during planning. This economic development zone only attracts a very small proportion of commuters from the surrounding neighborhood areas. This is solely due to the lack of proper land use around the LRT station in accordance with TOD principles. Over time the land use changes also relate the importance of commercial land around the light rail lines to support a successful TOD model.

The second study found evidence for an indispensable relationship between LRT Line and urban land indicators in Manila (Raguz, 2010). Accessibility and distance remain in consistent correlation with changes and fluctuations in the value of residential land and improvements can be seen with passage of time. In pre-LRT scenario, this correlation seems non-existent or is much weaker in magnitude. In addition, there seems little correlation between distance/accessibility to the LRT and land utilization in housing or commercial lands in terms of inhabitants and population density. It is in contiguity with the previous findings and results range from a total systematic lack of influence to a weak though steady relation.

According to Figure 15, itself exhibits that how the LRD system influence on the urban form of the city, case study of Manila. The way of development and urban expansion was developed as liner development along the LRT system. Moreover, number of buildings which means density and diversity was changed with the development.

To determine the impact of the LRT on accessibility in Manila, an exponential distance decay function was adopted. Exponential functions are more precise when measuring travels inside urban regions, but power functions are more accurate when measuring journeys between urban areas. The results indicated the accessibility value of each sampling unit (area) before beginning the construction of LRT. Additionally, attractiveness factors served to measure changes in land use variables.

Due to the elevated architecture of the LRT1, impedance values are assigned to links interfacing the jeepney/bus network, which represent the average access/egress characteristics to/from the LRT1 stations. As a second independent variable, network distances between each district and the LRT1 line were determined and transformed into classes (distance ranges). To determine the impact, accessibility indices and distances were compared to five urban land variables: residential and commercial property values; residential and commercial land use; and population density.

Both the effect of accessibility (as measured by network impedances) and proximity (as measured by distance) were correlated with urban land factors as independent variables. The data were collected from 1986 to 1996 for different times series and then processed to create a database, including secondary data for creating a transport network for the accessibility variable within GIS. According to the study, land values had a stronger link with accessibility following the implementation of LRT. Except for the 1993–96 period, the correlations for commercial land values were stable. However, the results were somewhat borderline and not as strong as those for residential land values. In the pre-LRT time, the regressions indicate that the possibility of projecting land values based on accessibility was very limited. Additionally, there was a strong correlation between accessibility and residential land values following the implementation of LRT.

Figure 15: The accessibility GIS analysis results, highlighting the changes in two scenarios; before (top) and after LRT1 (bottom). Adapted from (Raguz, 2010)

The relocation of housing units from the central business district to newly created outside areas of (among others) Quezon and Kalookan municipalities resulted in a decline in population

figures in the vicinity of the LRT1 line. The predicted significant increase the accessibility because of the LRT1's introduction had little effect, as accessibility was already high before the LRT1's introduction. In addition, the growth of urbanization was the ability to cater its capacity into one LRT line and all the services and facilities had been increased. The impact of LRT on accessibility and distance had a consistent correlation with changes in the value of land (particularly residential land) and improvements could be seen within time series. Technically, the LRT line had been influencing to the system which cater to the development capacity and expansion into one way.

Moreover, the influence of LRT on land values seemed minimal. The overall hedonic formula of proximity and access to public transport influencing the land values rules the scenario. Factors like preferences of the consumer, proximity to public health and education services, environment quality, neighborhood, urban landscape, and its economic potential were also included in the formula. Land factors such as availability and land speculation or inadequate application of Transit-Oriented Development (TOD) policy may cause incoherence in the LRT indicators and changes in land use.

Population density changes didn’t co-relate with the indicators. Because of location factors like priority for open spaces, free of pollution and congestion acted as driving –out features for migrating populations from the core of Manila to outer and newly developed northern and southern areas. These can be offset or thwarted by LRT effects. Previous research shows that mass transport isn’t capable of changing trends but in the long run, they might end up strengthening them.

Since LRT is unable to change the settlement patterns it can be deduced that it has no corelation with population densities. Overall, the conducted analysis provides evidence of the LRT's impact on a few major urban-land variables in Manila, thereby strengthening the correlations and regressions associated with the model used.

The two case studies are important for urban planners and transport planners to make future decisions and future direction. Finally, the demonstrated impact requires an appropriate policy development method. Also, an increasing number of studies can address associated planning challenges and determine the appropriate framework conditions for using the dynamic strengths of TOD in urban areas. As a result, research must be conducted to promote integrated and policy-driven urban and transportation planning in which participatory planning places property developers', stakeholders', and the general public's interests first.

2.7 Conclusion

In conclusion, it is often said, other means of public transport may be more cost efficient than train expenditures. While it is true that expanded roadway capacity, road pricing, bus transit enhancements, greater telework, and flex time may all help decrease congestion, according to the analysis, these are insufficient substitutes for urban rail in some cases. Although bus transit is excellent for serving dispersed destinations, rail is more effective at attracting riders and is more cost effective overall on major urban corridors, because trains provide a more comfortable ride, are generally propelled by electric motors rather than internal combustion engines (making train stations more pleasant than large bus stations) and can carry a greater number of passengers. Light rail service offers cheaper operating costs than buses with as little as 1200 peak-period passengers on a corridor and is especially suitable for destinations with more than around 2000 peak-period passenger arrivals to minimize the negative consequences of huge congregations of buses at a station. LRT can promote land use modifications such as pedestrian-friendly street layout and denser development near stations while also facilitating land use changes. As a result, some consider LTR as a key component of a planning paradigm called transit-oriented development, which aims to minimize reliance on personal vehicles. LTR supporters have emphasized on the non-transit benefits of the system. Development rights around rail stations and rights of way; improved

property prices surrounding stations; reduced automobile accident costs; reduced roadway congestion; and public health benefits connected to greater activity are among these advantages. Although these advantages are most noticeable in big, congested cities, light rail systems in several smaller cities tend to improve wellbeing from a cost–benefit standpoint. The great majority of rail transportation trips and passenger miles are likewise served by these networks. Light rail presence has various degrees of impact on environmental sustainability, depending on the methods employed in the research and the environmental sustainability metrics considered. For each of the selected environmental sustainability indicators in the research, the bivariate regression findings revealed distinct independent variable impacts. The regression analyses, on the other hand, show a more detailed depiction of the impacts of light rail and other relevant factors on environmental sustainability measures.

Chapter 3: Methodology

The process of selecting a research methodology include considering the purpose of the research, the researcher's epistemological concerns and professional standards, as well as previous work in this topic matter (Buchanan & Bryman, 2007). A methodology refers to the philosophy and structure that drive the entire research process. The research design method involves developing a strategy that connects philosophical principles to specific procedures. The methods refer to the specific data collection and analysis processes (Creswell, 2009). The research used mixed method and the basic premise here is that combining quantitative and qualitative methodologies provides a more comprehensive picture of an issue than any approach can provide on its own.

This chapter discusses the multiple methods of collecting data utilized and analyzed in this study, which include questionnaires, field observations, case studies, and Arcmap software. This research study employs a qualitative case study approach in which relevant literature is explored in order to discuss urban form and transportation as a emerging concern in the first section of the thesis. The case studies is important to advance the understanding of individual, group, organizational, social concerns. Case studies enable academics to capture the holistic and significant elements of real-world events such as individual life cycles, organizational and managerial processes, and adjacent transformation (Yin, 2003). To analyze a case study, the study examines the case's functioning and activities (Stake, 2013), and the primary purpose of this research is to comprehend Dubai Metro's transportation sustainability in terms of urban growth. Therefore, the case study of the impact of the Dubai Metro on land use, the period 2009-2020 was used as reference years, during which more Metro stations were developed (Chapter 4). Three Metro stations have been selected for land use and connectivity analysis: Jebel Ali, Al-Barsha, Business Bay Districts. The criteria used to select these stations as case studies for this research,

the location of stations within Dubai's urban network, the existing transport connections of the area, as well as it is and multi-land use functions, are all considered.

3.1 Research Approach

The research evaluates the redistribuation pattern of urban land use as well as population density after constructing Dubia Metro as an LRT system using the following indicators:

a) The impact of Dubai Metro on the development for the one-kilometer around the selected Metro stations (in relation to population density and connectivity).

b) Analyze the land use developments around the stations before and after constructing Dubai Metro.

The research approach focuses on a small geographical area and examines contemporary real-life phenomena through an in-depth contextual analysis of a number of metro stations in three districts and their impact on urban development. The research using remote sensing and GIS tools and the data were collected from Dubai Statistics Center records. Which are used in population analysis and OSM Database, USGS Satellite Images to calculate the proximity centrality with the road network (Table 3).

Table 3: The Investigation Techniques Used to Answer the Research Questions

Research Questions	Investigation Tool
How does the LRT affect Dubai's urban development?	Site visit & direct interviews.
What are the main factors affecting land use patterns after providing LRT?	Literature review and Previous studies.
What are the main impacts of LRT on urban development in terms of land use, population density and road network connectivity?	Remote Sensing and GIS. Collecting data from Dubai Statistics Center records. OSM Database, USGS Satellite Images.

3.1.1 Investigation Tools

This study used a mixed-methods approach, which is defined as the combination of qualitative and quantitative data in order to accomplish the research's objectives (Aspers & Corte, 2019; Hameed, 2020). The methodologies which have been used for observing the accessibility are covered by observation of the existing site, to carry out a qualitative method that provides rich descriptions and illustrations that can add potential for enhancing analysis and results and confirming accuracy. The methods refers to the theoretical underpinnings of research in a particular discipline, which may include principles, axioms, beliefs, and models. The following points describe the data collection which is used to reach the research findings and address the research questions:

1. *Quantitative Data*

Quantitative methodologies involve the systematic scientific research of quantitative phenomena and their interactions through the use of mathematical models to test natural-world theories and hypotheses (Creswell, 2009):

1) GIS and Spatial Maps: Method which offers several visual images of how development is distributed around the Metro stations over the time. The spatial concentration of population around the Metro area and an overlook through the accessibility modes in the Metro area.
2) Questionnaire: The data collected through a face-to-face surveys were analyzed in order to determine the influence of the Dubai Metro's provision on passengers' perceptions. The interviewer was physically present during a face-to-face survey to ask the survey questions and assist the respondent with their responses. By far the most significant advantage of the face-to-face interview is the interviewer's presence, which enables the responder to clarify replies or request clarification on certain topics on the questionnaire. In terms of the complexity and quality of the data obtained, this mode of survey distribution has a number of advantages over mail and online surveys. The age, gender, professional/employment status, and frequency of Metro service use are all factors to consider in the survey.
3) Population data: Statistics are used to identify and characterize subsets of populations at a particular point in time.These data are reported in GIS maps or Table format. The data are important to this study because the concentration of population is assessed in historical changes in order to determine why and how the phenomenon occurs and is carefully analyzed.
4) Documents and records: Passenger data for Dubai public transportation system and statistics on road accidents for the years 2009 to 2020 was collected from Dubai Statistical Center. This serves as a clear statement of the problem that accurately reflects the situation of the transportation system in the study area.

2. Qualitative Data

Qualitative research focuses on processes and meanings through the use of in-depth interviews, focus groups, and participant observation (Sale et al., 2002). Rather than relying on quantitative data, qualitative research employs descriptive approaches to produce meaning and insight about the topic under study:

1) Case study: The researcher has chosen the case study approach because it is an effective research method for acquiring tangible, contextual, and in-depth knowledge about a specific real-world subject. Performing a case study means analyzing a problem. According to the Naturalist worldview, this qualitative-based study is based on observations, descriptions, and interpretations of experiences of people or groups in a certain setting. This is how we can learn about the world (Salkind, 2010). Qualitative data is based on subjective judgments, emotions, and personal experiences rather than numerical results (Ladden, 2007). Additionally, it is a methodological technique in which a researcher employs methodologies such as participant observation or case studies to generate a narrative or descriptive account of a location or activity. Additionally, qualitative research is "a systematic subjective approach used to describe and give meaning to real experiences and situations" (Nkwanyana, 2015).The literature relevant theories can be supported through case study research, which is a critical evaluator assessment in defining the impacts prior to and following the establishment of the Dubai Metro. Detailed analysis assists in the study of land use, connectivity, and population density in three selected stations located within a one-kilometer radius of the Metro stations as a case study. The use of case studies offered a more detailed view of the urban growth and the introduction of light rail systems in the provision of services. According to Yin, it is an empirical investigation that examines a current phenomenon inside it is the real-world environment, when the distinction between phenomenon and context is not readily apparent,

and that makes use of a various source of data. Meaning that the sustainability or evaluation cannot be completed without investigating it and it is consequences in real time situation and environment (Yin, 2003). Additionally, as Zainal (2007) points out, the case study method can be used to test data within a specific geographical context and it has been applicable to real-life conditions.

2) Satellite imagery and google earth: A key tool for collecting data on earth resources and the environment. Due to the high variability, low resolution, and large data set of satellite pictures, satellite image analysis presents a significant difficulty. Therefore, the research includes additional data that easily accessed in online via mapping apps such as Google Earth.
3) Land use: The data typically stored in a raster or grid data structure, with each cell containing a value associated with a particular categorization (e.g., residential, commercial, industrial) affects the transportation through the attractiveness of traffic flows. However, uses analysis methods to distinguish the contribution of a particular feature, such as accessibility to a transit railway station.
4) Connectivity: The extent to which a location is served by the transportation network determines it is accessibility. Connectivity is defined as the ratio of the total number of arcs in a transportation network to the total number of nodes (Equation 3.1). It also can be determined as the total number of lines and the number of their joining points in a directly proportional manner. Lines with a high connection value are more linked than others and are thus expected to attract more traffic. A node with the highest proximity connectivity score has the shortest average path to the rest of the network's nodes. Degree centrality involves the assessment of which nodes in the network have the most direct influence. Connectivity can be taken as a parameter to measure the accessibility of a city. Thus, this study used GIS tools to measure connectivity. QGIS is a well-known free and open-source GIS software. The connectivity was

measured using the sDNA plugin via QGIS software. sDNA is a spatial network analysis tool with general applicability but is especially suited to simulating urban networks.

The following equation is used to determine the closeness centrality of node x in ArcMap:

$$Close\ Centrality\ (x) = \frac{nodes\ (x,y)}{Nodes\ Total-1}\ x\ \frac{nodes\ (x,y)}{dist\ (x,y)Total} \quad \ldots\ldots\ldots\ldots \text{(Equation 3.1)}$$

where:

- $Nodes_{Total}$ = The number of nodes in the network
- nodes (x, y) = The number of nodes that are connected to node x
- dist $(x, y)_{Total}$ = The sum of the shortest path distances from node x to other nodes

3.2 Assessment Methods

As noted from the above description, the study utilizes both qualitative and quantitative research. Aspers, & Corte (2019) claimed that qualitative research is multimethod and takes an interpretative, naturalistic approach to its subject matter. The understanding applied in this study when qualitative research utilizes several methods of data collection that include face-to-face questionnaire, field observation and case study. While these provide a source of primary data for the study, the Geographical Information System (GIS) and spatial maps give the source of secondary data as any data that is generated from a geoprocessing tool or data that has been modified without reference aerial imagery is considered secondary data. GIS technology is an excellent method for presenting the spatial data. The utilization of proper satellite pictures enables the analysis of spatial variation across the city which is critical for land use and transportation planning. Numerous studies have used this method to examine land use changes and urban development (Bielecka, 2020; Elmahdy & Mohamed, 2017; Yagoub & Alkaabi , 2019). GIS is a computer system that records, stores, analyzes, and displays data on the positions of elements on the Earth's

surface. One of the greatest challenges facing GIS users is the aquisition of detailed data sources that contain locational and attribute information on the built environment (Thornton et al., 2011). Depending on the process of generation, the quality of data might be affected by whether it is primary or secondary. Because primary data is generated by observing an image on a computer or interacting with the physical world. The likelihood of high-quality data is significantly increased, as long as the metadata or file name includes critical elements such as the map size for which the data is suitable or the stored coordinate system.

On the other hand, geoprocessing software generates data by following pre-defined algorithms that dictate how the incoming data interacts with other data or map measures. Secondary data may contain elements or false information. A GIS is an essential tool for modeling transportation and land use in urban simulations (Tao, 2013). ArcGIS is widely recognized as a great tool for solving geographical challenges. In this research, spatial data were analyzed and visualized using ArcGIS by ESRI and mapping software. Land use maps and administrative data were digitally imported into GIS, resulting in the creation of a new geodatabase that was then merged. According to available data, land use types were classified as commercial, industrial, residential, water bodies etc.). Multi-criteria analysis was implemented to classify and weight criteria in this procedure. Quantitative analysis, including scoring, ranking, and weighting, is required for multi-criteria analysis. Finally, an output map representing the land use classifications, population density, connectivity values was produced, and an analysis of the new land use pattern in contrast to the pre-existing land use condition was conducted.

Therefore, quantitative research looks into the numeric factors that affect the research topic. In this regard, data collection methods used include statistical data from previous records regarding the population. The records include those of land use that distinguish specific factors

such accessibility of an area to a transit railway station. The simulations in this study were conducted to address the research issues using the city of Dubai as a case study. To the author's knowledge, no further research on urban growth and LRT implications in Dubai has been done.

3.2.1 Geographic Information System (GIS)

The analysis methods used for the elaboration of the research consisted in that of the synthesis, the research method due to which comparisons were made between the previous works with the same purpose. In the case of maps, the images and information were available in the reference years in the Open Street Map (OSM) within ArcGIS Online, also the images from Google Earth Pro and Landsat 8-OLI sensor were used (Table 4). This tool is used to describe how to represent real world features and events using geospatial data models. It is the most appropriate method to address the research question, which is whether the presence of an LRT has an impact on the development of urban areas in terms of land use and population density. The most often used formats for geospatial data in GIS analysis are raster or vector. These remotely sensed data are frequently referred to as quantitative data since they accurately indicate the quantity of land surface features included within each pixel (Lwin et al., 2012).

Table 4: Data and Sources Used in Analysis

Type	Source	Year	Bands
Open Street Map	www.osm.com	2008 - 2020	RGB
Google Earth Pro	www.google.com/intl/en/earth	2008 - 2020	RGB
Landsat 8-OLI	www.usgs.com	2008 - 2020	NIR-SWIR1-RED

At the level of the analysis, an unsupervised classification was made at the level of green cover, build-up areas, water ways and barren land. This approach was used to extract the overall variation in land use in the case study area, without being able to differentiate between sub-areas of built-up areas such as commercial, residential, and industrial, which is where on-screen classification, digitalization, makes a difference.

The methods used for the analysis in the land-use change:

- Data frame properties > Projected coordinate system > UTM (Universal Transverse Mercator) 40N.
- Attribute Table of layer > Added New field name (Area) > Right clicked on Area and calculate geometry > Area calculated of all polygons in square meters.
- Tools > Analyst Tools > Statistical calculation > Calculated sum of area of polygons.
- Likewise applied to all Land use features.

The data sets were designed in the WGS-84 Universal Tranversal Mercator 40R area coordinate system, thanks to which the areas of each class were calculated using the Calculate Geometry functions in the Attribute Table - ArcMap.

The land use sets were extracted digitizing the images, datasets from which the statistics were extracted.

3.3 Selection of Metro Stations

Three districts areas were purposefully selected. The main criteria for selection are as follows:

i. Jebel Ali is one of the main ports and free zone, located 35 kilometers (22 miles) south of Dubai. Among the infrastructure projects built to support the port is the Dubai Metro, which links the area to the center of the town. Jebel Ali area is the last stop of Red Line of the Dubai Metro contains two stations Energy and Ibn Battuta Metro station. Recently,

Jebel Ali extended Metro line, Route 2020, which connects Jebel Ali station on the Red Line to EXPO 2020 Line through four stations: Jebel Ali (transit station on the Red Line), Gardens, Discovery Gardens, and Al Furjan.

ii. Al-Barsha is one of the city's most recent residential developments. Al-Barsha was selected for the unique the location that bounded by Al Sufouh to the north, Emirates Hills to the west, Al Quoz to the east, and Dubai Sports City, which will benefit in the connectivity analysis part. Also connected to property developments such as the Provident Estate, the Mall of the Emirates, and the Dubai Autodrome.

iii. Business Bay is one of the popular residential and professional hubs know as new CBD. The district covers 5,900 square kilometers and include offices, residential buildings, as well as a road and canal network. In future, it will serve as the regions business capital and freehold city with world-class activities and a high-speed lifestyleIts a CBD in Dubai constructed as mix land use and business cluster along a new extension of Dubai Creek from Ras Al Khor to Sheikh Zayed Road.

3.4 Conceptual Design Matrix

The framework is divided into five matrices, starting with pre-analysis, which includes a broad description of the city's urban form, problem definition. To begin addressing the research challenge, a conceptual design matrix for the principles of sustainable urban form and their associated detailed 'design elements' was developed through a review of the literature review, as shown in table 5. For each scenario, the findings are analyzed using GIS analysis. In pre analysis existing transportation system is evaluated and the problems are identified to set objectives through primary and secondary data.

Table 5: Conceptual Design Matrix for Sustainable Urban Form

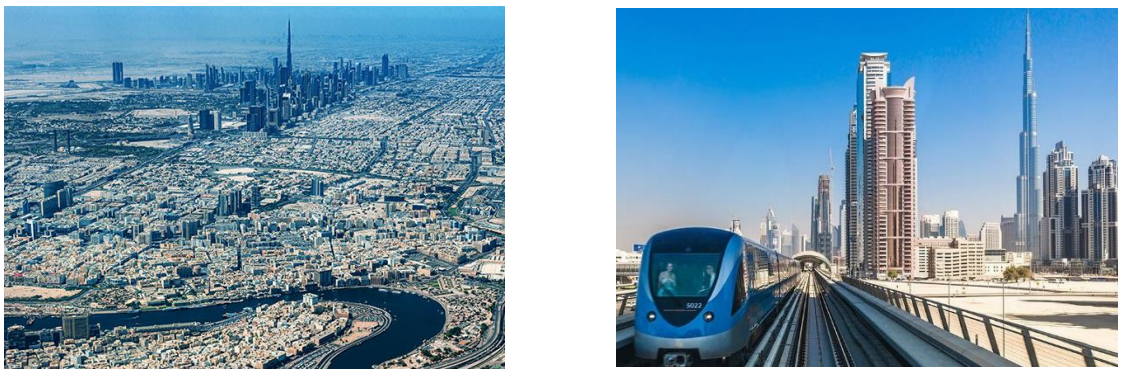
Principal	Design Elements
Density	– The high residential densities in both the current downtown core and the central area of the new Capital District, to establishing the critical mass required for public transportation and dynamic street life. – Gross population density of 50 to 60 persons per square kilometer. – Retail density is scattered throughout the city, providing convenient, transit-accessible services in strategic locations rather than in occasional regional malls.
Transportation	– Availability of public transportation that is reliable, rapid, and comfortable. – Faster parking system by developing a smart parking system that notifies drivers in advance of available parking spaces, hence reducing time and congestion. – Establish a transportation network that connects all facilities in the city center and surrounding neighborhoods. – Routes that are safe, shaded, well-lit, and attractive for pedestrians that connect to transportation hubs, services, and facilities.
Accessibility	– Shared amenities and public transit hubs should be positioned within 500 square meter or walkable distance of residences, respectively. – Cyclists should be able to cycle in and around community facilities, public parks, and services. Connect the rest of the city by bicycle, bus, and foot. – Local services and amenities are centralized around the transportation hub.
Connectivity	– Establish a network that is well connected to public transportation hubs and a pedestrian network. – Enhance the district connectivity to central city facilities by providing walkways through parks, green spaces, and recreational facilities. – Consider an adequate walking distance from the house, employment, or facility to the nearest public bus station.
Mixed Use	– Assure enough access to a variety of services, amenities, and land uses (residential, office, retail, etc.). – 40% to 60% of the surface area should be used for commercial purposes, 30% to 50% for residential purposes, and 10% for public services. – Reduce vehicle trips by multi use of buildings and services close to people's homes and workplaces that are necessary for residents' everyday lives.

Chapter 4: Dubai Case Study

This chapter provides an overview of the Dubai's urban form, the current situation of urban transportation systems, and highlights the LRT system to investigate the main transport problems in Dubai and assess the impact of Dubai Metro on the urban development.

4.1 Overview

Dubai is second largest city in UAE after Abu Dhabi, situated in the Arabian Peninsula's eastern part. Dubai occupies 4,114 km^2 of the UAE's total land area of 83,600 km^2 (Anonymous, 2020). The rapid transformation of Dubai during the last few decades demands greater critical analysis. Three issues motivate this profile. First and foremost, Dubai is a worldwide metropolis and an international commercial center. The city's remarkable development in terms of population growth, geographical expansion, and economic growth is the second concern. The third concern is Dubai's nascent position as a metropolitan area. Dubai has become one of the most contemporary cities in the world, with the world's second tallest twin buildings, the "Emirates Twin Towers," the world's tallest hotel, the "Burj Al-Arab," and the world's tallest tower, the "Burj Khalifa." Figure 16 depicts Dubai's fast change trend as well as the Dubai Metro.



a) Urban Development pattern of Dubai b) Dubai Metro

Figure 16: Urban Transformation pattern of Dubai. Adapted from (Saundalkar, 2021)

Between 2000 and 2004, the yearly pace of construction was 5%, while the number of completed structures rose by 11% each year (Abdelgalil & Bakheet, 2004). It has experienced a significant population growth due to migration from villages and suburbs in seeking better jobs, higher incomes, and a better lifestyle. Urban development and population growth are two key factors that are rapidly straining the city's transportation network. The massive number of visitors in Dubai often burdens the city's transportation system.

4.2 Urban Development of Dubai

Dubai grew out of a small fishing village known as the Creek, which divides the city into two parts: Deira and Bur Dubai (Figure 17). It is a naturally occurring inlet of the Arabian Gulf, where the city's economy was heavily reliant on fishing and pearl diving in the Creek.

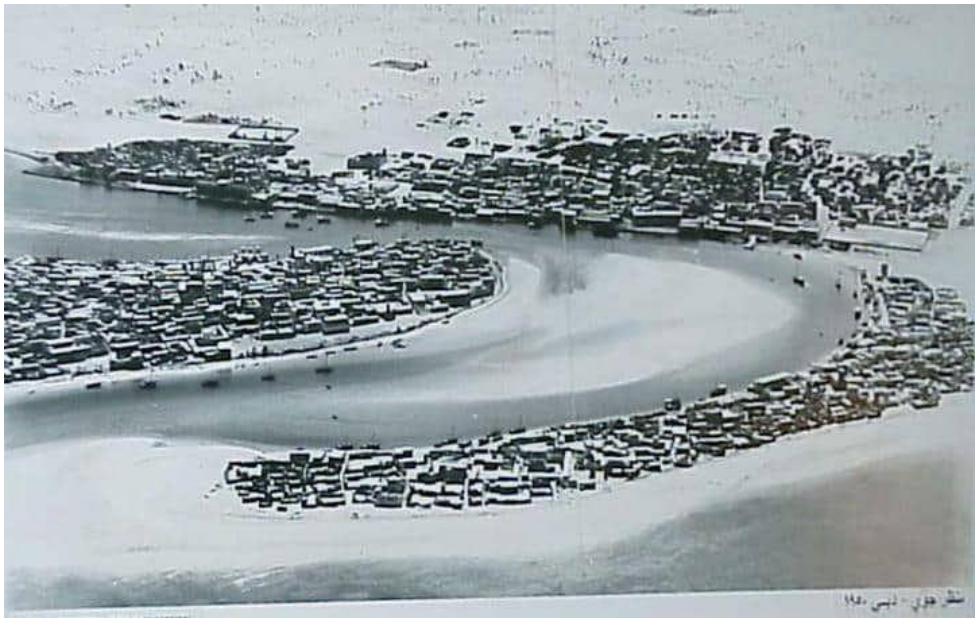


Figure 17: Dubai in 1950s. Adapted from (Mariam, 2013)

To understand the modern history of Dubai as it is establishment in 1833, the transformation phases are summarized below (Pacione, 2005):

From 1900 to 1955:

A low speed of development and low physical expansion due to controlled financial growth and minimal population growth. The maritime transport was the main dominant because of the location of Dubai between the Mediterranean and the Indian Ocean made this a popular place to trade. As the number of passing ships increased, the Creek began to grow. The urban layout of the city was divided into three distinct regions as a consequence of population growth: Deira, the largest and major commercial center, and Bur Dubai and Shindagha to the west separated by a wide stretch of sandy land known as Ghubaiba, which was flooded at high tide. Al Shindagha, the royal dynasty of the previous dwelling, had 250 houses with only Arabian residents at the time. By 1955, the city had shrunk to only 3.2 km^2.

From 1956 to 1970:

Due to poor urban form in Dubai and lacked paved roads, utilities, port facilities, and water, prompting John Harris to developed Dubai master plan. It served as a framework for future development and transformation projects that spatially separated districts for different functions by mixing the spatial functions between the three settlements (Al Shindagah area, Deira merchant class area, and Bur Dubai), as shown in Figure 18. The master plan has incorporated enhanced zoning into land expansion: manufacturing, commerce, residential quarters, health, and education. Envisioned the development of Port Rashid created landmarks such as the World Trade Center.

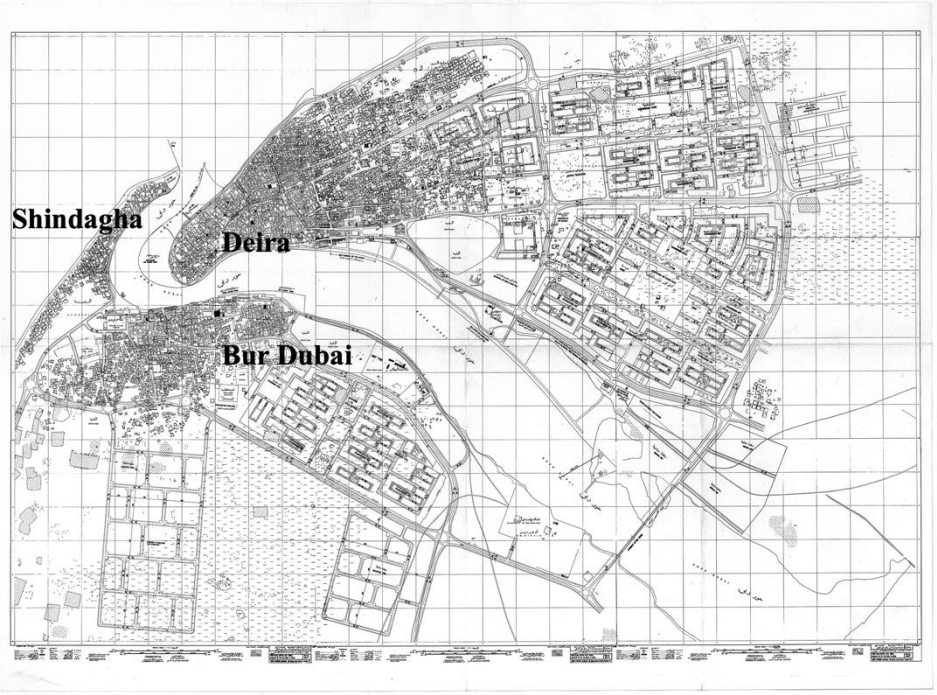


Figure 18: Dubai master plan in 1960. Adapted from (Poulin, 2011)

A period of compressed growth based on the 1960 grand plan, which planned for the creation of a street and road structure, the division of the town into areas for diverse land uses, and the construction of a new town center. These objectives were within reach because of Dubai's pre-oil resources. The master plan's methodology revealed a powerful central regulator over municipal growth. During this time, it was understood that an official institutional framework was required to inform and lead the next phase of urban growth. Dubai Municipality was created in 1957 to administer and manage all public works under the authority of the city council, whose affiliation was primarily reflected by the posts of the top merchants. The housing market system in Dubai, which is clearly from the Western world, also helps to guide the outline of urban growth. Land ownership is founded on two concepts that had been agreed upon by Arab-Islamic cultures. Any portion of land inside a communal settlement that has been inhabited by a homestead for a long time belongs to the resident. The most significant event in Dubai's modern history occurred in 1966, when oil was discovered in a Fateh oil field. It was exported for the first time in 1969, the

emirate's economy started to grow, the currency was developed, and the largest port was established, resulting in the establishment of a strong infrastructure network.

From 1971 to 1980:

A period in which intended peripheral regions are implemented. A new and more determined master plan was developed in 1971, due to rapid urbanization and the accessibility of wealth development, see Figure 19. The development evaluation text included a plan with a road network and land-use designations. The map maintains an emphasis on the city surrounding the creek. Roads that extend beyond the map's borders indicate Dubai's potential growth. The creation of a ring road around the city and an outer street network to the suburbs was part of the concept.

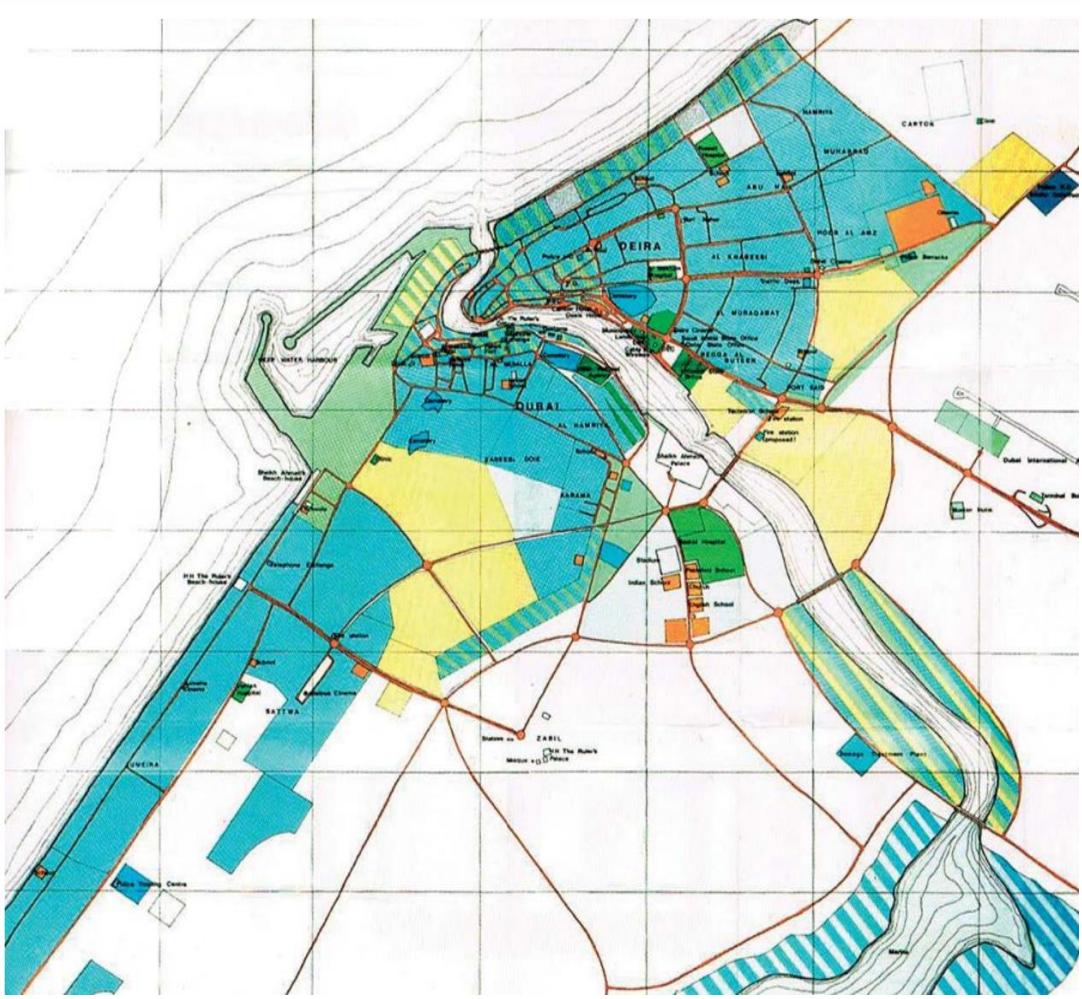


Figure 19: John Harris's 1971 master plan for Dubai. A. Deira district; B. Bur Dubai district Adapted from (Virtudes et al., 2017).

The Shindagha Tunnel, which connects Bur Dubai and Deira below the stream, and the construction of two bridges were also significant transportation expansions (Elsheshtawy, 2019). Therefore, the connecting city districts on double sides of the Creek. The region east of the Creek, near Deira, quickly developed into the town's primary financial and ruling center, the hub for offshore and re-export maritime operations, and the location of the international airport. The international import and cargo port, as well as dry harbours and other important manufacturing sectors, as well as the World Trade Center 's icon, were built on the opposite side of the creek. Jebel Ali Port, which has 67 berths and occupies a land area of 134.68 km^2, has played a key role in Dubai's development into a sophisticated port city and economic hub. Other areas were set aside for health, education, and leisure/recreation expansion to the south of the city (Gabriel, 1987). The Sheikh Zayed Road (SZR) is a modern road in Dubai that acts as the city's major thoroughfare. From the Trade Center Interchange to the emirate of Abu Dhabi's borderline in the district of Jebel Ali, 55 kilometres north, the route travels parallel to the coast. This region, dubbed "New Dubai," was rapidly emerging as the city's new trade and economic hub. Dubai quickly established itself as a hub for re-exporting to nearby ports and local markets. As a result of the influx of traders, the city grew into a regional trading center. Dubai's expansion into non-oil businesses has progressed, with property investment, financial services, and, most importantly, transportation being among them.

From 1990 to Present:

The growth over the past two decades has marked Dubai as a benchmark not just for developed countries but growing economies around the world, particularly as regards infrastructure. In light of both the magnitude and variety of expansion plans as well as the physical extension of the city, this phase is known as rapid urban growth, and it covers 605 km^2 in 2004. The government introduced many elements of prospective economic sectors, including the construction of

Smart Cities/Communities, a better lifestyle toward more friendly surroundings. The ongoing expansion of Dubai's economy has resulted in a notable rise in the diversification of its economy. This in turn necessitated the expansion of Jebel Ali Port's ability to accommodate the region's growing shipping sector. Currently, the yearly urban development proportion is 3.9%, and according to strategic plan, the urban area extended further about 501 km^2 by 2015. The development from the previous century decades to the present day. In the Figure 20, the aerial view of city in 1980, it looks like nothing any development in the territory but later with the passage of time, strategic planning, urban expansion, and population growth with several factors every vacant land has been bitten by the urban area and it is peripheries in 2020. A massive difference can be seen within the last 50 years.

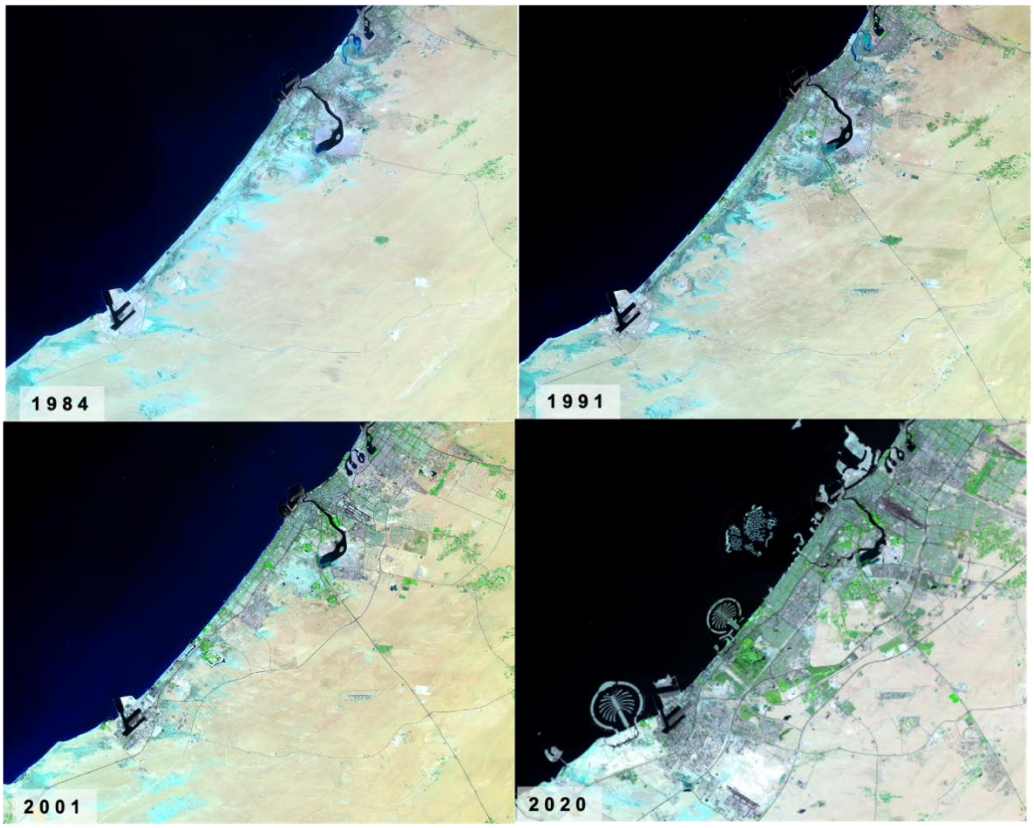


Figure 20: Dubai urban development from 1970 to present day. Adapted from (ESA, 2020)

The city was stabilized in the mid-1990s, and many international trading organizations relocated to Dubai as a result of the city's fast expansion. Dubai was willing to concentrate on the rapid development of essential infrastructure due to the global increase in oil prices. The establishment of the Jebel Ali free zone sparked the creation of other free zone clusters, including Dubai Internet City. Dubai has been known for its skyscraper construction initiatives in this age, notably the Burj Al Arab, the world's tallest self-supporting hotel (Arab, 2016). The Palm Isles, the creation of three artificial islands in the date palm shape (Palm, 2009); The World Islands, a massive artificial archipelago of 300 islands in the shaping the world (Update, 2007); and Burj Khalifa, which is the world's tallest man-made building structure.

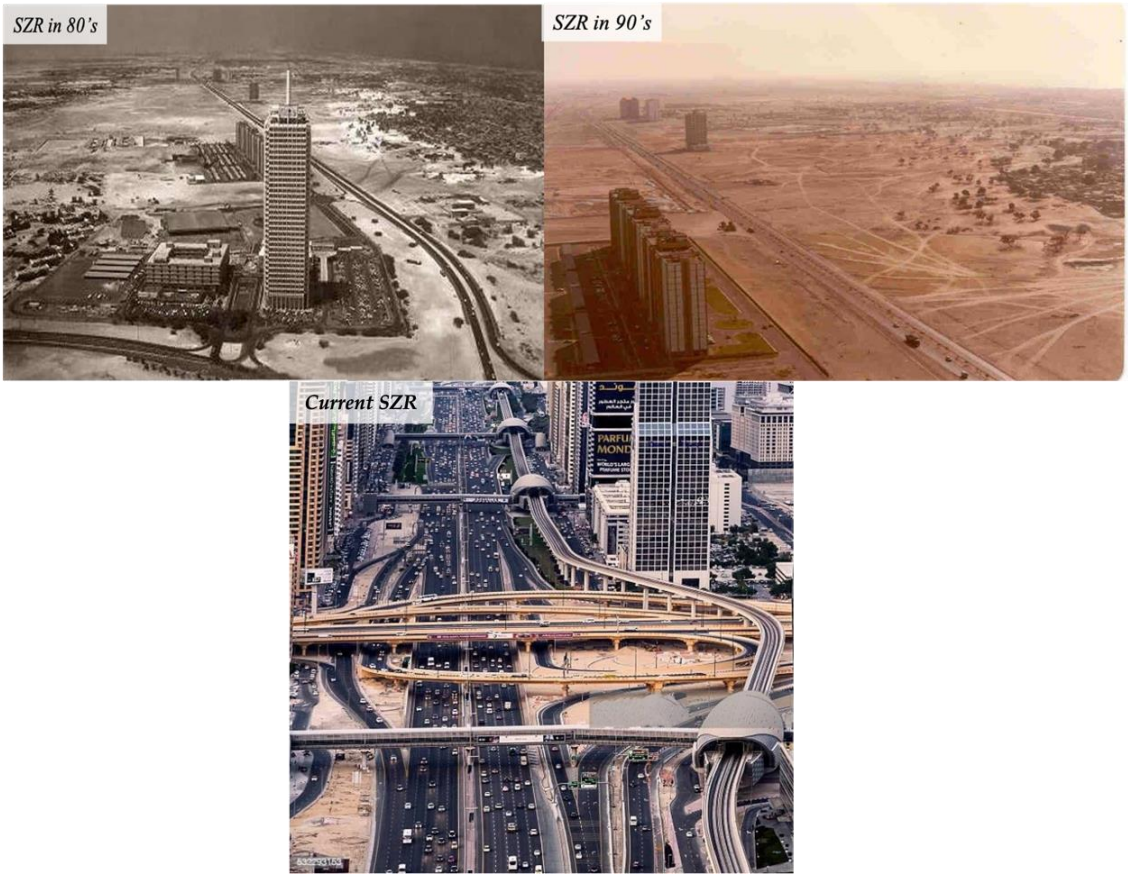


Figure 21: The evolution of Dubai's Sheikh Zayed road transportation system from 1980 to the present. (a) SZR in 80’s, (b) SZR in 90’s, and (c) Current SZR. Adapted from (123RF, 2020)

The evolution of urban transport network in Dubai is reflected on Sheikh Zayed Road (SZR) and represented in Figure 21 in three different decades. Abundant of sandy area around the dwellings and very few developments exist, however, afterwards by the growth of industrialization, business and economy, many countries aimed to move their business to Dubai. With the passage of time growth of buildings and roads construction started and increase about 40% more than in 1980's. After the migration of different ethnic groups and businesses in Dubai territory, more development started, and buildings started to convert in vertical than horizontal growth. Almost 80% of vacant land and Sandy area has been developed into a smart city through the skyscraper buildings and territory become into the smart city, as seen in 2019.

The Different locations generates the demand for transport. The Figure 21 also reflects that transportation has had a direct impact on urban growth and the spatial distribution of opportunities in a variety of forms to cope with urban development. Dubai has risen in prominence as a world-renowned financial hub for foreign investment. This offers an increasing number of opportunities for people to obtain employment from several different countries.

4.3 Urban Planning Pattern of Dubai

Since the year 2000, around 15% of Dubai's entire area was developed, with a total size of 1.6 million square meters (672 km^2). Geographically, Dubai is divided into 221 communities, each of which covers an area of almost 5 km^2. Within a community, social-economic characteristics are comparable, but population distribution varies amongst communities. These borders are also utilized for administrative reasons, such as publishing yearly demographic and socioeconomic reports released by the Dubai Statistics Center, the Municipality of Dubai, and other administrative officials. The urban area in Dubai in the year 2000 and the owed land for large developments in the year 2010 are represented by socio-demographic variables within a neighborhood. Only approximately 8% of the allotted area had been developed as of 2010 (Ibrahim &

Younes, 2011). Large-scale developments include the Palm Jumeirah, Dubai Downtown, Dubai Marina, Dubai Land, and Dubai International City. Several of these endeavors are on a city-scale, such as Dubai Land, which has a potential population of over 1.7 million people (Mohammad et al., 2014). Figure 22 depicts the land use distribution in Dubai, demonstrating that the majority of regions are mixed-use projects.

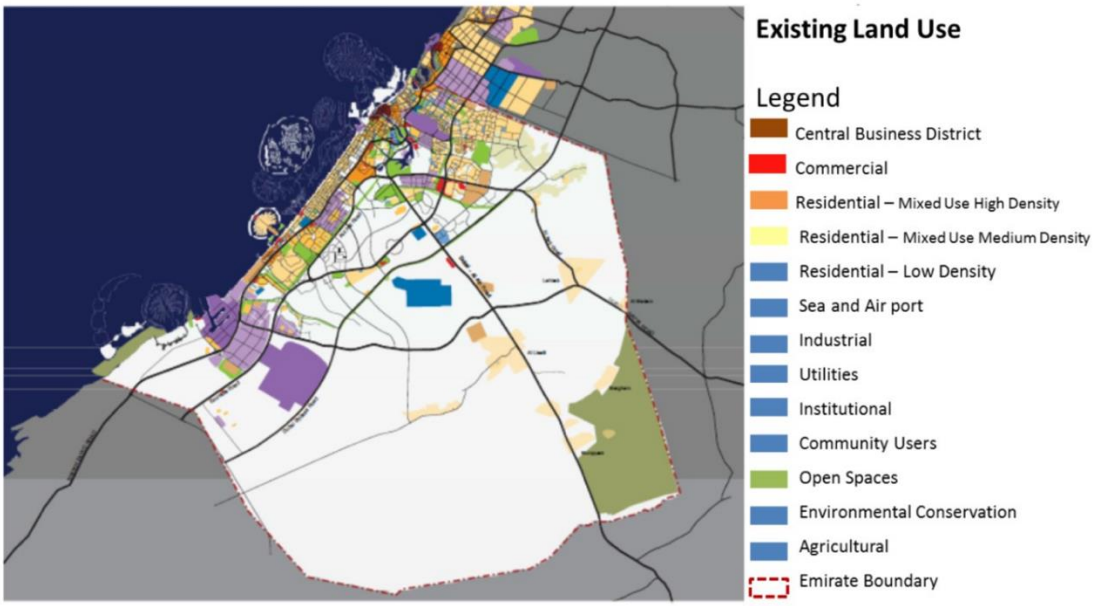


Figure 22: Urban area variation in Dubai. Adapted from (Mohammad et al., 2014).

Dubai's growth has sparked an expansion in the neighbouring Emirates of Abu Dhabi, Sharjah, and Ajman, notably in term of housing and transportation system (Municipality, 2010). Dubai's daytime population increased to 2.7 million in 2011. With two main entry points (east and west), passengers from the emirate's east side account for 22% of total travels, while travelers from the west account for just 2.8%.

4.4 Population Growth

It was stated that round the year 1970 the urban growth in the city gets into a new direction. At the same time of urban advancement, the demographic growth also started to accelerate. In

1968 the inhabitants were around 59,000. In 1985, it was close to 370,000 people (Pacione, 2005). From the end of 2001 to the end of 2007, population growth has been rising (with a huge value for the end of 2005). In 2001, the population was estimated to be approximately 910 000 people. According to a 2005 census report, Dubai was the second biggest emirate after Abu Dhabi, with a population of 1.3 million people, accounting for around 32% of the UAE population (Al Awad, 2008). By the end of 2007, it had grown to around 1.5 million people, and by the end of 2010, it was expected to reach 1.9 million people (Statisticts, 2007). However, the research focuses more on the population change from 2008 to 2020. Figure 23 illustrates the difference of population between the 2008 and 2020.

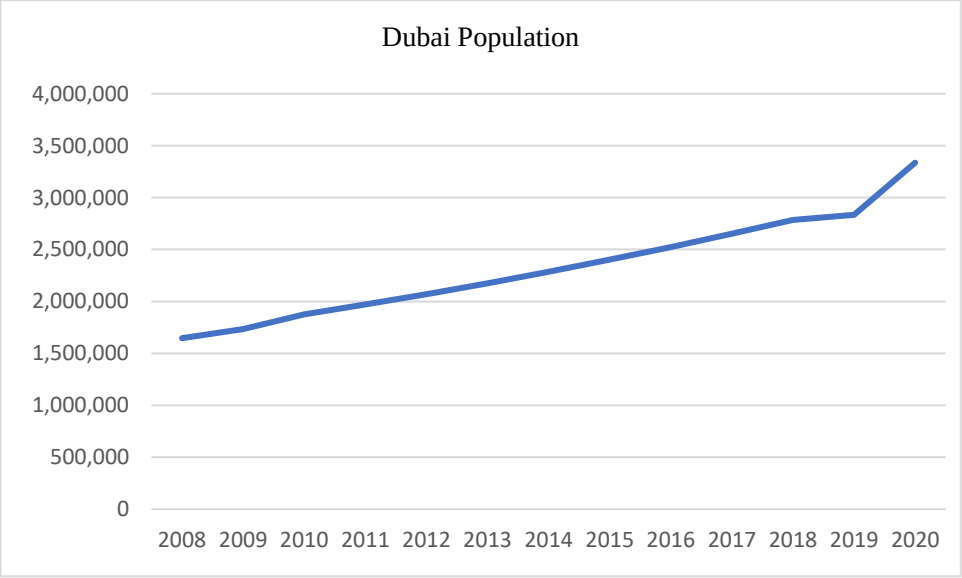


Figure 23: Population growth from 2008-2020. Adapted from (Dubai Statistics Center, 2021).

In early 2000's, there were 53% of the population born in a foreign nation, and the emirate's demographic characteristics show that the majority of the population is male and between the ages of 20 and 40 (Pacione, 2005). After that the population has grown at the fastest rate, reaching 1.6 million in 2008. In addition, Dubai's population growth rate was 8.25% in 2008, due to natural population growth and considerable net inward migration. The net migration, defined

as inward migration less outward migration, has been the primary driver of the population growth rate in Dubai for 2008 (Al Awad, 2008). The second explanation is that Dubai's financial success has increased demand for labor of a sort and quantity that was not available in the past, necessitating the hiring of foreign workers to meet this need.

By end of 2020, Dubai's population reached 3.4 million, an increase of 55,300 from the previous year and a growth rate of 1.63% according to the Dubai Statistics Center's demographic report. Despite the attained population growth rate, the growth rate decreased as a result of the processes and conditions surrounding the Covid-19 epidemic, which swept across the world. Population growth within the UAE, and particularly in Dubai, is strongly influenced by foreign worker recruiting, in addition to natural increase.

4.5 Public Transport Systems in Dubai

Since the year 2000, Dubai's tremendous expansion has dramatically increased the need for transportation. As a result, Dubai's regulatory authorities built the Roads and Transport Authority (RTA) in November 2005 and transferred transportation responsibilities from related agencies under Dubai Municipality and Dubai Police to RTA. As a result, they are responsible for transportation services and infrastructure (such as roads, railways, and buses) both within Dubai and to neighboring emirates. In the Middle East Dubai has become the most congested city. The authorities have spent large amount on Dubai infrastructure and roads, though this has not kept step with the exceeds in the number of vehicles. This, coupled with the persuaded road traffic phenomenon, has led to growing problems of congestion (BMC, 2016).

4.5.1 Dubai Bus

Bus transportation is the most often used mode of road transportation in Dubai. Whether it's for their procuring everyday requirements or other purposes in the morning or getting from

work in the evening time. According to a study almost 10 million individuals utilize road transport every year (the local bus transportation system throughout the country is controlled by the RTA (Edensor & Jayne**,** 2010). This is an administrative form that mainly ensure that local bus transport is most effective enough to fulfil the needs of the people of Dubai. Presently there are more than 190 routes covered by buses of this corporation, which carry about 30 million people a week. Most of the buses are comprising on 51-seaters, with more than 1600 bus stops. With a network of 1,518 buses and connections to Metro stations, the Public Transportation Agency provides local bus services. There are intercity lines, 62 lines, and eight rapid lines to convey travelers to neighboring emirate states. The entire network connects 82% of Dubai's metropolitan regions and transports about 369,248 people daily.

4.5.2 Dubai Taxi

Taxis are the primary mode of passenger transportation. Taxis are one of the most frequently used types of passenger transportation in many cities worldwide. Taxis are essential to a city's image. It is an integral part of the transportation system in most developed and rising cities. The taxi's function is more like that of a balanced mobility alternative than it is to that of a secondary mode of travel in compared to public transit. Many local and foreign residents, as well as tourists and visitors, use cabs in Dubai's growing city. In 2016, the annual number of taxi rides reached 104 million, however, the fleet is now at 9613 and is expected to reach about 12,765 in 2020. Taking a cab in Dubai is regarded to be a pleasurable, relaxing, convenient, and reasonably priced experience. The RTA is the Dubai government authority in charge of the taxi industry's growth and administration. Taxis do about 200000 excursions each day on average, transporting over 400,000 people. Dubai Taxi offers a variety of service options, including women's taxis, which were among the first in the world to accommodate gender-specific needs, as well as a taxi on demand. Countless places throughout the world declare a taxi indication as to the average

number of taxis per 1000 people. This metric is known as the Taxi Availability Index (TAI). According to a survey in European cities, the regular availability index across 23 cities in the globe is comparable to or more than three taxis per 1000 inhabitants. It's also worth noting that fast-growing Asian cities like Singapore have a high taxi-to-population ratio of 5.2 taxis per 1000 people, but Dubai has 3.71 taxis per 1000 people and is aiming for a taxi availability index of 4.09 taxis per 1000 people in the future (Darbéra, 2010).

4.5.3 Water-Transit System

According to Hvidt, water transportation has continued one of the most appreciated means of transport in Dubai. Since of the increasing relevance of Dubai as a foremost business center in this region, the need for people to transfer from other states to Dubai has been on the rise (Hvidt, 2009). However, the RTA has three kinds of local marine transportation services in Dubai Creak: Abra (Small boats), water bus and water taxi. These marine passage modes share some features, but differ mainly in the comfort level of service, fare, and loading or volume consumption. Abras are usually utilized to ferry people or belongings across waters, such as Deira to Bur Dubai. Though the government has credited ferries to help in movement of huge cargo, the small boats are remained quite prevalent. Figure 24, showing the primary routes for the Dubai Abra that crossing the Creek. Route 1: Connects Deira Old Souk to Al Ghubaiba Abra stations. Route 2: From Dubai Old Souk Marine Station to Al-Sabkha Station and vice versa.

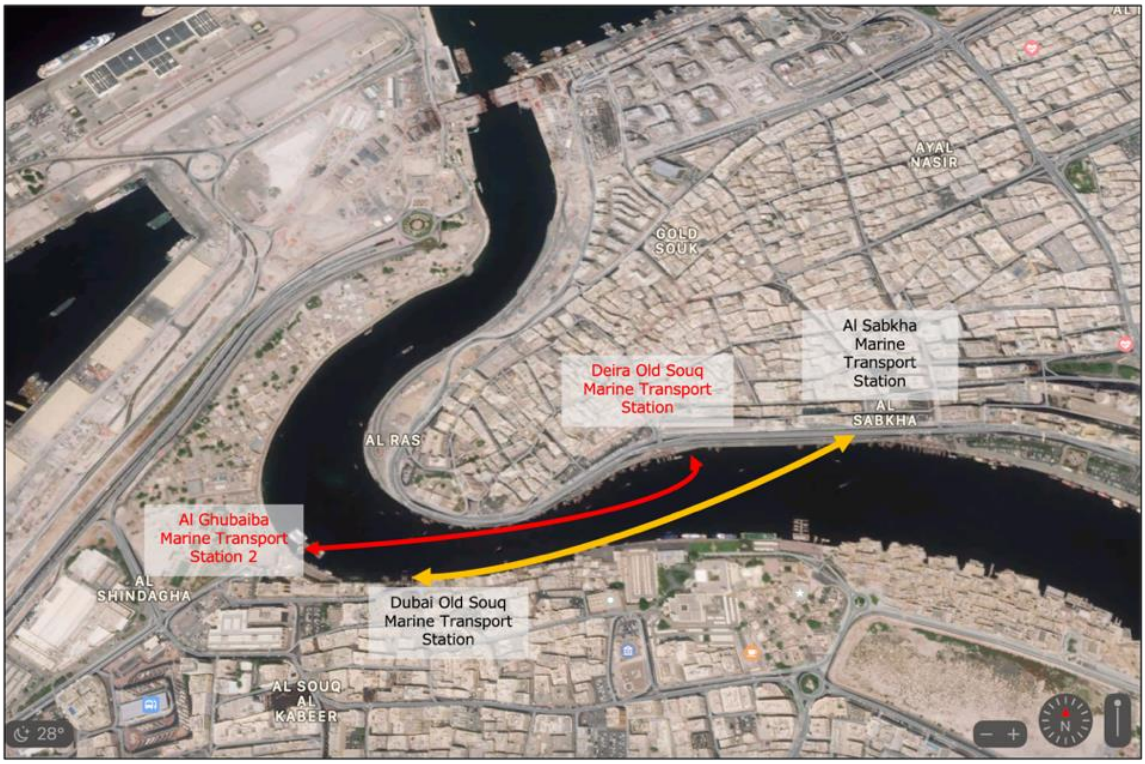


Figure 24: The primary crossing points for the Dubai Abra. Adapted from (Fridell, 2010)

The Dubai Water Bus System is an additional method of transport that is emerging admiration in the City of Dubai. The research by Fridell notes that the Water Bus System was a thoughtful effort to rage traditional modes of transport with some of the advanced means of transport. The water buses were planned to look like the traditional boats, but it has contemporary features that make it greater to the old-style boats. Unlike the outdated boats, they are motorized by engines that have improved the speed. It is constructed like a bus to guarantee that travelers are not affected by direct sunlight, or rainfall, just in case there is a downpour. Like other public transport, the water buses have explicit routes that they take to transport people from Dubai to other states, and back to Dubai. Most of the up-to-date water buses are air conditioned in order to enhance experience of the passengers through the trip from one location to another (Fridell, 2010). Dubai's water bus service connects Al Jaddaf with the Dubai Canal Marine Transport Station.

Figure 25: The primary crossing points for the Dubai water buses. Adapted from (RTA, 2020)

The water bus operates along a 15-minute route around Dubai Creek, stopping at up to eight stations, as illustrated in Figure 25. The Dubai Canal is bordered by business activities and residential areas with a major attraction as the canal sidewalk features a shopping center, hotels, luxury homes, as well as walkways and cycle routes. Their potentially rich riverine habitats and amenity features contribute considerably to the supply of vital ecosystem services, as well as creating a one-of-a-kind living environment. Dubai Marina Mall - Marina Promenade, Dubai Marina Walk - Marina Terrace, and Dubai Marina Walk - Dubai Marina Mall are just a few of the 'Canal Foot Bridges' that connects the urban settlement to major crossing locations. The street design dominated by a perpendicular to the Creek axis, which allows for the most flexibility in the street network's pattern development such as SZR.

4.5.4 Dubai Metro

As is the case with all of the world's modern cities, Dubai's transportation demands are developing rapidly in response to increased demand caused by an upward trend in international company relocations, an increase in commercial activity, an increase in tourism, and an increasing population. Moreover, the main highway Sheik Zayed Road cannot meet the increasing needs due to the rapid urban expansion from Dubai Creek to Jebel Ali. As part of it is urbanisation drive, vision, and environmental concerns, and in order to close the gap and create connected communities while optimizing sustainability initiatives and their environmental and economic advantages to residents. The Dubai Government conducted studies to determine the most efficient and cost-effective solution to traffic congestion and pollution; the studies suggested the establishment and development of a light rail system for Dubai City. The world's longest automated driverless train system was built in less than four years with the inauguration of the Gulf region's first Metro (Al Masar, 2019). An LRT system offers a large carrying capacity and is environmentally friendly spanning at 75 kilometers (Mohan et al., 2012). It uses about half as much energy per passenger kilometer as a road-based system.

The Dubai Metro system has various features that contribute to being fast, dependable, safe, and convenient for passengers. The platform screen doors, derailment containment along the mainline of the Metro, continuous fencing, and an Intruder Alarm System to keep people off the guideway, and track maintenance vehicles are among them. Concrete barriers and a mechanism for detecting wayside obstructions protect the tracks.

Dubai's significant investment in public transportation infrastructure has proven to be a success. Since Dubai Metro system is widely recognized as one of the most advanced in the Gulf region. The project is a major shifting point in Dubai's history, as the newly established transport

system began to change the residents' lifestyle and mobility habits. With A well-functioning transportation system such as modern taxi fleets, evergreen water taxis, bus service that connects Dubai's key commercial districts and employment clusters was important in the Dubai Metro's success.

Dubai Metro has included all modern Metro rail trends, and as a result, the Dubai Metro system is being built in three phases, as following:

Phase 1

The phase one of the Metro has 70 km of lines and 47 major Metro stations with 9 underground stations. It consists of both two Metro lines namely the Red Line and Green Line. Table 6 summarizes the two lines' vital statistics, including the length and number of stations, depots, and parking lots. The project's Red Line began revenue service in September 2009, while the Green Line began in September 2011. The Red Line serves 29 of stations with a track length of 67 km, while the Green Line serves 18 stations over a track length of 23 km. The Metro serves 32,000 passengers each hour, or around 10% of Dubai's population (WHO, 2020). The rising number of passengers corresponded to Dubai's growing population and business.

Table 6: Summary of the Phase 1 Lines Adapted from (Al Masar, 2019)

Lines	Sections	Construction Year	Average Speed	Stations	Length (KM)	Underground Length (Km)	Underground Stations	Depots
Red line	Rashidiya – Jebel Ali	2009	60 km/hr	29	67	5	4	2
Green line	Al Qusais- Creek	2011	38 Km/hr	18	22.5	10	6	1
Total				47	89.5	15	10	3

The Red Line runs the length of the city, from Jebel Ali to the Sharjah-Al Rashidiya boundary. The Red Line passing majority of tourist attractive and iconic Dubai magnets such as mal of the emirates, Burj Khalifa, the Dubai mall etc. The Metro enhances this use's and magnet's

appeal by providing direct transportation access with legible reasons and an attractive appearance for pedestrians.

The Green Line starts in the old Dubai area. It is passing major archaeological and historical sites and monuments such as the Dubai Museum. The spice souk, gold souk etc. This attracts more tourists to these areas with more accessible places. Certain Metro stations are built to seem like traditional Emirati homes, including structural and architectural elements that match the surrounding area's architecture. Furthermore, the Red Line's catchment area includes new and current service centers, newly constructed mixed-use property, at least four large retail malls, and two of Dubai International Airport's busiest stations. The majority of the Green Line's 18 stops, on the other hand, are located in the historic CBD region, which stretches along both sides of Dubai Creek.

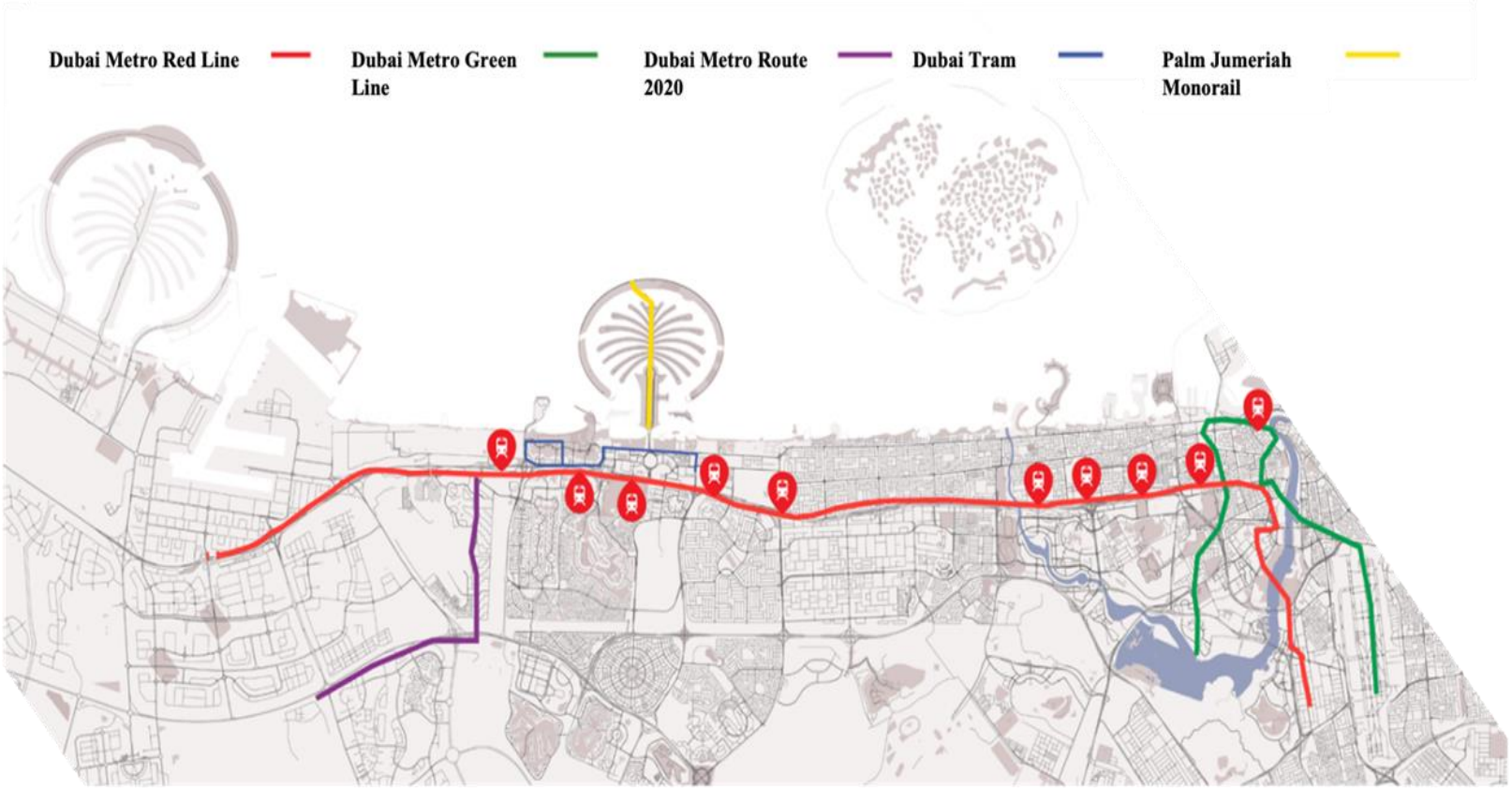


Figure 26: Metro network and tramways in Dubai. Adapted from (Dubai Rail Network, 2020).

Dubai Tram is considered the first tramway design outside of Europe to be fueled by a ground-based electric supply system directly adjacent to the track, eliminating the need for catenary cables. It is also the world's first tramway plan to include Screen Doors in passenger stations and platforms that are deeply equipped with the tram's doors opening and closing mechanism. Ensuring maximum eligibility, complete safety, and security for passengers while also protecting the air-conditioning quality inside both stations and carriages from external environmental conditions.

The Dubai Tram was established in 2014 in Al Sufouh, and the Al Sufouh transportation system is the principal tram network in the gulf region. The Dubai tram, depicted in Figure 26, traverses 14.5 kilometers between Dubai Marina and the Palm Jumeirah and Al Sufouh. It is the Gulf region's first contemporary tram application and is being developed in two phases. The tram is 44 meters long and has a carrying capacity of 408 passengers: with 11 stations as stops (including many landmarks). It considers as a loop that runs around Dubai Marina and connects to the Dubai Metro and the Palm Monorail. Footbridges were constructed to connect these disparate modes of travel, ensuring pedestrian safety, connecting commercial and residential zones, and reducing run-over incidents.

Phase 2

The Metro second phase was primarily to connect communities to the EXPO 2020 location. Seven additional stations, including one that links to the Red Line, one at the EXPO site, three elevated stations, and two subterranean stations, have been constructed:

- Route 2020 is 15 kilometers long (11.8 km viaduct, and 3.2 km underground) starting at Nakheel Harbour's Tower Station.
- Fifty additional trains, 15 of which will be used on the EXPO 2020 line and the remaining 35 to improve the overall operation of the Dubai Metro.

- The capacity of Route 2020 in both directions is expected to reach 46,000 people per hour (23,000 riders per hour per direction.
- Three Main Power Distribution Stations (MPS) and one Traction Power Supply Station are being built (TPS).
- Jebal Ali Deport expansion (maintenance and storage) to handle additional train stock and accommodate the needs of new developments.

Shown in Figure 27, it serves densely populated districts such as The Gardens, Discovery Gardens, Al Furjan, Jumeirah Golf Estates, and the Dubai Investment Park, which together have a population of more than 270,000.

Figure 27: Dubai Metro's 2020 extension. Adapted from (RTA, 2021)

Phase 3

While the Dubai Metro's two main lines are now fully operational, the city continues to seek out new transportation improvements and development of Metro. The future phase of the Dubai Metro is divided into three phases: 2020, 2025, and 2030, with 2020 having already been finished. RTA By 2030, there will be six major lines: red, green, purple, blue, pink, and gold. By 2025, the system is expected to have 58 new Metro stations and an additional 91 kilometers. Expanding it further, by 2030, it is planned to open 69 new Metro stations and add 221 kilometers of rail to the system. Eventually, by 2030 there will be having overall 421 km rail length of Metro and 197 Metro stations around the Dubai Metropolitan area, as shown in Figure 28. According to the plan, all Metro lines would converge at meydan, which is also likely to have a station for Etihad Rail. The purple and gold lines are scheduled to launch in 2025, while the blue and pink lines are scheduled to open in 2030, further data is provided in Appendix C.

Figure 28: The future phase of the Dubai Metro is divided into three phases: 2020, 2025, and 2030". Adapted from (RTA, 2020)

4.5.5 Dubai Metro as Sustainable LRT

The LRT technology is used by Dubai Metro because it allows for more flexibility in attaining sharper bends and steeper slopes. In addition, the LRT system is easy to operate within the city, making it particularly practical for a tiny Metropolis like Dubai (Narayanaswami, 2017). The train systems of the Metro network include the world's biggest online protocol camera infrastructure, which is supported by a comprehensive and completely integrated network-wide operation control system that integrates communications and facilitates advanced operational management, as well as some of the most advanced maintenance systems available (Botelle et al., 2012). The Dubai Metro is an electric passenger train with a high capacity, frequency, and grade separation from other traffic in a vast urban region. This is also known as the best and sustainable transport system which have an underground, subway, elevated railway system in Dubai urban area (Mushtaha et al., 2019). This Metro system also includes urban guided transportation options that function on their right of way and are separate from the road, train, passenger, and pedestrian movements. It was designed to operate at surface level and above Metro stations with physically separated access to it. This strategy makes the Dubai Metro more efficient and effective in a sustainable manner (Mushtaha et al., 2019).

The construction of Dubai's Metro system played important role in ensuring the city's sustainability in the following ways:

i. Saving Travel Time and Self-regulating System

Previously, the travel from Al Rashidiya to Jebel Ali took approximately 140–170 minutes. However, it now takes around 55–75 minutes due to the construction of the Red Line connecting these critical nodes. Also, it connects to the 29-station, almost 53-kilometer-long southwest-to-northeast line that extends from Al Rashidiya to Jebel Ali. Moreover, before 2011 travelling from Etisalat

to the Creek take around 70 – 100 minutes and after the construction of the Green Line which connecting Etisalat to the Creek Metro stations only takes around 39–40 minutes (Ahmed, 2021). This line contains 19-station with more than 23-km of distance runs from the Escalate to Creek Metro stations (Al Kaabi, 2014). An intelligent system guarantees a high level of safety due to it is self-regulating system. Where the software system of the Vehicle Control Center (VCC) continuously analyzes data and adjusts automatically in the event of a breakdown, a stuck door, or other such crises. It communicates with the Vehicle Onboard Controller, a computer that is included into each train to guarantee it is operation runs smoothly.

ii. Expanding Transit Capacity and Improving Service Quality

The number of passengers using public transportation (Metro, Tram, Buses, Marine, and Shared Mobility) in Dubai has increased considerably over the last decade, from 6,909,438 in 2009 to 236,044,210 in 2020 and highest rate goes to Dubai Metro, show in Figure 29 (Dubai Statistics Center, 2020). The tram was established in 2014 therefore there is no data before the 2014 and the shared mobility. Due to the tram establishment in 2014, there is no data prior to that year, and shared mobility has no records prior to 2017. The RTA bus is part of the Metro system, which includes feeders that interconnect the city's major Metro routes to the rest of the city (Keilo et al., 2012). RTA also offers discounts to passengers who travel by bus immediately after exiting the Metro to reach areas of the city that are not serviced by the Metro. This encourages individuals to choose public transportation rather of driving their own car, which helps to alleviate traffic and environmental issues.

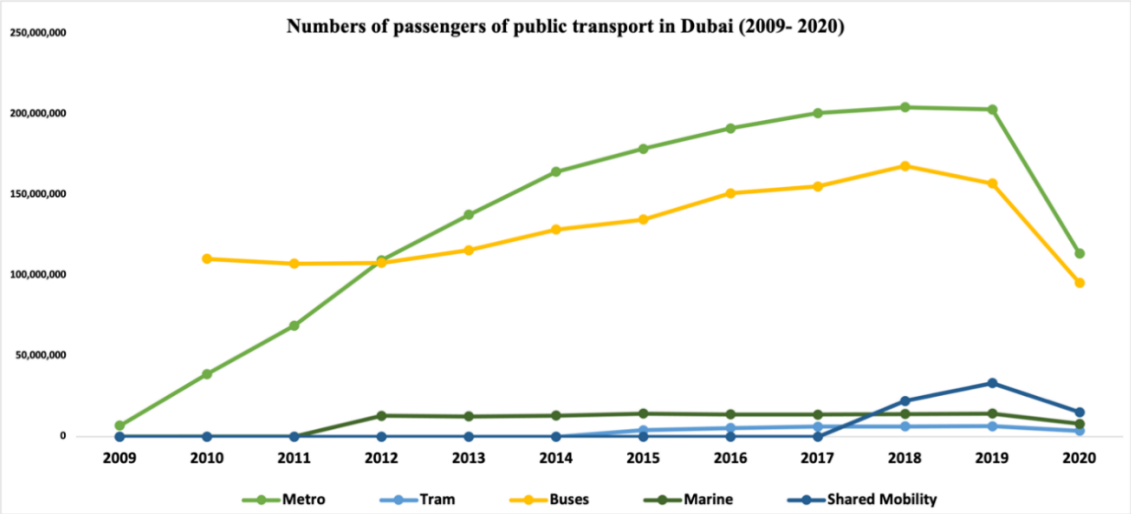


Figure 29: Public transportation passengers from 2008-2020. Adapted from (Dubai Statistics Center, 2020)

Furthermore, the punctuality and time management of the driverless Metro reduces a lot of human error from the network. There are a total of 79 trains available for Metro service. The Red Line has a capacity of 11,675 passengers in each route during peak hours, with 51 trains in service (Abdalla, 2011). It operates approximately 79 trains with a design capacity of 25,720 passengers per hour, which would necessitate the use of 106 trains. Additionally, the Green Line features 16 trains with a design capacity of 6,396 passengers per hour (Government of Dubai, 2019). This demonstrates the dramatic advances that have improved the transportation system's reliability. Additionally, by increasing public transit use in Dubai, the RTA contributes to the city's carbon reduction efforts. In 2018, 642,000 tonnes of CO_2 were avoided by using public transit instead of driving a car (Roads and Transport Authority, 2020).

That is, the passengers saved money by taking public transit rather than driving. Additionally, this method of transportation has the potential to provide significant environmental benefits. If the

journey is 20 miles round trip, switching to public transit may save $6,500 per year in carbon emissions (C2ES, 2017). Dubai's RTA announced that the Dubai Metro played a positive and methodical strategic role in increasing public transportation use from 7% of total transportation in 2005 to 30% in 2020 (Government of Dubai, 2020).

However, in 2020, because of the pandemic's emergence, passenger demand for public transportation services fell precipitously. Additionally, social distancing efforts have resulted in the imposition of capacity limitations on public transportation vehicles because of the pandemic. The government has established a new Master Plan to aid the city's attempts to alleviate the effects of the COVID-19 outbreak, speed its growth in the economy, and lay the groundwork for a bright new post-pandemic future.

iii. Reducing Traffic Congestion and Stimulating the Dubai Economy

Eliminating daily commuting journeys from Dubai's roads. As the statistics in Chapter 1 Section 1.2 demonstrate, car accidents have decreased as more people begin to travel by Metro. Consequently, there are fewer automobiles and buses on Dubai's roadways, a higher average speed of traffic, lower fuel costs, and fewer traffic accidents. According to the RTA, the Dubai Metro is not only an effective way to minimize traffic in an urban area; also serves to improve public quality of life and travel safety by ensuring the highest degree of comfort and security feasible for all passengers, able-bodied and disabled. Increase transportation convenience is the major objective of the development. It’s also enhanced the amount of tourism and business visitors, a population that is critical to Dubai's economic success, as well as revenues generated by advertising and station naming (Corporate branding). Additionally, the Dubai Metro not only earns money, but it also supports the community's economic growth by offering low-cost transportation to all Dubai residents. Since the start of the Dubai

Metro, residents daily commuting costs have dropped dramatically (Kamarudeen et al., 2018). Dubai Metro takes social role by encouraging cross-cultural communication through a variety of programs and events. It provides many job possibilities as well as a safe and enjoyable working environment for it is employees. Under the umbrella of RTA, Dubai Metro has participated in several local, international, educational, social, and environmental Corporate Societal Responsibility (CSR) projects for social welfare (Bobley, 2016). It offers transportation coverage and connects all the city's essential areas and plans and studies are underway to expand the network into the suburbs via future phases. On a regional scale, Dubai Metro has been instrumental in encouraging neighboring countries to invest in rail transit projects. The lessons learned from the project's effective implementation will undoubtedly result in further regional success stories.

iv. Energy Consumption and Energy Surveillance

According to RTA, the electric power has been saved via the structural design and architectural design of the Metro station and public spaces allowing natural light into the stations and spaces.

Similarly, Dubai Metro conserves fuel by recycling 80% of the water used to clean trains, turning off escalators during off-peak hours, and harnessing natural light in all Metro stations. Moreover, the using of robots to clean the Dubai Metro stations is innovative. The robot is extremely effective at conserving water while cleaning and giving an excellent level of sterilization. It may be pre-programmed to clean floors automatically, without the need for human interaction.

Computer controls are used to monitor energy usage using a Supervisory Control and Data Acquisition (SCADA) system. The data is constantly checked. Maximum Power Demands and Power Consumption the Power Distribution System is built on the foundation of load analysis and voltage

drop calculations, which are used to calculate facility power (non-traction), rail system power (traction), and total power (Al Ali, 2015).

To save energy, the authority also employs optimal power control measures, such as regenerative braking power combined with automated train control. Moreover, the air condition provision in Metro stations is special. They are using district cooling technology for air condition, and it also been major energy saving.

The best practice of Dubai Metro is using regenerative power. The regenerative power is fed back by means of electric inverter in every time when train brakes and lead to re-use already existing energy for another consumption. This method has resulted in a more sustainable and reversible energy usage pattern in the Dubai Metro. As a result, it saves up to 25% to 30% of the energy that the train system would normally consume (Ramadan, 2010).

4.6 Conclusion

Dubai Metro is the city's first rail transit system, consisting of the red and green lines. Dubai was originally comprised of two smaller districts, Deira and Bur Dubai, but has since expanded to a total size of 4,114 km^2. The population has risen significantly over time as a result of migration from villages and suburbs in search of better work, higher salaries, and a better lifestyle. Urbanization and population increase are two major elements affecting the city's transportation system. The ongoing expansion of Dubai's economy has resulted in a noticeable increase in economic diversification. As a result, the government has invested in new infrastructure to alleviate demand on existing systems and a shift toward more sustainable environments. Due to the availability of a favourable combination of contemporary taxi fleets, water taxis, bus service, and, eventually, the LRT or Metro system that connects key commercial areas and activity centers, Dubai's public transportation system is widely

considered as one of the most sophisticated on the Arabian Peninsula. The Dubai Metro is a sustainable form of transport because it provides an effective alternative method of transport that alleviates congestion, reduces travel time for passengers, reduces air pollution, consequently improving environmental quality, and improves mobility within the city. The RTA has made energy-saving a priority in all of it is Transportation projects, notably the Dubai Metro. To save energy, the RTA employs optimal power control techniques, such as regenerative braking power combined with automated train control. At Metro stations, high-efficiency electromechanical equipment and fully integrated energy control systems are being installed. Air conditioning systems at Metro stations and depots are also using district cooling technology, which is more energy efficient. The implementation of these modifications has aided the RT in a favourable way. In conclusion, the Dubai Metro will continue to develop because of demand and innovation. While the Metro was constructed to alleviate the city's growing traffic congestion, it has also aided Dubai's economic expansion by facilitating tourist and commercial transportation. This demonstrates Dubai's continuous determination and commitment to be an international transportation hub and financial hub for the Middle East.

Chapter 5: Results and Discussions

Nowadays, it is very well known that accessibility is the most important factor of decision, influence, and concretization of human activity in a certain space (inside a large urban center, at it is edge and even in neighboring locations).

The relationship between public transport and human activities is increasing the development and the presence today, being a topic of interest for each of the inhabitants of a space, which is accelerated by the growing interest of people in managing their own time.

The accessibility of a space relatively deeply influences the attractiveness of a location (Raguz, 2010). Both at the level of society from the perspective of people and at the level of potential investors in commercial, hotel and recreational infrastructure. Thus, the lower the accessibility of the space, the denser the population, economic and recreational activities, industrial activities, and other important activities will be reduced, diminished and with a small contribution to the local economy.

This chapter is divided in two sections, the findings and discussion regarding the effect of the Metro on population growth, land use, and connectivity in three distinct areas of Dubai GIS analysis. The three stations are Jebel Ali, Al-Barsha, and Business Bay. Each Metro station and it is surrounding area within a one-kilometer radius. Satellite images of the three areas were collected, and then each feature on the map was digitized using ArcMap.

5.1 Dubai Urban Form

Dubai has witnessed a very rapid change in urban growth. To achieve the aim of the study, the author has studied and developed the urban distribution patterns of Dubai before and after the construction of the Dubai Metro; from a model built within a GIS analysis. To measure Dubai's urbanization, an analysis called Normalized difference built up index (NDBI) was conducted. Satellite

photos were required for this approach with the USGS provided the data (Earth Explorer). The 2008 analysis used Landsat 7 data, whereas the 2020 analysis used Landsat 8 data. Since Landsat 7 data covers 1999–2013 and Landsat 8 data covers 2013–2021. As a result, data were gathered according to their years of availability.

The main aim of developing these patterns was to study the influence of the Dubai Metro on this distribution pattern. However, the study focusses only on the role of LRT on the urban development in general and on the urban land use.

The Figures 30 and 31 illustrate the changes in urban pattern between 2008 (before the construction of the Dubai Metro) and 2020 (after the completion of the second phase of the Dubai Metro). Areas in red color illustrate the build-up infrastructure, including road network, buildings, parks and other constructed features, and the light-yellow color shows the non-build-up and sandy area that is not constructed. The study first determines the built-up area through satellite (NBDI) and then converts it to vector using the conversion toolbar. After converting to a vector, the author created an area field in the Attribute Table and then used calculate geometry to determine the area of both years (2008 and 2020). The results were positive, which means that computed the change in build-up area change over a 12 year.

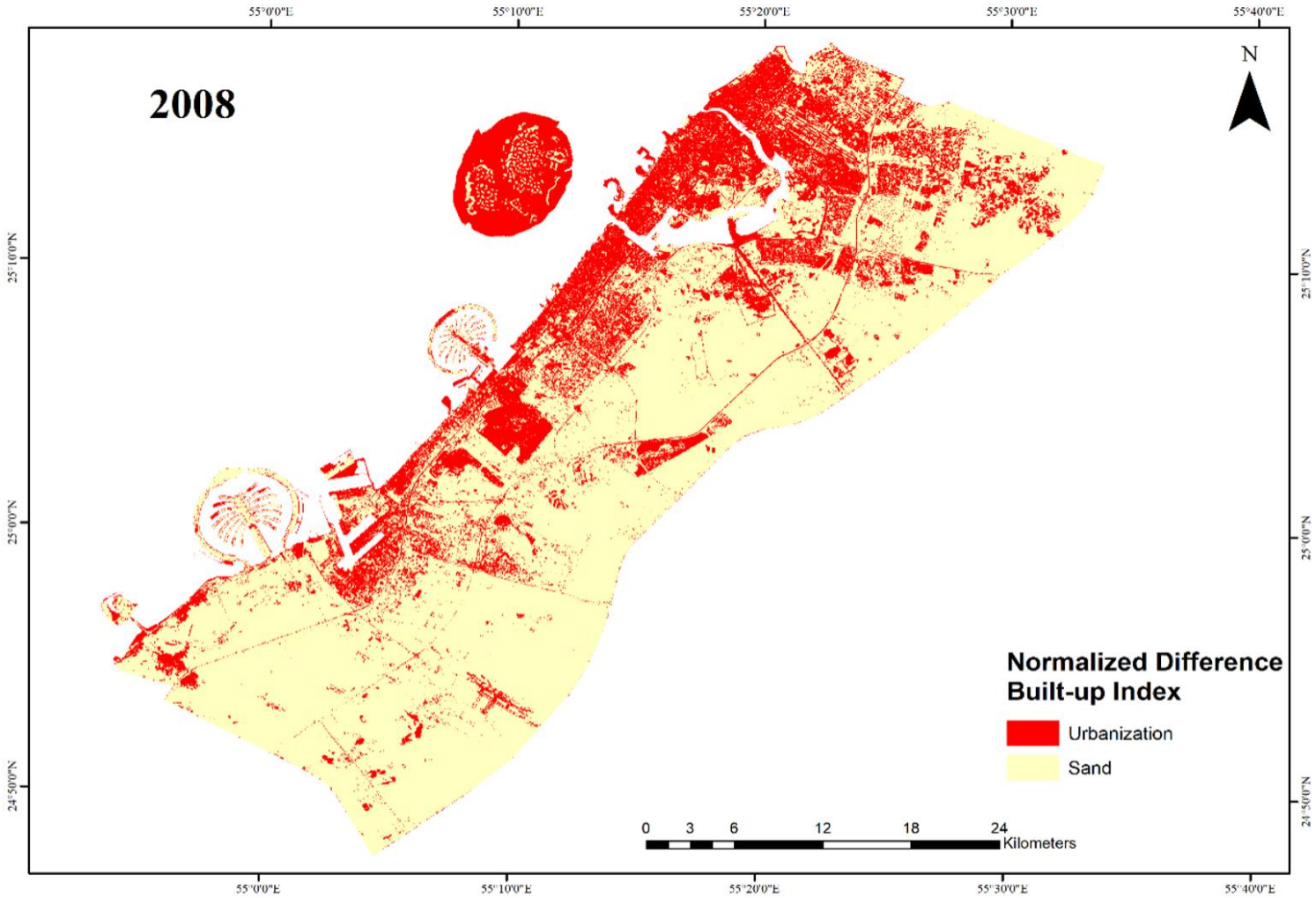


Figure 30: Urbanization of Dubai before Dubai metro in 2008 produced by ArcMap

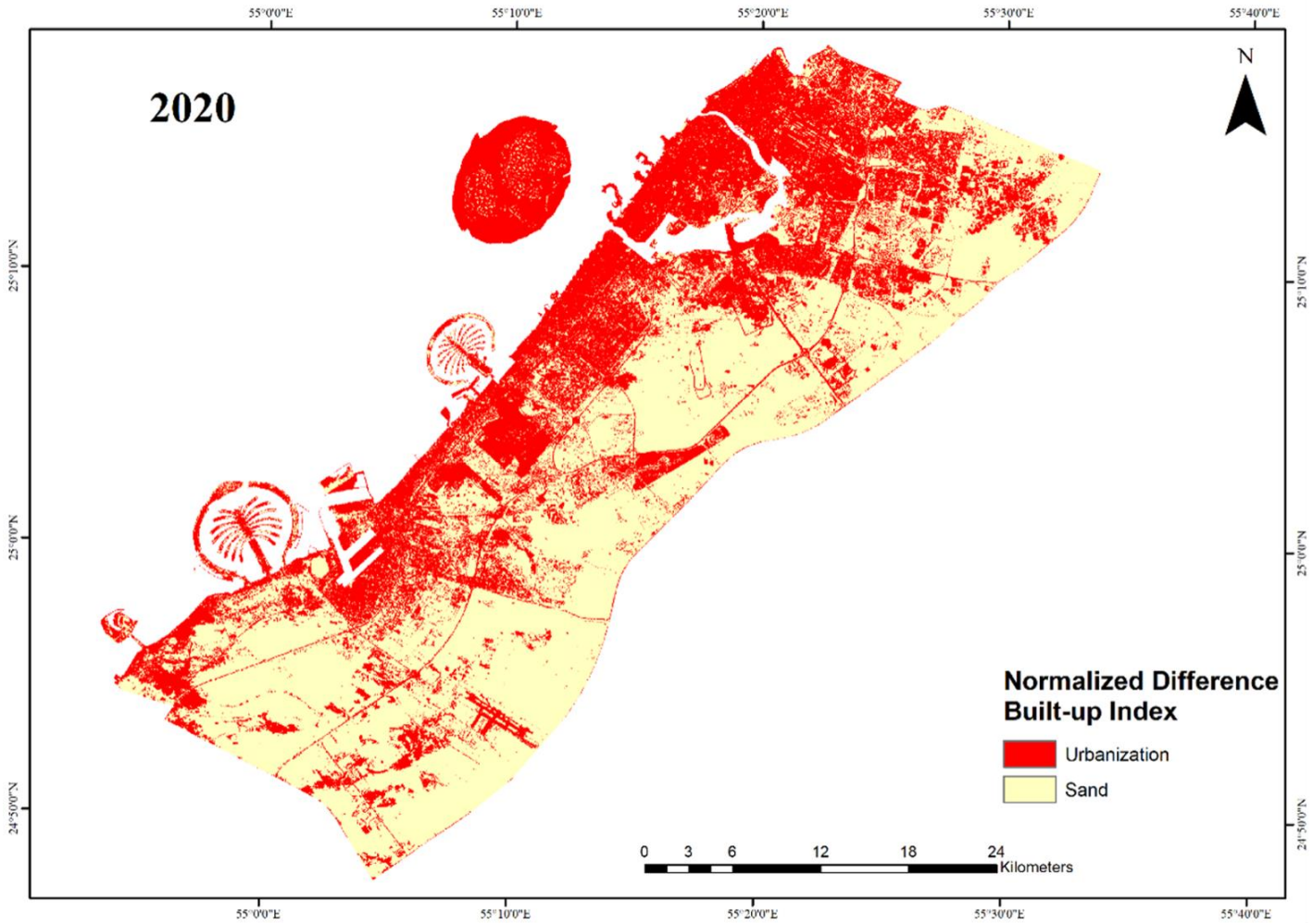


Figure 31: Urbanization of Dubai after Dubai Metro in 2020 produced by ArcMap

During the 12 years from 2008 to 2020, population was also increased along with the build-up area. According to Table 7, Dubai land was covered only by 27.49% with urbanization in 2008. After a rapid change in urbanization growth and population, 42.18% of the land was covered by the built-up area in 2020. Consequently, almost 15% of the land was changed. Furthermore, according to the NDBI analysis, with the implementation of the Dubai Metro and rapid development of infrastructure facilities, the urbanized area percentage over the total land area had been enhanced by about 15% in 2020. Population density also changed swiftly. In 2008 there were 58 people per square kilometer after few years in 2020, it increased to 118 per square kilometer. There was a huge change in population growth as well. Like other cities of the world, some places grow and urbanized, the population density is low in Dubai, both objectives grow altogether. From 2008 to 2014, it increased about 100,000 per annum. By 2016, it had jumped near to 3 million, and the last 3 years, it increased faster. As in 2019, it was only approximately 3 million, but according to a recent survey, it is 3.4 million in 2020, which implies that direct 400 thousand population expanded rapidly in a year.

Table 7: Dubai Development in 12 years.

Year	**Urbanization (km^2)**	**Urbanized Area Percentage / Total Land**	**Population**
2008	371.86	27.49 %	1,645,973
2020	570.60	42.18 %	3,400,800

The population changed rapidly in the past 12 years caused by urbanization and other factors. This includes the business development in the region, migration of the employees of neighboring

countries mostly labor and people for businesses. But the Dubai Metro also has a significance role in development and most of the urbanization growth alongside of the Dubai Metro.

The primary reason is that the built-up areas are concentrated along the Dubai Metro line rather than dispersed throughout the city. These findings reflect a positive impact of the Dubai Metro on city development in Dubai overall. Additionally, the Metro's location was selected by its accessibility to employment and shopping. The population moved to the edge and developed these areas into residential and commercial zones. As the Metro is located in the center of the business hub and it connects one end of Dubai to the other, the majority of businesses and building development have occurred alongside or near the Dubai Metro. Accordingly, a lot of new developments were boomed in the surrounding Metro stations such as Discovery Gardens, Alfurjan, Jumeirah Golf Estate, and Dubai Investment Park.

Metro has a wide role in rapid urban growth in the region specifically close to the Metro connections. As a result, the Metro serves critical locations and projects by connecting Dubai's Metro lines to these dense Metropolitan districts.

It has witnessed a massive population growth due to migration from villages and suburbs to the city searching for employment and a better life. Many residents prefer convenient public transport. Thus, the built environment and residential areas have been expanded by the expansion of transportation systems. Secondly, it attracts tourists towards the Metro because of the connectivity and ease of walking. Allowing a more environmentally friendly and productive use of services and resources, and to create a more comfortable and convenient human habitat.

In summary, the analysis results highlight the huge development of Dubai in both urbanization and population aspects during the past 12 years from 2008 to 2020. The population is still growing as the economy of the country is improving. The vacant land of the country is also decreasing by the

massive infrastructure building up day by day. In the Dubai region, mostly skyscraper buildings are exponentially, but the parks and new roads are not growing like other buildings as these features also should improve along with other buildings.

5.2 The Impact of Dubai Metro

The LRT has a great impact on urban areas due to offering more accessibility and increasing economic agents and investors who are getting more opportunities to develop new businesses. Land use in areas where new Metro stations, new public bus stations, urban railway lines, or related facilities and utilities are built undergoes radical changes.

In other words, the lack of a Metro network in a certain area has a negative effect on the environment due to using cars more intensely, creating traffic congestion, increasing energy consumption and air pollution. Thus, showing the usefulness of the Metro network and justifying the reasons why the appearance of a Metro effects land use and population density near the Metro stations.

In the first phase of analyzing the impact that the Dubai Metro has had on land use changes, the focus has been on collecting the imaging elements that comprise Dubai, used to extract multi-temporal spatial land use data.

The prepared satellite imagery from the Lansat 8-OLI and the external sources (OSM, Google Earth Pro) were used to identify the changes in the reference period in 2008-2020, using ArcMap as a primary software. The data was extracted and digitization by the previously mentioned procedures (Chapter 2).

5.2.1 Population Density

Dubai Metro's annexed territories have experienced an increase in population that has been one of the most significant effects of it is impact. This growth can be explained by the urbanization phenomenon resulting from the development of transport infrastructure in general and the LRT in particular, thereby maximizing the potential of the place through accessibility and thereby increasing it is value.

The process of urbanization, also known as urban sprawl, is characterized by an increase in the number of people leaving and working in a city or Metropolitan area. In the last 10 years, Dubai has experienced a dramatic change in it is urbanization and land use, unlike anywhere else.

Figure 32: Population distribution pattern before Dubai Metro in 2008

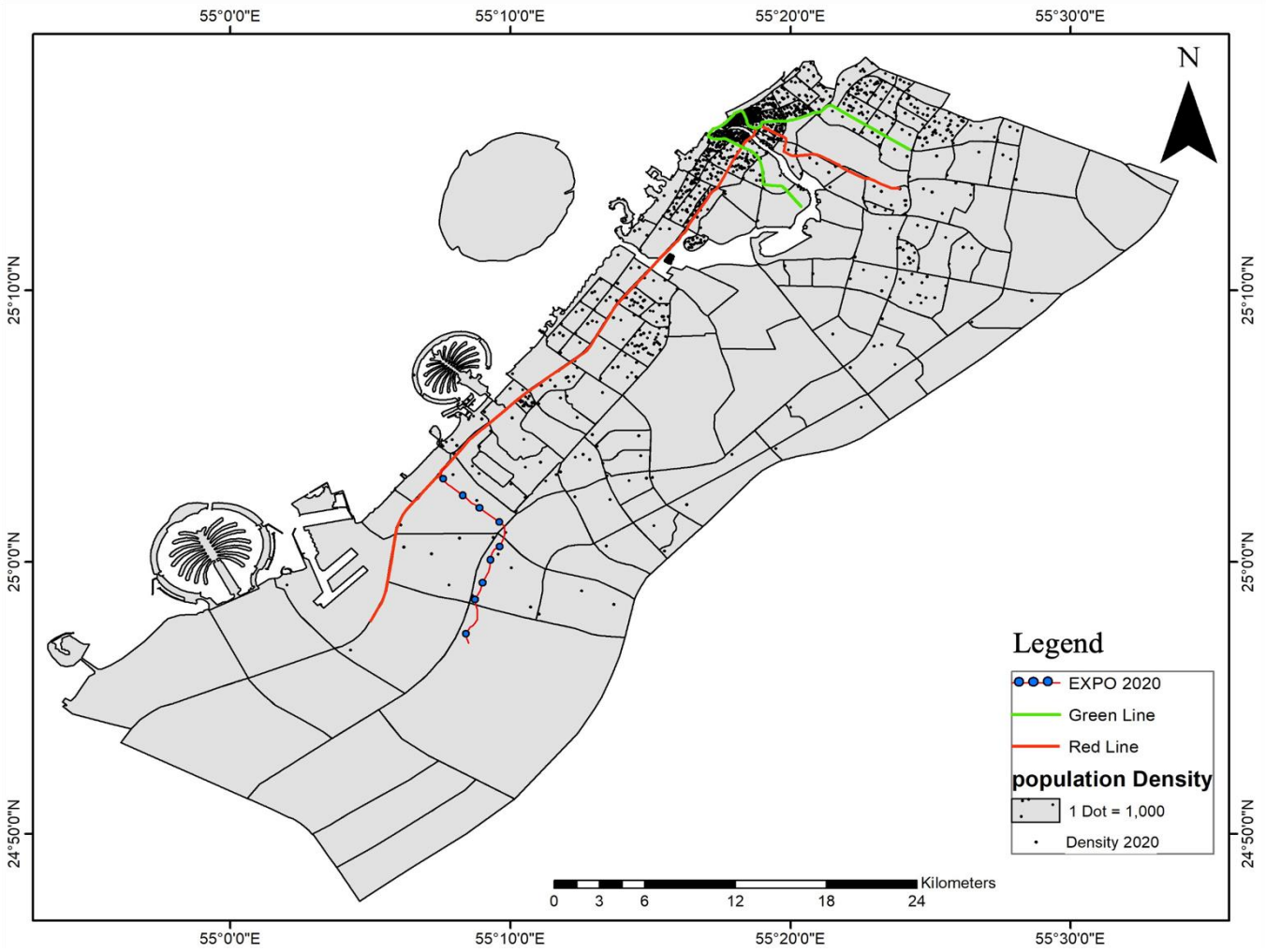


Figure 33: Population distribution pattern after Dubai Metro in 2020.

The population growth and urbanization are trending in the same direction. The concentration of the population is shown mostly in the coastal area with a not very large extension on the Northeast – Southwest sides, with inconsistencies at the middle level of the area where the population density is very low. The most populated area seems to be in the North East (NE) of the area, continuing timidly along the coast near Palm Dubai. This low population density in the area is given by the underdeveloped areas in terms of infrastructure in the surrounding areas, where primary needs such as transportation, whether fast or not, are currently non-existent. This lack of an easy transport method such as the Metro is not of interest to the population and implicitly to economic developers.

As shown in Figure 32, the concentration of the population is shown mostly in the coastal area with a not very large extension on the Northeast – Southwest sides, with inconsistencies at the middle level of the area where the population density is very low. The most populated area seems to be the one in the NE of the area, continuing timidly along the coast near Palm Dubai. The lack of a convenient mode of transit, such as the LRT, is irrelevant to the populace and implicitly to economic developers in this period.

After the construction of the Dubai Metro, several factors contributed to rapid population growth in the area, including the tourism industry, infrastructure development, political stability, and trade liberalization. To cater the increasing urban population growth and increase people's financial status, it's necessary to support the infrastructures and developed networks of the transportation system. Therefore, the LRT have important redistributive effects and influence where and how development occurs in the area.

Twelve years later, Dubai, which is rapidly urbanizing, is expanding it is boundaries, developing infrastructure and, indirectly, Metro lines, as illustrated in Figure 33. The distribution

pattern of the population density around Dubai Metro is the linear settlement that concentrated and more saturate close to the stations.

The development of the Metro system is very visible by extending the high population density in the bordering areas of the SW area, especially in increasing the density on the NE side. The new Metro line developed new residential areas where residents felt secure living near fast, sustainable modes of transport; as demonstrated in phase 2, Section 4.5.4.

As urban centers become more densely populated, there is growing congestion across many transport modes prominent to an intensification in commute times. As a result of this urbanization trend, the cost of conducting private car transport increases - given rising fuel prices and pollution - which this has led to the introduction of taxes to discourage the use of cars in the city. Subsequently, commuters prefered using public transportation for traveling. Thus, the relationship between the development of new Metro lines and the increase in population density is validated by the the Dubai Metro's impact on the city and especially on the increasing areas of residential and economical type.

Furthermore, this population growth is driven by both employees' aims to decrease travel times by avoiding traffic jams and more recently by traders looking to reduce costs and provide social security mobility. Dubai was developed in entirely commercial or residential clusters and, more recently, mixed-use areas. Consequently, Metro system was available, this population growth and rapid development boom around the Metro lines. Accordingly, with an agglomeration of the development in existing and imminent neighborhoods; a growing Metro and tram network beside increasing population density. Therefore, there was a high demand for residential purposes as well as commercial activities besides along the Metro lines.

Jebel Ali

Figure 34 illustrates the distribution of population density in Jebel Ali First, Second, and Third. In 2008 the Jebel Ali First had a population of 35855, Jebel Ali second had 1099 and Jebel Ali Third had a population of 1013. The Population density in Jebel Ali First was found 1662 people per square kilometer. In Jebel Ali Second 219 people per square kilometer and in Jebel Ali Third there were found 202 people per square kilometer.

The population distribution is analyzed according to their distance from their residential location using the formula total population divided on the total area. There were 100 people were living at that particular distance in their specific area. Most parts of Jebel Ali were sparsely populated. The estimated distance of the living population is 1.67 miles per 100 people density. This distance was 1.07 miles in Jebel Ali Second and 0.87 miles in Jebel Ali Third, significantly less than the distance between the other two components of the local district. As a result, Jebel Ali Third has closer population distances than the other two portions. However, the distance was shorter on the Jebel Ali First's South-East side, where the distance estimate was 0.37 miles per 100 persons.

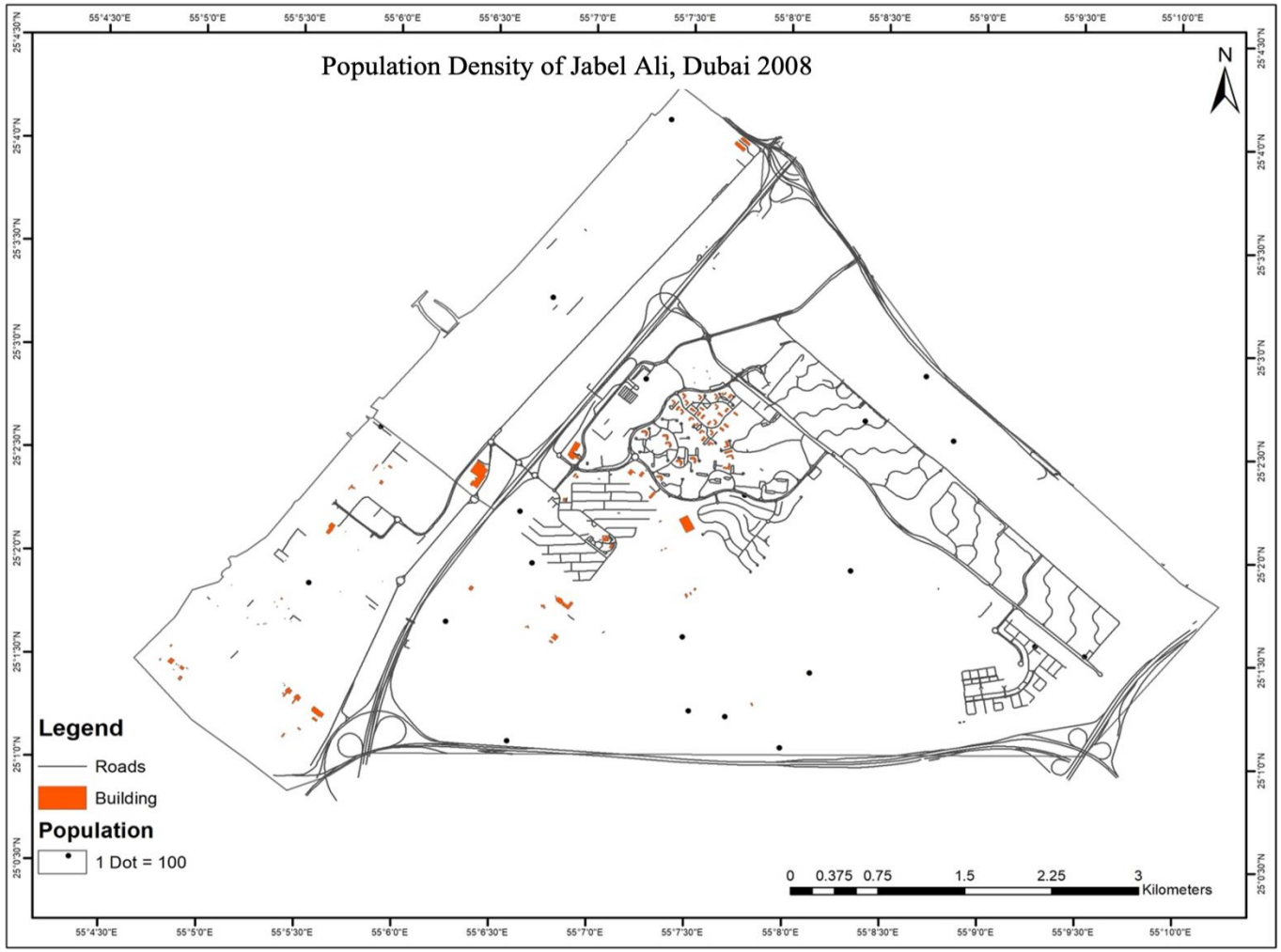


Figure 34: The patterns of population distribution in Jebel Ali district before building of the Dubai Metro system.

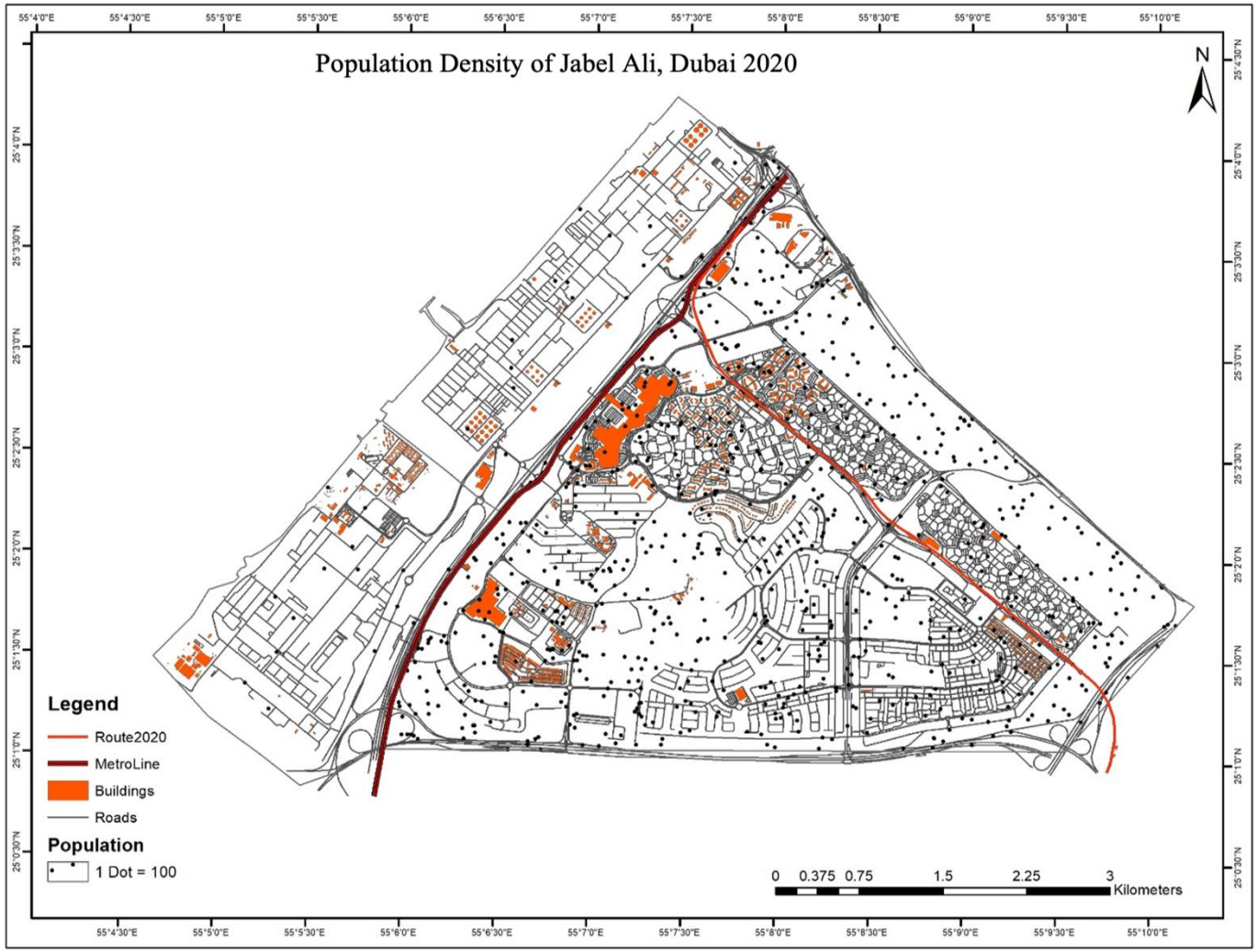


Figure 35: The patterns of population distribution in Jebel Ali district after building of the Dubai Metro system.

The population change map in Figure 35 depicts the difference between 2008 and 2020. The population density grew tremendously in the Jebel Ali First district, which had a population of 76,016 and a land area of 21.5 square kilometers. Jebel Ali Second has a population of 1570 and a land area of 5.06 km². Finally, the Jebel Ali third district which covers a 5-kilometer square and is inhabited to 1513 people. In Jebel Ali Second and Third, there has been little population change, but the maximum number of inhabitants has increased in Jebel Ali First. The population density in Jebel Ali First is 3491 people per square kilometer, 313 people per square kilometer in Jebel Ali Second, and 302 people per square kilometer in Jebel Ali Third. Along with population growth, the number of buildings expanded dramatically. Along with the Metro Stations in Jebel Ali, the number of buildings has expanded significantly, particularly commercial buildings. The living distance in Jebel Ali First was found 0.08 miles per 100 people, 0.18 miles per 100 people in Jebel Ali Second, and in Jebel Ali Third, this number changed to 0.29 miles per 100 people living distance.

Al-Barsha

According to Figure 36, the 2008 population density map analysis output. According to the Dubai Statistical Center, the city has a population of approximately 11,237 people and a population density of 2809 people per km^2. It can determine that the highest population density cluster is located between al-Barsha and Sheikh Zayed Road (E11). It represents just 0.68% of the city of Dubai's total population.

In 2020, there was a total population of approximately 40,202 and a population density of 10,166 km^2, which is approximately 1.2% of the Dubai of total population, Figure 37.

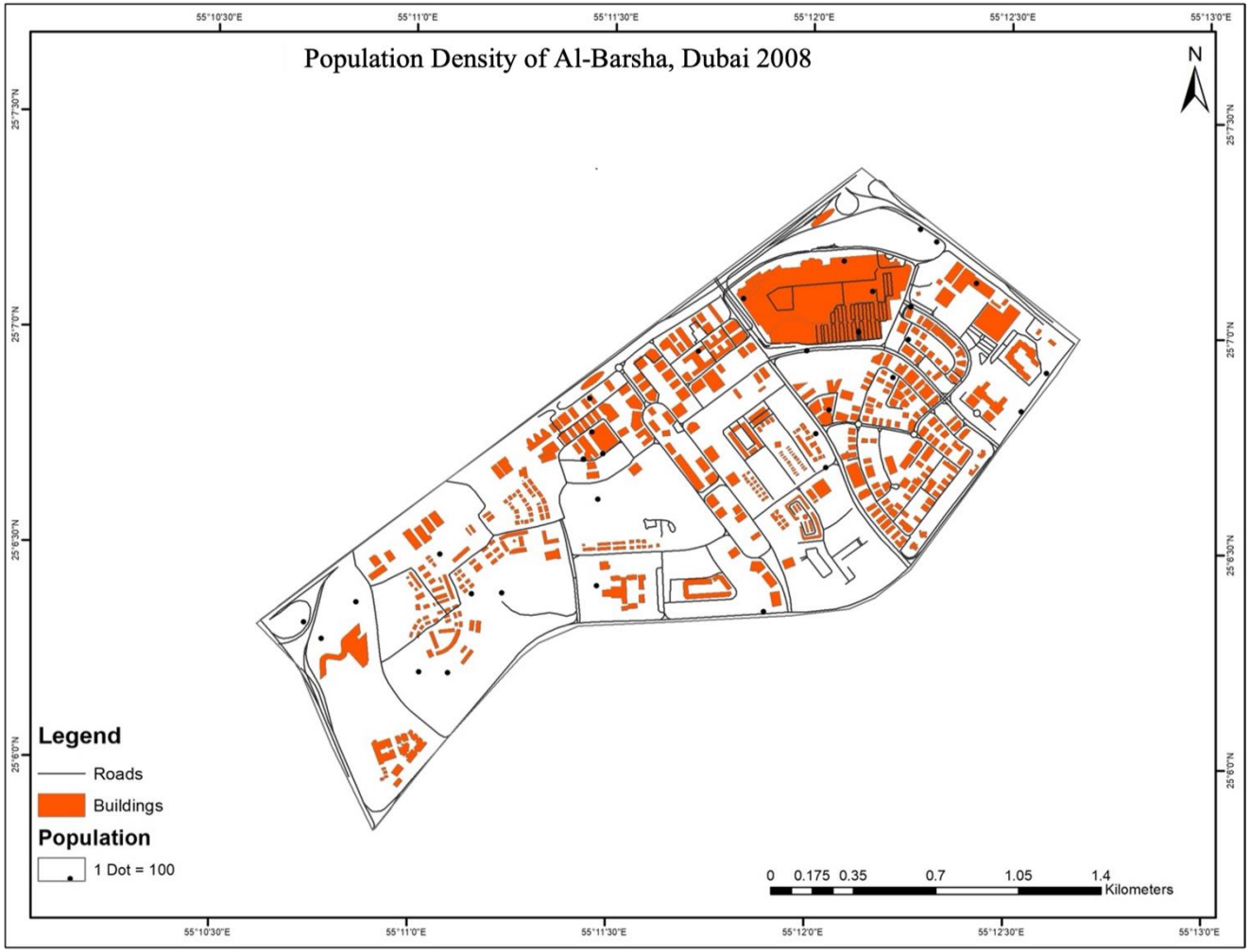


Figure 36: The population distribution in Al-Barsha district before building the Dubai Metro system in 2008.

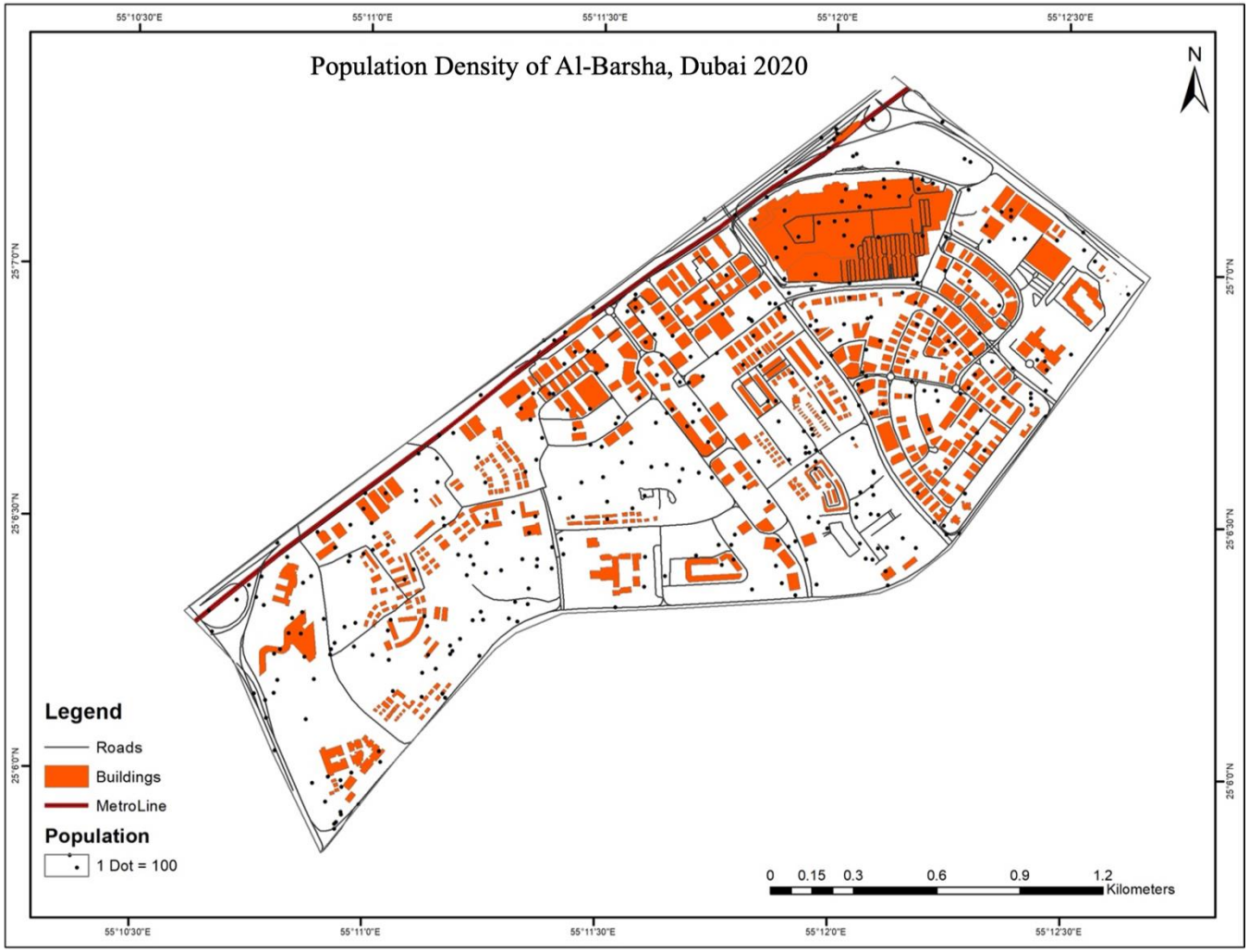


Figure 37: The population distribution in Al-Barsha district after building the Dubai Metro system in 2020.

Business Bay

The distribution of population density in Business Bay is depicted in Figure 38. In 2008, Business Bay had a total population of approximately 4400 and a land area of 6.1 kilometers. The population density was determined to be 720, which is a very small number of people in this district. According to the map below, it demonstrates the distance between people residing in 2008 in terms of 100 people density. The distance between people was estimated to be approximately 0.010 miles. In 2008, a sparsely populated area in the community district was discovered, while a low distance distribution near the building sites was discovered.

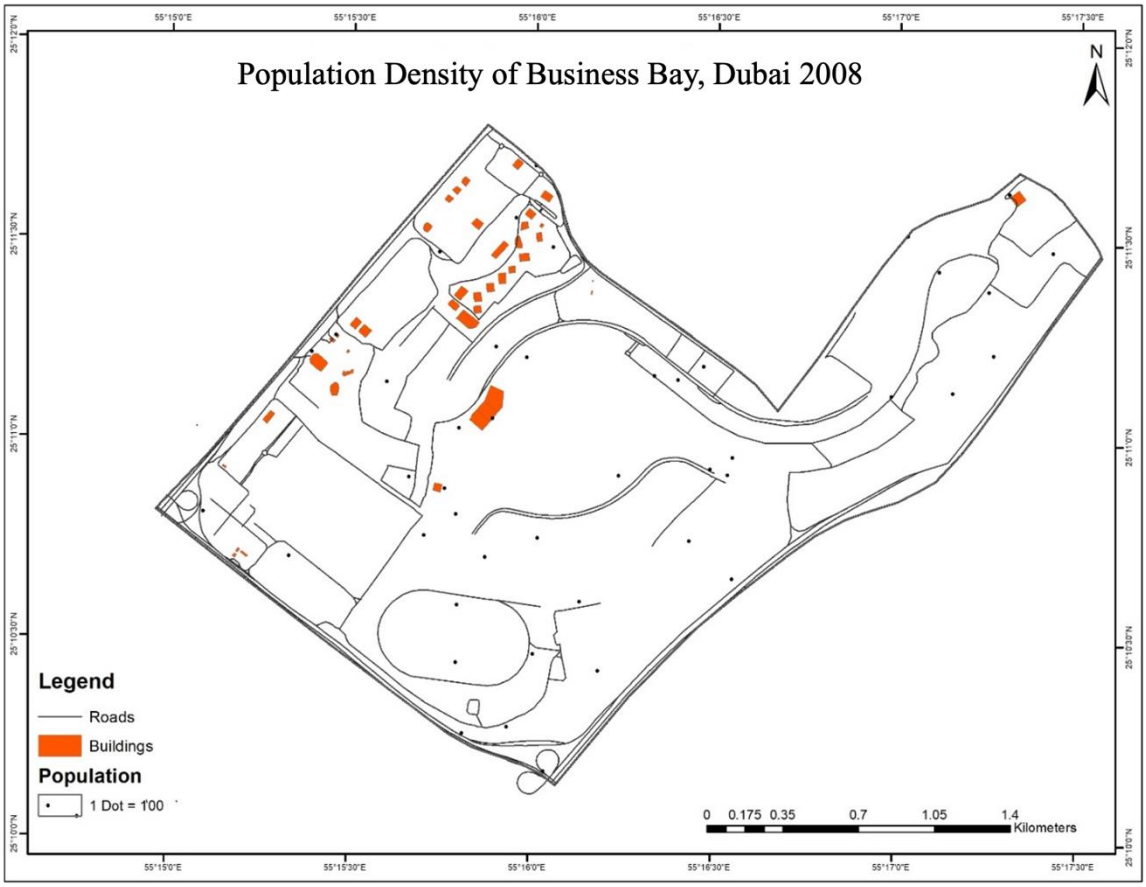


Figure 38: The population distribution in business bay district before building the Dubai Metro system in 2008.

In 2020, a massive change seen in population in the year 2020, shown in Figure 39. As in the 2008 population size was very low and sparsely populated but in 2020 the population number enlarged rapidly and distribution become too closer than 2008. On the other hand, Building's ratio was also change and grow exponentially especially close to the Metro station in Business Bay. The population number found in 2020 was 21,497 having area of 6.6 square kilometer. Business Bay had a population density of 3469, which means that the number of people living in per square kilometer had increased by more than 350% by 2020. The number of buildings continues to increase, with the majority being around the Metro station and north of the water canal.

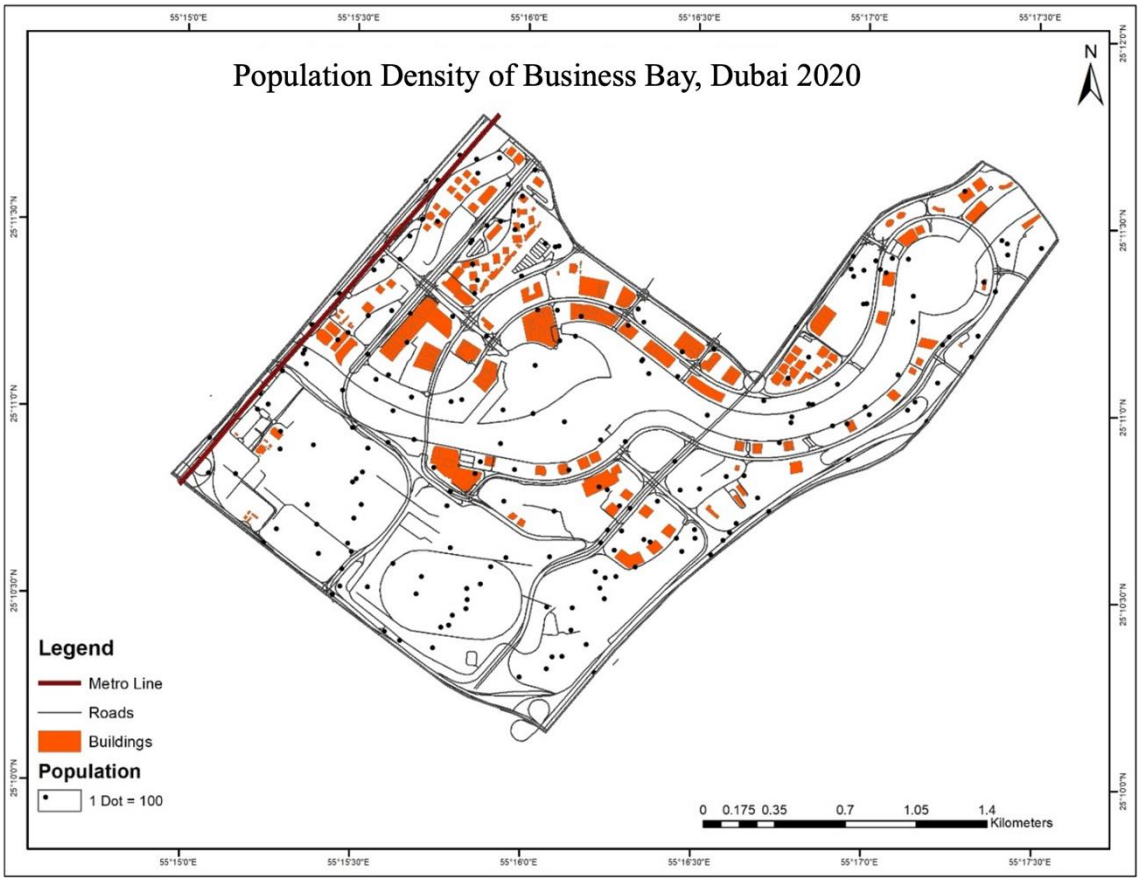


Figure 39: The population distribution in business bay district after building the Dubai Metro system in 2020.

According to the map, the average distance covered by the population living per 100 people density is 0.02 miles. The building's size and density are also grown, particularly in the proximity of the Metro station. This is also a significant reason for the population distribution being higher than 2008 levels, owing to the rise of the business district, particularly the Burj Khalifa (a pioneering skyscraper in the world) and other well-known businesses in that district. On the other hand, the Metro route and Business Bay Metro Station have a significant impact on population distribution, particularly in the direct proximity of the Metro Stations. The majority of the population lives close to Metro stations in order to gain access to them more rapidly than those who reside further away.

5.2.2 Land Use Change

Land use indicates the use of land for human purposes, which can consist of built and non-built structures. Land-use change mainly depends on many reasons. Among them, increasing population or population accessibility is a driving tool for the change of land use. Because a growing population need additional housing space in addition to services, recreation, and other necessities for living. That’s why land-use change also depends on population. Land use and transportation are integrated into a dynamic process that includes spatial and temporal changes between two systems. These changes in land use are highlighted by the emergence of a transport node, as is the case of Metro stations that connect with the rest of the city, through the positive impact of the value of the land around it. This positive impact on the value of the land is best seen in the desire of the population to accept a residence in one of these areas knowing that it has a fundamental connection with the city center or other places important to them. Economic agents enhance the potential that these valuable

lands have in producing economic benefits while providing necessary services to the resident population. The three selected Metro stations were identified using satellite imagery (for more details, see Appendix D).

Jebel Ali

Land use analysis was applied to Jebel Ali District in Dubai to see the differences in land use cover in 2008 and 2020, which are defined in the Figures 39 and 40. In 2008, the phenomenon of urbanization spread to Dubai was to develop the city in the form of a generous expansion of the city.

Figure 40 represents the Jebel Ali's land use before the construction of the Dubai Metro. It shows industrial areas and residential areas dominance, but with very few roads, green spaces, recreational and commercial areas. The lack of these facilities indicates that the area lacks a transport network that can support a large influx of people, implicitly a more accentuated development. The year 2008 surprised Jebel Ali in full development, but still with much to bring to attract the population that was to live there in 2020.

The year 2020 comes with impressive changes in the use of land in Jebel Ali, thus making the appearance of the new Metro line that accentuated the change of the land use of the area. This district is served by three Metro stations: Jebel Ali, Ibn Battuta, and Energy respectively. With the addition of three new stations on the EXPO 2020 Metro's Red Line: Gardens Metro Station, Discovery Gardens Metro Station, and Al Furjan Metro Station. Residential buildings, green spaces, commercial and industrial spaces have seen a spectacular increase due to the rapid transport facility in this area. Thus, the value of the area increased through the connectivity and accessibility conferred by this new transport network, attracting both the population that was to be resident, as well as economic and industrial operators. The changes regarding the land use can be observed in Table 8, which represents

the area of each land use class with values from 2008, 2020 represented in hectares as well as the change between these classes in percentages.

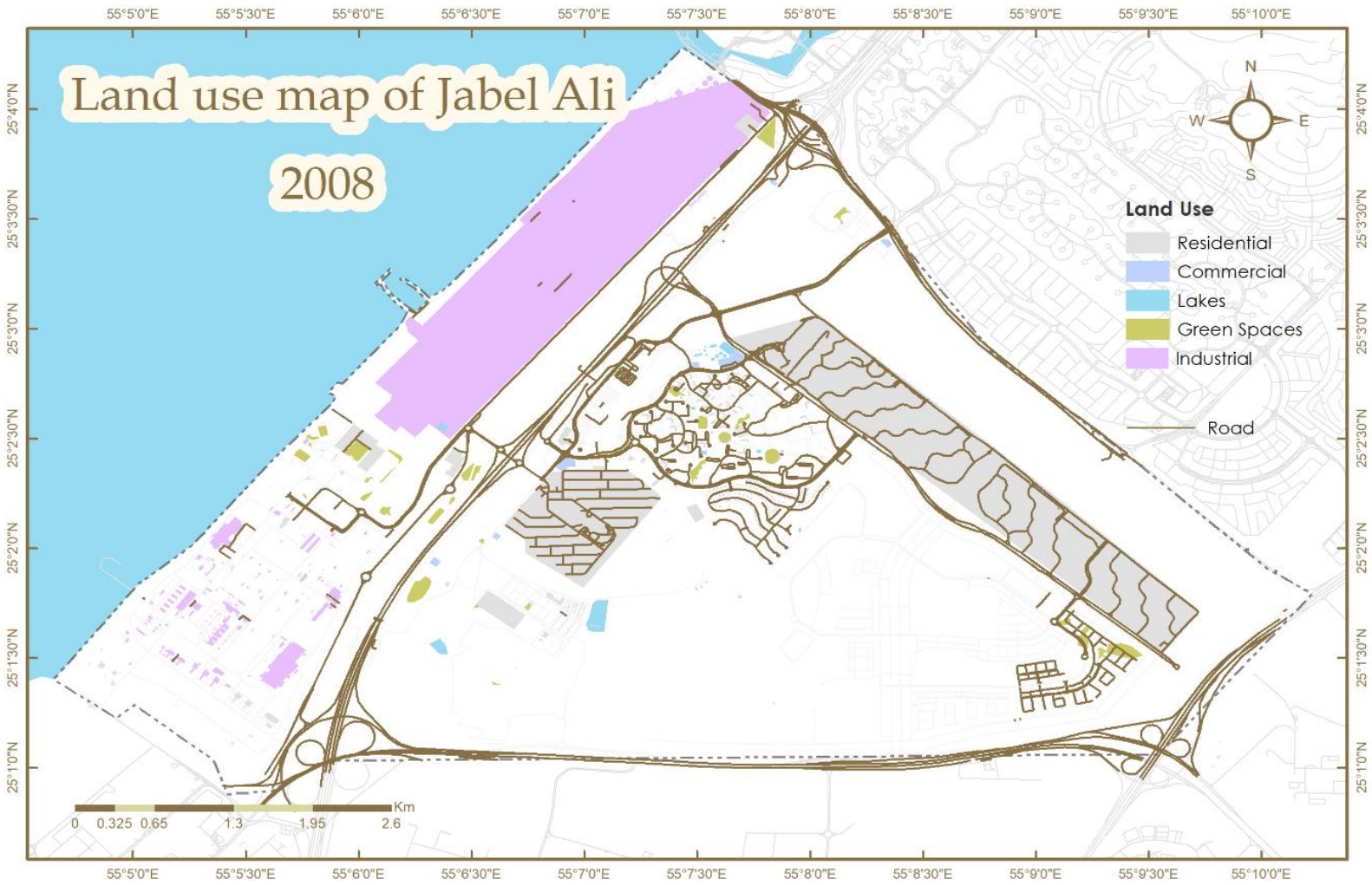


Figure 40: Land use of Jebel Ali district before construction Dubai Metro in 2008

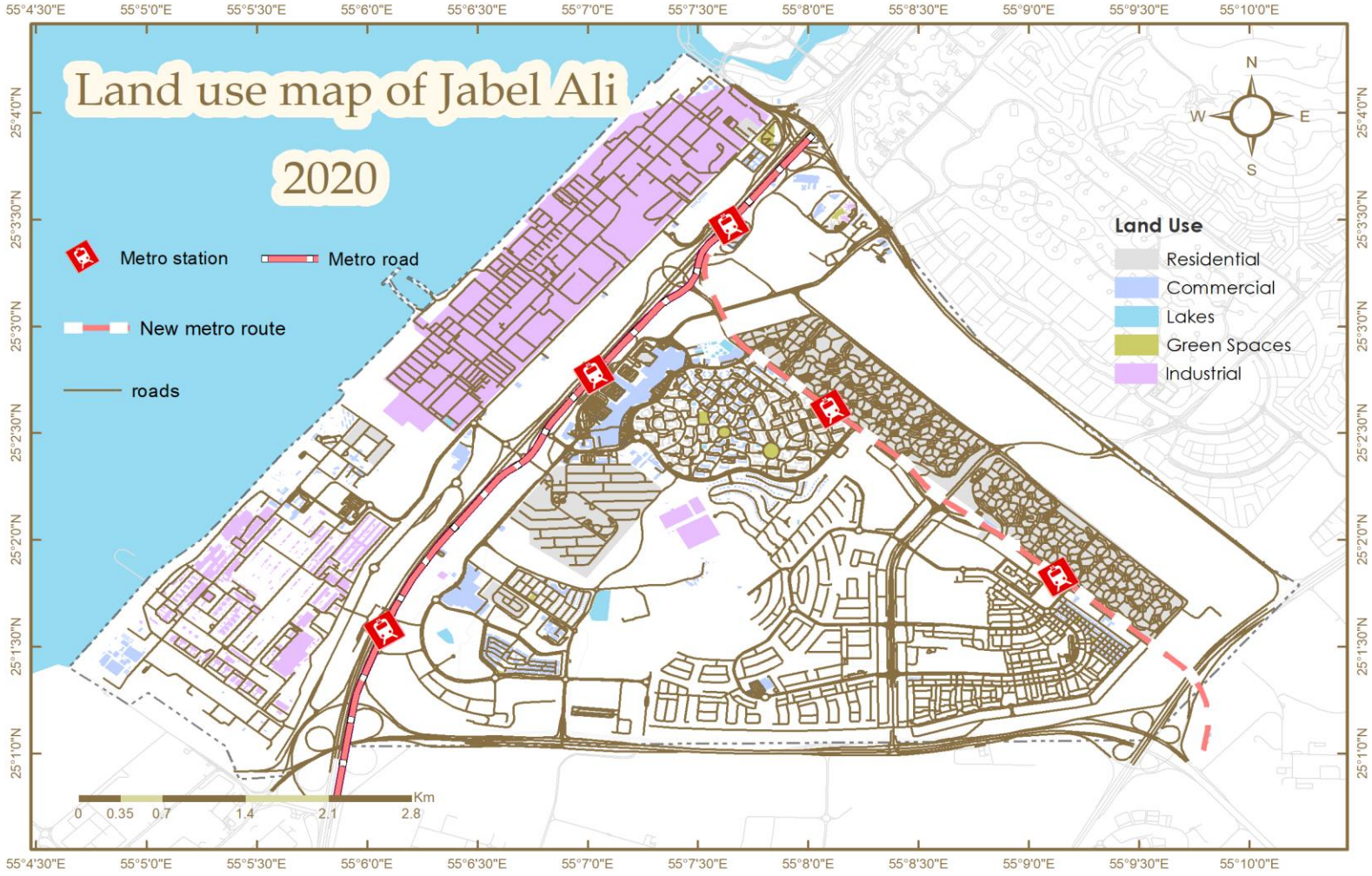


Figure 41: Land use of Jebel Ali district after construction Dubai Metro in 2020

Table 8: Change in Land Use at Jebel Ali.

Land Use (ha)	2008	2020	Changes %
Residential	37	273	643
Commercial	74	474	542
Industrial	252	299	19
Green space	28	13	-52
Lakes	8	8	0.0
Main Streets (km)	192	543	182

The changes in land use due to the advent of the Metro, showing that residential areas have grown from 37 to 273 hectares, representing an increase of 643% since 2008. In line with the increase of residential spaces, implicitly of the population, the commercial areas increased by approximately 542% from 74 hectares in 2008 to 474 ha in 2020, in the same trend being the industrial spaces with an increase of 19%, as well as main road network with an increase of 182%.

Accordingly, the commercial areas increased by approximately 542% from 74 hectares in 2008 to 474 ha in 2020, in keeping with the increase of residential areas. Meanwhile, the industrial areas increased by 18%, and the main road network with an increase of 182%.

The only class that has suffered a decrease in surface area is that of green spaces, which have decreased by about 52% due to the construction that followed in this area within the residential, industrial, and commercial ones, and the lakes have remained unchanged.

Al-Barsha

Al-Barsha District is another area where the advent of the Dubai Metro has shaped a huge change of scenery between 2008 and 2020, as shown in Figures 42 and 43. The area around Al-Barsha Metro station is characterized by a medium-sized street plot with commercial buildings and few residential spaces. The main means of transportation is a personal car or street-level public transportation. With

the appearance of the new Metro line, Al-Barsha experienced major changes, making it possible for residents to get fast and direct connections to any area in Dubai. The district is served by two Metro stations: Dubai Internet City Metro Station 2 and the Mall of the Emirates station, which is the district's busiest station. Residential area increases dramatically in 2020, meaning a population increase that makes commercial spaces more necessary. The number of petrol stations in Al-Barsha reflects the district's development. This is implicit in the increase of residential areas. Additionally, new kinds of classes have appeared in the neighborhood, including green spaces that serve as recreational.

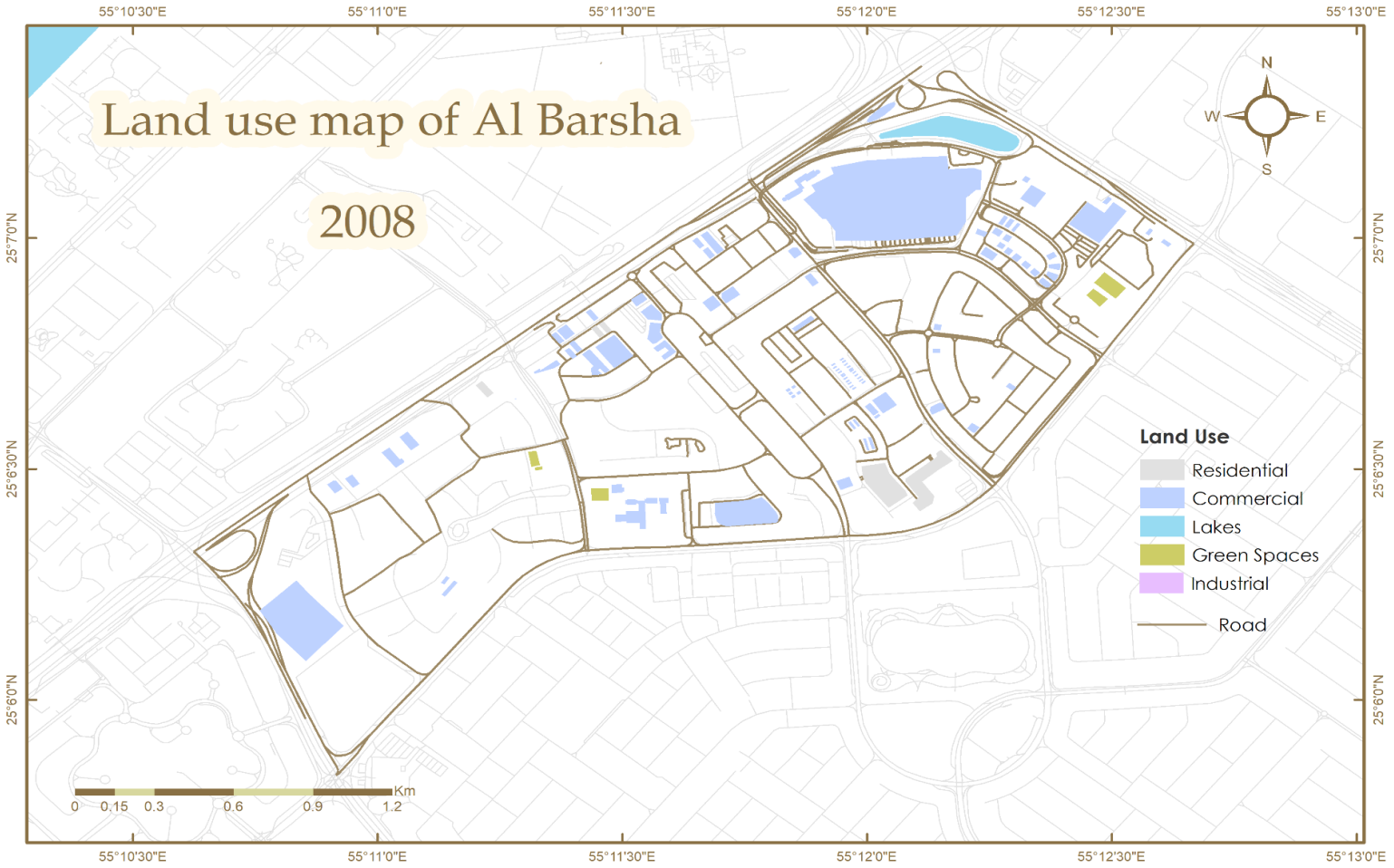


Figure 42: Land use of Al-Barsha district before construction the Dubai Metro in 2008

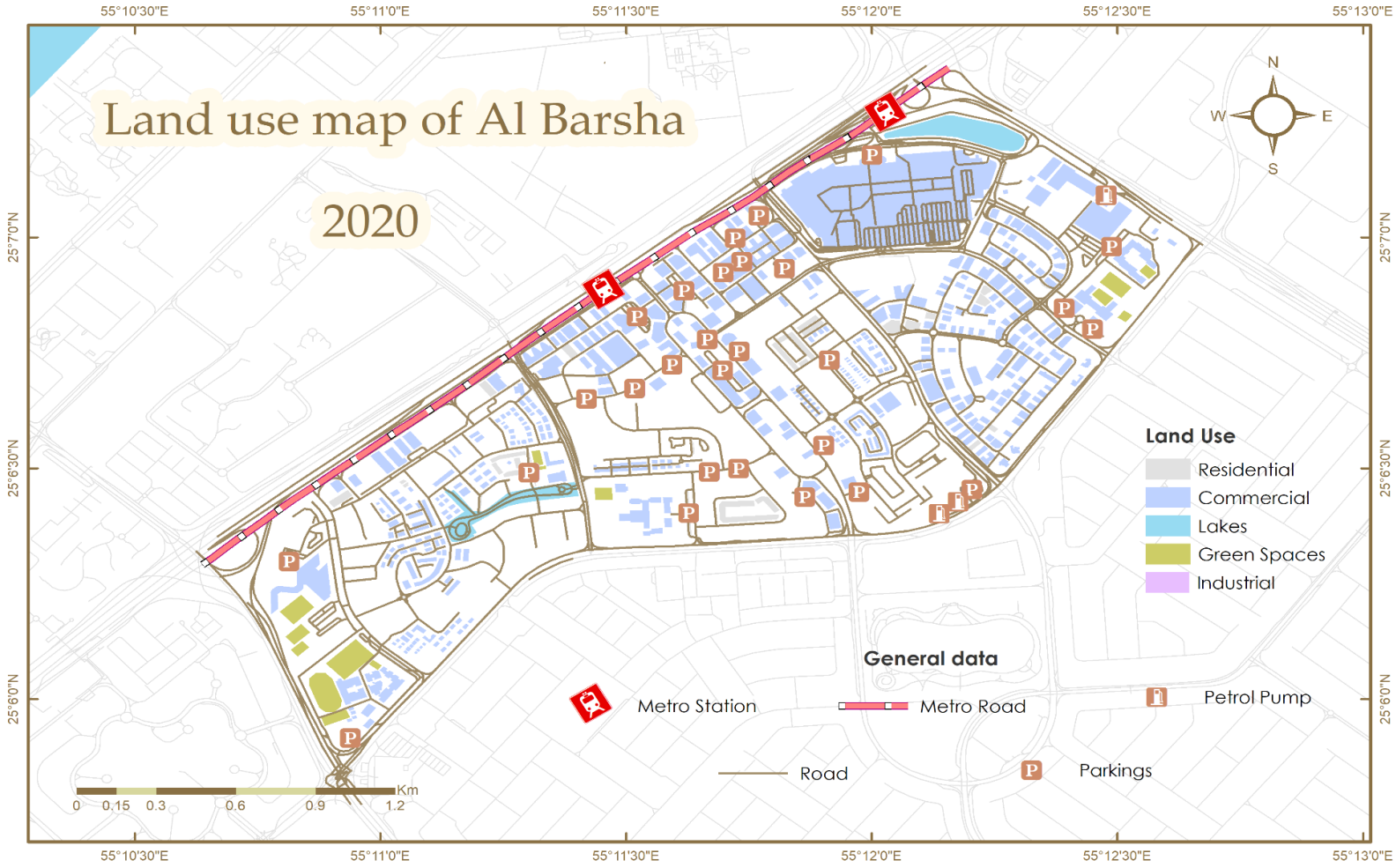


Figure 43: Land use of Al-Barsha district after construction the Dubai Metro in 2020

Table 9: Change in Land Use at Al-Barsha

Land Use (ha)	2008	2020	Changes %
Residentials	10	22.63	125
Commercials	34	296	760
Industries	-	15	-
Green spaces	2	10	532
Lakes	4	4	0
Roads (KM)	62	101	64

At the level of Al-Barsha, there is a large increase in commercial and green spaces of approximately 760% and 532%, respectively, all due to the growth of residential areas by 125%. Also, the street plot increased by over 64% from 2008 to 2020. In Al-Barsha, the residential area/residential land use is developed far from the CBD, and after developing two Metro stations, the residential area increased, depending on CBD also increased near two Metro stations. As shown in Table 9, the size of the commercial land use has been increased by 760% from 2008 to 2020. The increasing rate between residential land use and commercial land use is much more different, and the increasing rate of commercial land use is higher. It happens because the Metro station is near CBD, and people can access it easily. It is also noticed that before constructing the Dubai Metro, there was no industrial land use in Al-Barsha. However, after constructing the Dubai Metro, industrial activities started to be developed within the area of Al-Barsha. It was also noticed that the percentage of green space has increased due to nature conservation, and Dubai aims to increase the share of clean energy to 29% and the Emirate's energy demand by 30% by 2030 (Ministry of Energy, 2011). In Al-Barsha, the area of lakes or the waterbody remains the same within 12 years from 2008 to 2020. Road expansion/increasing is normally happened to facilitate more people.

Business Bay

Business Bay District is Dubai's new Central Business District. It is developed alongside the old CBD as a commercial, residential, and business hub. It is also being developed as a new extension of Dubai Creek, extending from Ras Al Khor to Sheikh Zayed Road. Moreover, Business Bay offers a well-established business environment and has been a major contributor to the city's economic boom. In addition, Business Bay also offers free zones and freehold areas as well as opportunities to locate stores on the Dubai mainland.

Additionally, analysis indicates that it is the least developed of the three cases in 2008. The majority of the area is desolate, with the only commerce and residential centers concentrated in a tiny area in the northwest (Figure 44).

Along with the urban development of the business bay, the Metro's impact in 2020 brings significant changes to this area, attracting more people and investors to relocate. The development of business bay has had a significant impact on the movement of people to this area, but the Metro has accelerated this growth. As a result, significant residential and commercial land use changes have taken place (Figure 45). This district is served by a single station, Business Bay, which is located near to Downtown Dubai (Burj Khalifa and Dubai Mall). Additionally, it serves Al Wasl, a district to the west of the station. Residential and commercial areas are already sprouting up on both sides of the water arm, generating significant alterations, particularly on the left bank, where no such development existed in 2008.

Unlike Jebel Ali and Al-Barsha, the Business Bay Districts does not include industrial land use. It dominates mainly residential, commercial, and green spaces together with water activities and other natural areas, making a perfect built environment.

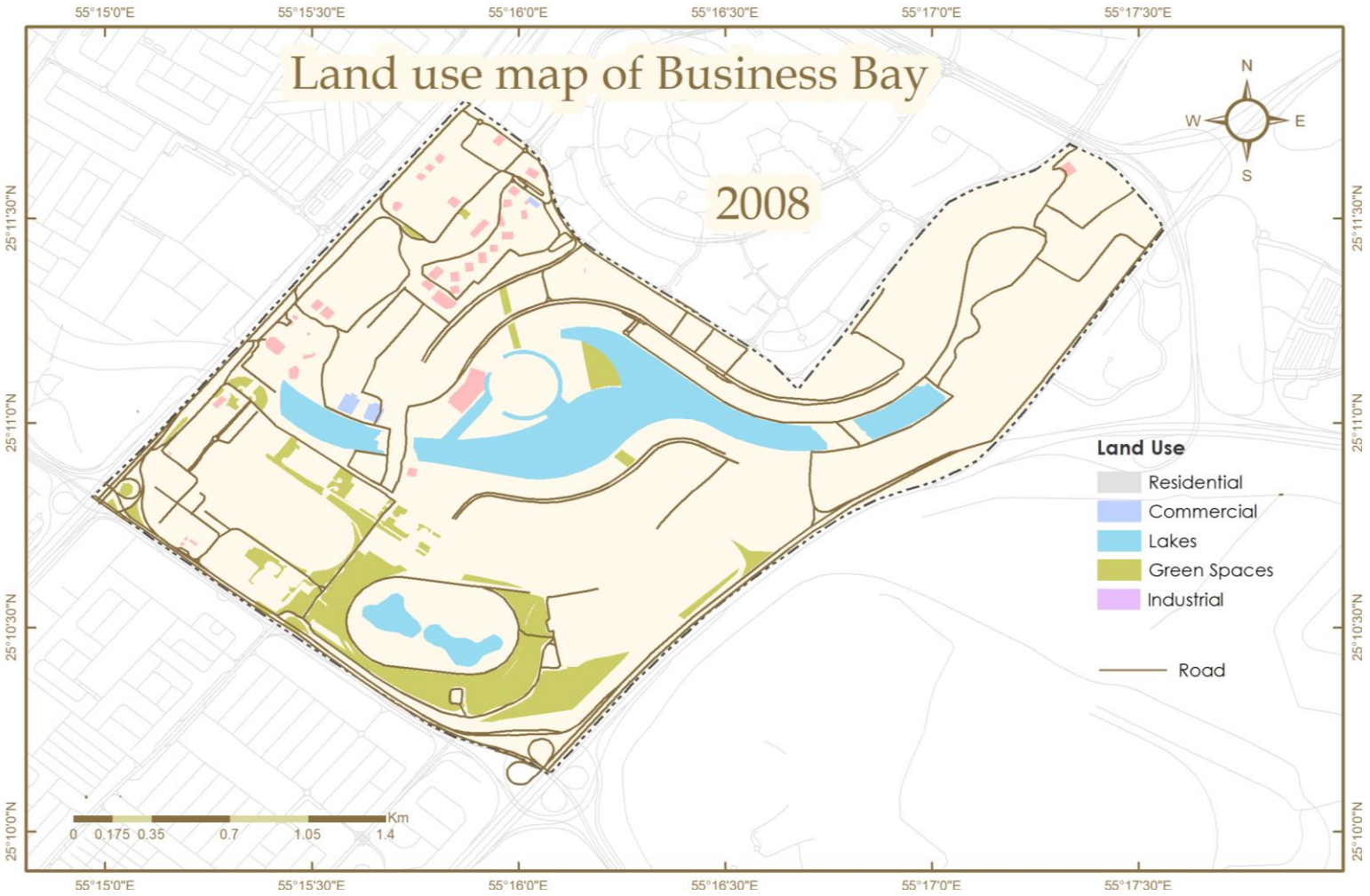


Figure 44: Land use of business bay district before construction of the Dubai Metro in 2008

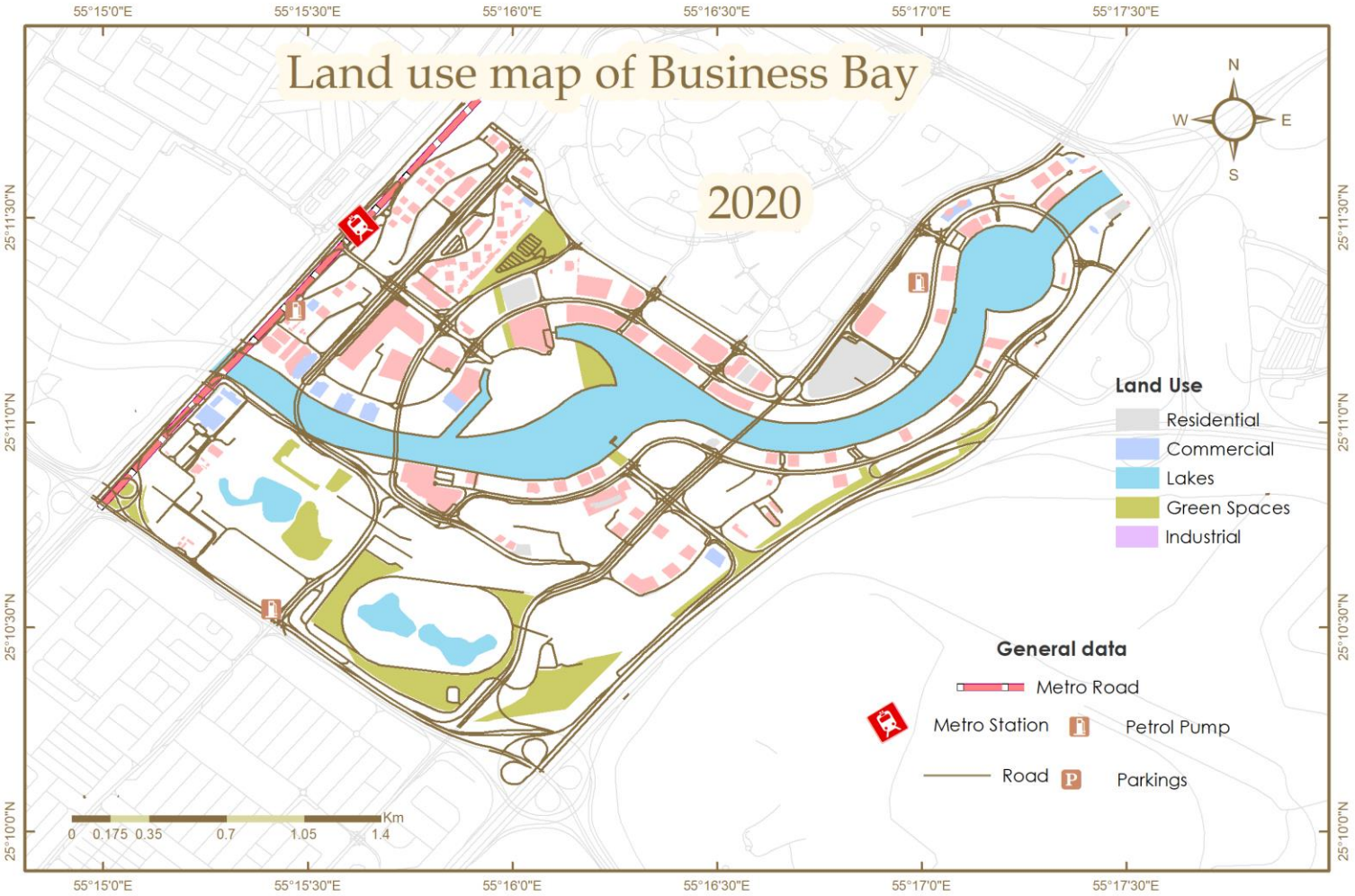


Figure 45: Land use of business bay district after construction of the Dubai Metro in 2020

Furthermore, after constructing the Metro along the Business Bay, it changed the urban form compared to 2008 and 2020. Moreover, according to analysis and research, in 2008, there is not a considerable residential population in Business Bay. The commercial land use development has been increased up to 387%, as shown in Table 10. Thus, wetlands such as waterways and lakes develop by more than 100% in the period 2008-2020, but unfortunately, green areas suffer by losing up to 37% of the surface. These developments attract visitors from all over the world for business and pleasure. The city has a car culture; the vehicle is central to all activities and movements. Therefore, a wide range of potential transport and economic impacts are associated with this development, including increasing investments opportunities, creating new jobs, quality of life, diversifying energy sources, and fostering economic development and revitalization. Accordingly, it is proven that the Metro in Dubai was acted as a positive influencer of development in all aspects.

Table 10: Change in Land Use at Business Bay

Land Use (ha)	2008	2020	Changes %
Residentials	-	5.81	-
Commercials	1.15	5.64	387
Green spaces	41.2	25.78	-37
Lakes	5.673	11.58	104
Waterways	48.77	103.2	112
Roads (KM)	54.35	121.91	124

5.2.3 Connectivity

Connectivity refers to the quality of travel and is achieved by using access management approaches to give access to a variety of land uses at the community and individual levels. It prioritizes travel time, cost, alternatives, comfort, and safety while catering to the requirements of everyone in the community. The relative placement of an object to the destination centers is known as connectivity. When it comes to connectivity, there are many distinct degrees of hierarchy.

Having a well-connected network of roadways and pedestrian facilities can assist to disperse traffic, shortening travel distances and times, enhancing transit routing, and shortening walking distances. Analyzing the closeness centrality enables us to understand how people move through public transportation networks. Also, human travel behavior affects the distribution of traffic flows in transportation networks. All these factors can help to alleviate traffic congestion on city streets.

Generally, connectivity is not measured referencing a benchmark, but recent studies are discussed based on the visual interpretation of the output. The connectivity output can be interpreted using different classification methods via GIS software. This study used the quantile method for data classification. Finally, the result was interpreted by preparing maps. Therefore, the result is discussing comparing the results of the city itself.

If a transportation network's degree of connectivity is greater, it indicates that the system is more effective. When enough network lines connect all adjacent points, the highest degree of connectivity is indicated. On the other hand, accessibility provides the measurement of journey time and travel quality (at the individual and community levels) using access management techniques to facilitate access to various locations. Additionally, it considers travel costs, travel possibilities, comfort, and risk while meeting needs. Thus, connectivity in this study is defined as taking the quickest path to the study area (Metro stations). If more people access the study area through the shortest routes

across adjoining nodes, this changes the relationship between connectivity and accessibility in the study area.

The section investigates three catchment areas within a one-kilometer radius of Metro stations in this study. Thus, the results for each model based on a specific catchment area show the impact of the Metro on the land use within that catchment area in comparison to the land use prior to the Metro's establishment. This threshold point was determined for a variety of reasons. To begin, it is based on what appears to be an acceptable distance for users to walk to a Metro station, as determined by an RTA survey, which revealed that walking distances up to 1.2 kilometers are acceptable, while park-and-ride, and/or feeder buses are acceptable for distances greater than 1 kilometer (Roads and Transport Authority, 2011). Secondly, a wide number of previous researches have employed comparable thresholds, ranging from one to two kilometers from a rail station (e.g., Agostini & Palmucci 2008; Du & Mulley 2006; Gibbons & Machin 2005). As well as indicators of accessibility to public transportation (i.e., distance to the nearest highway, distance to the nearest Metro station, and the number of Metro stations within a given catchment area).

Jebel Ali Metro District and Surrounding

The three different colors of the symbol lines (Green, Red, and Yellow) indicate the various degrees of connectivity in the area. Although Jebel Ali is a well-known landmark district in the city, it contains a variety of land uses including industrial, residential, and commercial. The main road that runs through the area's northwestern section connects it to the rest of Dubai. The green network line indicates a low degree of connectivity. There is no congestion of traffic or business in that section of Jebel Ali. Because the majority of the built-up area in that section consists of residential houses and a small amount of industrial space, the routes are used exclusively by concerned individuals. Second, yellow network lines represent a network with a moderate level of connectivity. There is neither

extremely low connectivity nor a high volume of business, although this network does see high traffic. The building types are predominantly residential plus commercial, which includes hotels, restaurants, shopping malls, and living apartments all inside the same structure. As a result of this, the transit network in this section of the area becomes quite crowded. The final color (Red) indicates the zone with the highest connectivity, which is always experiencing a large volume of traffic. And all of these paths connect to the Jebel Ali Metro station, which is located on both sides of the study area. The Dubai Marina, the parks, and the Dubai exhibition line all contribute to the traffic. Skyscraper buildings exist on Dubai Marina (comprising commercial and residential space), The Gardens (residential space), and the EXPO Line, which is a massive economic and trade corridor that attracts traffic, as well as a Metro station in the right-center of three junctions, which is the primary reason for the zone's high connectivity. The connectivity analysis shows that Jebel Ali Metro Station and it is surrounding has higher connectivity level comparing to other areas. The above-mentioned good connectivity for the Jebel Ali Metro station contributes to the development of a sustainable, living, economically, socially, and environmentally accessible area.

In the case of sustainability, Jebel Ali has all the premises for longevity and support for a very high traffic of people who can simultaneously cross the side streets due to the sporty and enlarged infrastructure compared to other areas. Thus, Jebel Ali shows an exponential growth of the population living in the area, given the fact that there is a special infrastructure and automatically a connectivity to the Metro area that has appeared in this neighborhood. The distribution of the population and the interpolation of it is values, show an exponential growth of the population living in this area or in the immediate vicinity of the new Metro line. The highest population growth can be observed in the Dubai Investment Park 1 area, where the population increased by more than 1000% from 2008 to 2020, registering an annual growth of more than 92%.

The appearance of a Metro station in a neighborhood is a phenomenon recognized by the rapid growth of the population and the rapid development of infrastructure, which is the most important premise for increasing connectivity in the area and developing adjacent transportation infrastructure to support more people.

In terms of connectivity, this neighborhood benefits significantly from public bus and taxi lines. The connection with the rest of Dubai is made through three main bus lines 91, 91A and 99. The only inconvenience of this type of transport is the long travel time in certain parts of Dubai, for example a trip from the town center takes about 139 minutes, time that is high due to the fairly large distance from the city center, and an average of trips that are recorded in the entire region of Dubai is 120 minutes. This example illustrates how much time would be required in the absence of Metro service. Using the town center as an example because the town center is far from the Jebel Ali area, and if someone takes the Metro from the Jebel Ali Metro station achieving a destination or even rounding the entire city of Dubai will take much less time than using a personal mode of transit system.

Here comes the appearance of the Metro that shortened these distances substantially, namely, a Metro ride from The Town Center takes 79 minutes, about 60 minutes less, the average Metro ride in the same areas is 35 minutes. Thus, the utility of the Metro is again highlighted and is probably the best and easiest method of connectivity in Dubai.

In addition, in Jebel Ali there are two Metro stations, one very close, just 6 minutes' walk, and the other 26 minutes' walk, at the same time the Metro is 56 minutes' walk. Jebel Ali can only be reached on four bus lines, these being 99, F54, 91, 91A.

In terms of numbers, there is a strong correlation between residential areas, population, and connectivity in this area. Thus, the best values of connectivity are found around residential centers,

characterized by areas with huge population densities. With a major impact on the transport network and transport infrastructure, but with a road network very well developed by quality and number of streets.

The connectivity map of the Jebel Ali area (Figure 46) shows the distribution of the types of connectivity from the areas. Thus, the residential areas are noted, as well as the most important from a social, economic, and financial point of view of Jebel Ali, which has a high connectivity, surrounded by residential, industrial and economic areas that have a lower connectivity characterized by average. Finally, the areas on the edge of the district, usually characterized by high streets, of great importance, but being in small numbers are attributed to an area of low connectivity, since it does not contribute exceptionally to transport and connectivity within the district. it contributes more to the connection of the district with the other areas of Dubai.

Jebel Ali ultimately represents the best connectivity in the three areas, distinguishing itself from the others by the multitude of areas of high connectivity.

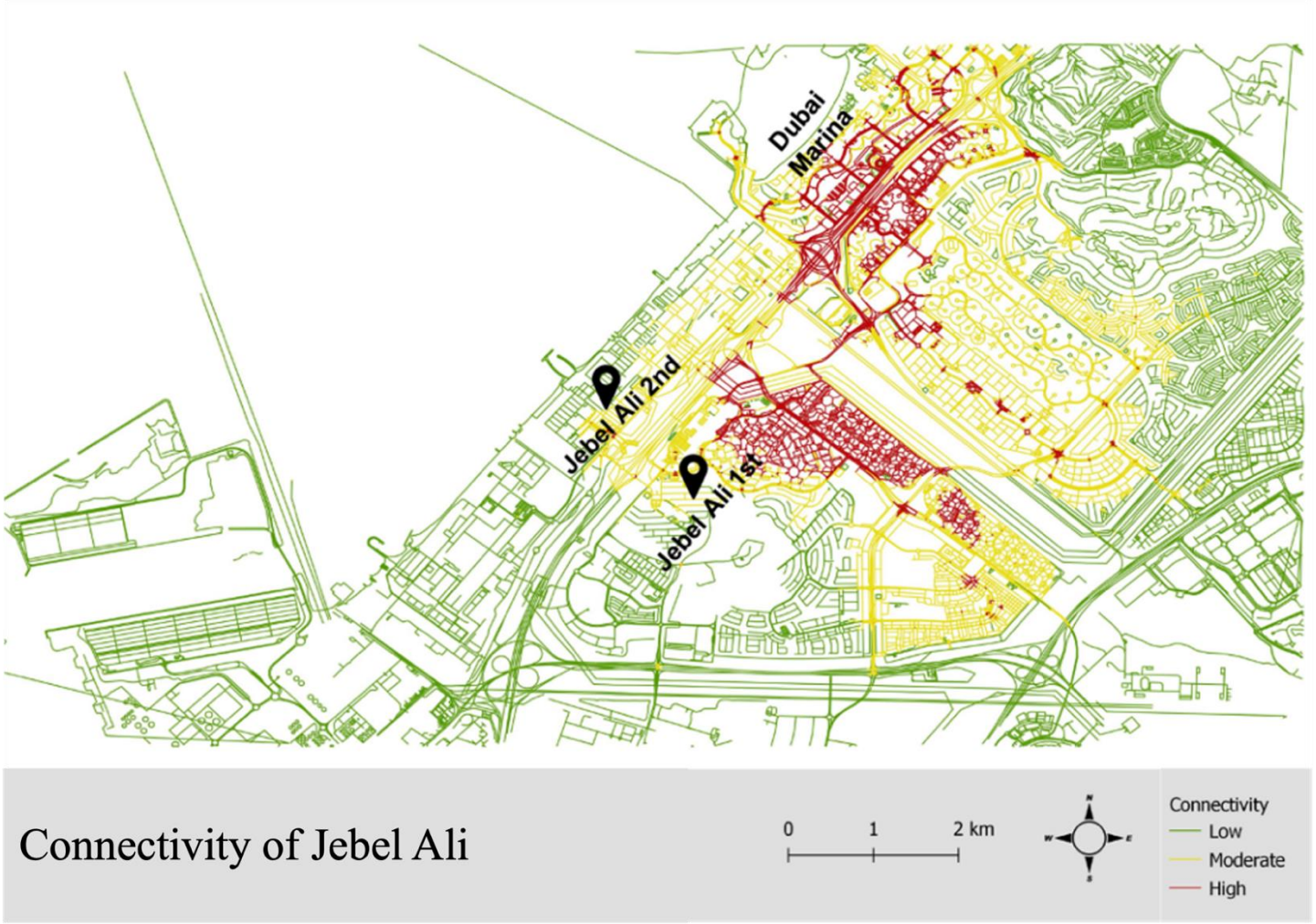


Figure 46: Connectivity of Jebel Ali district in 2020

Al-Barsha Metro Station and Surrounding

The connectivity analysis shows that Al-Barsha Metro Station and it is surrounding has higher connectivity level comparing to other areas, but a little bit lower than Jebel Ali and Business Bay.The reason why Al-Barsha ranks third among connectivity is the lack of large residential spaces and transport infrastructure adjacent to it,

The biggest difference between Jebel Ali connectivity and Al-Barshadistrict connectivity is that in Jebel Ali, it was represented by the streets adjacent to the main ones, more precisely the residential and connecting streets of this area, and in Al-Barsha, the high connectivity it is represented by the main streets that cross the district and the newly created Metro line.

In terms of population, it is growth in Al-Barsha is similar to that of Jebel Ali, over 1000% in the last twelve years and an increase of more than 94% per year. These numbers indicate that Al-Barshais in a continuous development in terms of population and infrastructure.

The main problem, which Jebel Ali did not have, is that the areas with moderate connectivity are missing, the predominant ones being those with low connectivity.

In the case of Al-Barsha, the location compared to the center of Dubai has a major advantage over the time spent in transportation, so here the connectivity with the center of Dubai and it is areas of interest is made by bus lines 84, 93, F33, the same number of lines as in Jebel Ali, as well as the Metro line. Here the journey takes an average of 53.7 minutes, most of the trips being around this number, (Figure 47).

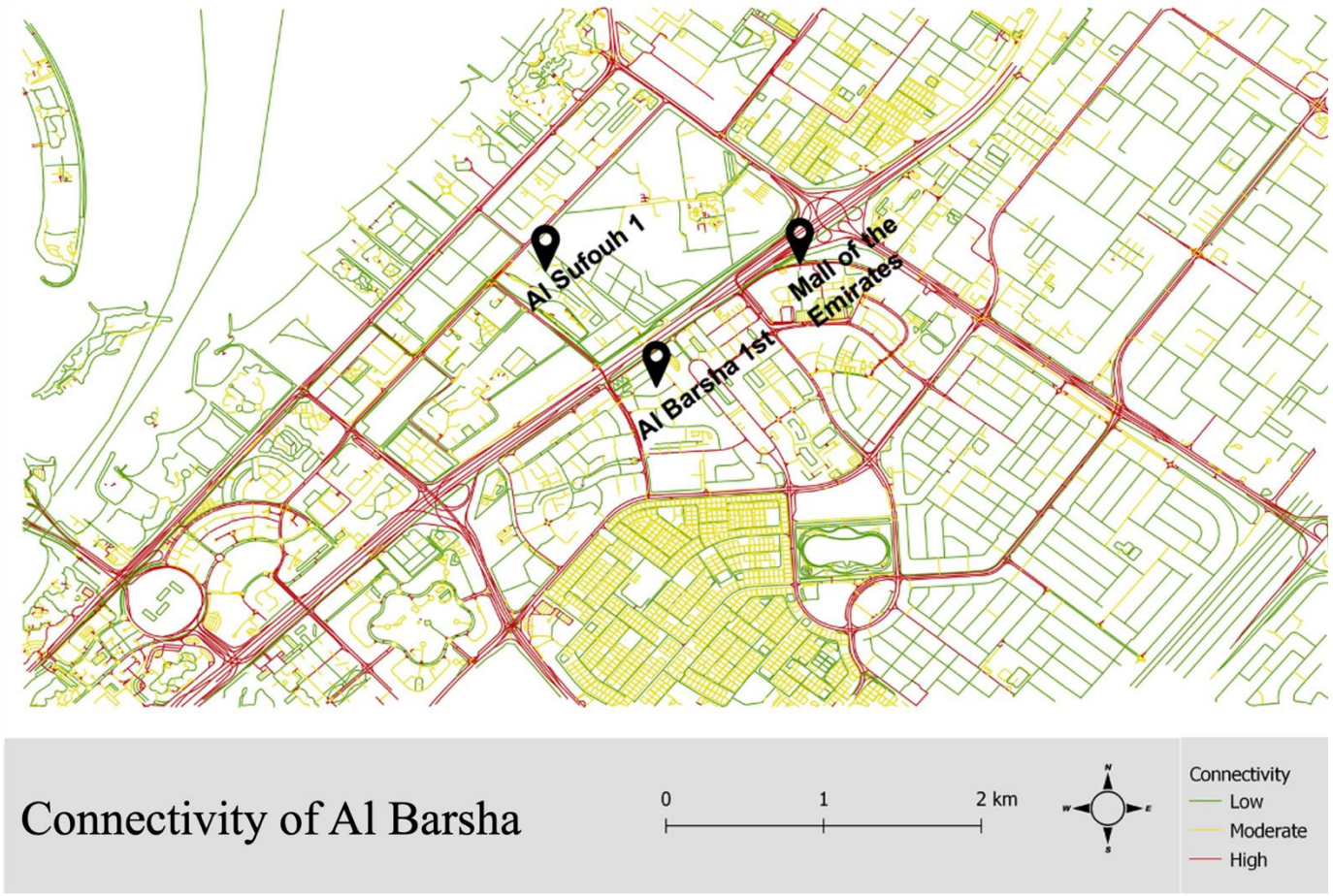


Figure 47: Connectivity of Al-Barsha district in 2020

In the case of the Metro, the trips are faster but do not reflect such a big difference as in the case of Jebel Ali, here the average trip is 44.6 minutes, about 9 minutes less than in the case of the bus trip. Around Al-Barsha there are four bus stops all less than a 13-minute walk away, while the Metro station is a 10-minute walk away. Thus, there are a larger number of bus lines leading to Al-Barsha, seven in number (Government of Dubai, 2018).

In fact, the lack of residential areas and the existence of large shopping and industrial centers can be the saving factor of this area, since the pressure on transport infrastructure is not extreme in Al-Barsha, so the streets on which the greatest pressure is put are transit. The line of Metro stations at Al-Barsha level are in an almost perfect correspondence with a high level of connectivity except for Al Sufouh which is a short distance from one of these areas.

In the future, a possible development of residential buildings and centers will put much higher pressure on transport infrastructure and will force the authorities to rapidly develop this factor which is often found to be defining for the sustainability of a space such as this one, Al-Barsha.

Business Bay Metro Stations and Surrounding

Compared to the other two areas, Business Bay is more in the pattern of the Jebel Ali area, with a high density of high connectivity around the district center and residential centers that dominate the central landscape along with the commercial ones.

At the population level, there is a smaller increase than in the other two districts, with a net increase of 600% in the last twelve years and an annual population growth of over 57%. Figure 48 indicate that the area is already highly developed, the population is largely established, and the new residential establishments of the district will begin to put increasing pressure on the transport infrastructure, which is quite developed.

Business Bay is much better in terms of it is connectivity with the center of Dubai due to it is proximity. Travel from the most important places in Dubai to Business Bay by bus takes an average of 62 minutes, while the Metro takes you to the same places in about 37 minutes, at almost half the estimated time by bus.

The bus stops are only less than 8 minutes' walk which gives the greatest advantage of connectivity to the Metro which is 25 minutes' walk. There are also situations when the Metro is a more important way to connect to areas where the bus is non-existent or takes too long. There are generally 6 bus lines connecting Business Bay to the rest of Dubai and only one Metro station to Burj Khalifa.

At the level of the connectivity map of the Business Bay district in 2020, there is a massive concentration of areas with high connectivity in the center of the area. In the areas of maximum interest near Burj Khalifa, areas where there is an impressive pressure on the infrastructure network. to the resident population but also to the tourists who visit in a huge number the city of Dubai. This area of maximum connectivity concentration is also surrounded by moderate connectivity in the Al Sufouth 1 area, and it is surroundings.

The coastal area has a higher distribution of average connectivity areas in the area compared to it is opposite area due to the access roads to the coast of Dubai which is also a tourist attraction and an important economic pillar of the city.

Low connectivity is also present around Business Bay, but the concentration of the other two, moderate and high, makes it not felt by the population in the area.

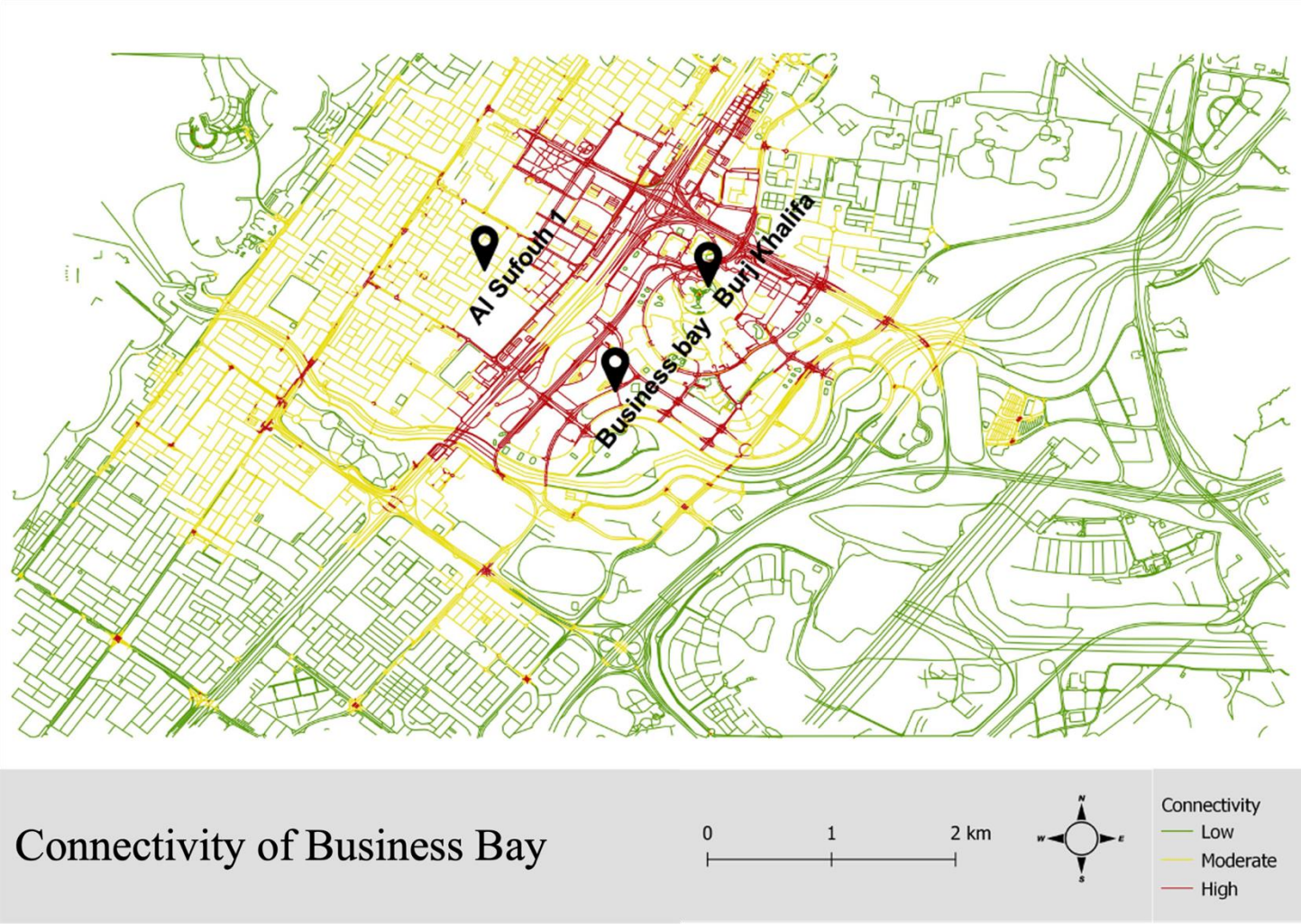


Figure 48: Connectivity of business bay district in 2020

5.3 Discussion

This study has found evidence of consistent relationships between Metro rail and urban expansion and change of land uae indicators. Accessibility and population growth are positively correlated with changes in the land uses (especially residential land), and improvements observed throughout time. Meanwhile, this association is either non-existent or significantly weaker in the before LRT random population increase. By comparing the two years, the effect of LRT on land use has been proven to be significant. As previously established in related case studies, accessibility and connectivity not only allow people and commodities movement, but also result in economic development and subsequent changes in land use.

Between 2008 and 2020, Dubai experienced massive urban expansion, it is motivated by a desire for additional living space and other domestic conveniences. The primary factors influencing Dubai's urban development are industrialization, better infrastructure, an increase in the standard of living, and cheaper land prices. As a result, the city outskirts grew into increasingly suburbs areas with most of the construction occurring near Metro stations and line routes. Without a doubt, population density increases during these 12 years in tandem with the expansion of urban development. Thus, the increase in population density and fast urbanization reflects economic progress in the region, as well as the development of Metro lines, which facilitated and improved the everyday commuter's trip. Most people live in proximity to Metro stations and surrounding districts, which contributes significantly to population growth. Residential and commercial constructions account for the majority of urban land use growth associated with the Metro line. It refers to the skyscraper structures that contain shopping malls, offices, and apartments.

Particularly, the Jebel Ali area has these types of buildings that have grown rapidly since the arrival of the Metro line. Surprisingly, Jebel Ali seaport is Dubai's largest international seaport. As

Jebel Ali constitutes most of the study area, it is necessary to determine which Metro station plays a prominent role in the Jebel Ali district. With a significant maritime economic zone, Jebel Ali station attracts more commuters seeking access to Dubai's largest seaport. This expands the region's accessibility even further. Similarly, Al-Barsha had only residential buildings before the Metro system but has since become an economic icon in the area due to its commercial massive buildings and living apartments. Business bay had a high population density before the construction of the Metro and other commercial buildings, but when the Metro's operation began, a greater number of people began to cluster near the stations, particularly in the adjacent districts. The primary reason for the comfortable ride and time savings is to get daily commuters to their destination in the shortest amount of time possible. As population increases and land-use changes because of increasing urbanization, accessibility has increased significantly in all three areas, particularly in the network adjacent to Metro stations.

Also, according to the elementary investigation of transit profile and urban space temporal profile, that depict the Dubai Metro initiative was make a positive impact on Dubai urban form which makes the high densities, complex situation. As well, due to the Metro initiative, the population grew exponentially grow with the last 12 years which attracted more commercial land utilization in and around the Metro stations. Also, the land use density and land use represent the land utility change and land value variation of the study area. There is remarkable variation in, last 12 years with the Metro Initiative. Finally, the connectivity change due to the station initiative can be seen. According to centrality and connectivity analysis, how the road network getting change can be seen. Around the Metro stations, the road network is more congested with a high number of road linkages, and connectivity was changed as cluster nodes developed around the stations. Those stations are having high centrally values compare to other nodes.

To demonstrate the urbanization caused by the Dubai Metro, the research conducted a brief analysis of areas within walking distance of Metro Stations; consequently, a 500-meter buffer zone around metro stations was determined to examine the size of the buildings. To indicate the development growth that is located within radius circle, a computational analysis has been performed using GIS, by draw the buildings before and after establishing the metro station within the buffer zone. Then create a new area field in the Attribute table. After that, the additional area was calculated. This reflected the changes and calculated how much growth occurred inside that buffer zone only as a result of being close to Metro stations. The result assessed the changes and calculated the amount of increase that occurred just because of proximity to Metro stations, see Table 11.

Table 11: Calculating the Growth of Three Districts from 500-M Radius.

Districts in Square Meters	**Jebel Ali (2008)**	**Jebel Ali (2020)**	**Al Barsha (2008)**	**Al Barsha (2020)**	**Business Bay (2008)**	**Business Bay (2020)**
Buildings in 500 meters from Metro stations	81.5	290394	215359	346614	28986	79342
Comments	Extremely significant change		Small Change		Significant change	

Due to its excellent connectivity to the pedestrian network, five metro stations, and other modes of public transit, Jebel Ali's development has risen significantly around metro stations to around 290,394 square meters. Connecting the district to the city's central facilities by providing pedestrian walkways through parks, green spaces, and recreational amenities within a 500-meter walking distance or to the nearest public transportation station. When the preparations for the Dubai Expo process began, the location of the Expo was chosen far from the city center, but due to the

presence of the metro, they were able to build it based on the metro connection to the city center that can carry people from the airport direct or their hotels to many business events taking place like International Conferences. When the Dubai Expo preparations began, the location was chosen far from the city center, but due to the presence of the metro, they were able to build it around the metro, which connects to the city center. Dubai Metro can transport people directly from the airport or their hotels to a wide range of business events including Expo 2020 and international conferences. Dubai is now prepared to hold incentive events for large corporations. Jebel Ali district provides an efficient platform for businesses, enterprises, and international organizations with the completion of the Dubai Metro. the triggered expansion of the metro has led to the expansion of the built environment and new developments have occurred in the metro area in a variety of activities including the Garden, Discovery Garden, and Al Furjan.

Al Barsha has two Metro stations and one of them is the busiest stations in Dubai, that is connected to the Mall of the Emirates, which explains why there is small change in this 500m due to the inclusion of the Mall's massive construction in one of the stations. Al Barsha used to be a collection of small buildings, the majority of which were residential, but after the provision of two metro stations, this district became a commercial hub, with numerous hotels opening near the station.

As one of the CBD's new towns, the grew in Business Bay because of to be an employment hub that enables both industry and inhabitants to be relocated from the old central city. The LRT proved important in transferring employees from the urban core to the new town's economic development zone, thereby achieving population relocation aims. As a result, Business Bay's buildings has grown dramatically, with over 50,000 square meters increased.

5.3.1 Related Theory and Explanation of Results

In cases when public transportation has been shown to influence urban growth, the majority of data are compatible with associated theory. (Cervero, 1998) and (Wegener & Fuerst, 2004) studies demonstrate that factors such as accessibility, mobility, land use mix, spatial integration, and urban configuration increasingly impact urban area decisions. Concluding that the influence of urban Metro system on land development is great. The anticipated large accessibility increases due to the introduction of lifht rail transit influenced because accessibility was already critical before the Metro was Initiated. In Dubai from 2008 to 2020, the large number of small transport units provided seamless accessibility and connectivity change can be seen. Also, the trip attractive factors land utilizations such as offices, commercialization, business, apartment, industries, and other utilities, major infrastructures... etc can be seen in Dubai surrounding the Metro stations. Transport investments such as RT necessarily made a major impact on the urban environment of Dubai, and it is one of the key factors that generate development. The urban expansion and improvement would be considered in the case of areas lacking transport infrastructure or in "advanced" transport networks, where there is a significant step of accessibility shifts or solutions to major transport conflicts, such as traffic network bottlenecks. Additionally, (Hall and Marshall, 2002) recognized two critical contextual factors relating to the impact of transportation investment on development: infrastructure investment has resulted in land use development in growing economies; and the regulatory context, such as planning controls, implies that public transport-led development tends to flourish where policies favour public TODs. Thus, these significant consequences are visible in the context of Dubai Metro development. Additionally, it is critical to recognize that the Metro investment was a critical component in the growth of TOD in Dubai. Table 12 summarizes the findings with comparisons to previous investigations.

Table 12: Comparison of Findings from Previous Studies with this Investigation

Author Name (Year)	Geographic Area	Methodological Type	Results	This research
Raguz (2010)	Manila, Philippines	Geographic Information System (GIS)	The population decreased after the Manila LRT because the city grew and new local CBDs developed, and residents desired open space free of congestion, which resulted in migration away from the city's center.	Opposite to our findings as the Dubai's population remains concentrated around the old area, but after building the Metro, the population preferred to live in places further from the city center.
Xia et al., 2017	Beijing, China	Geographic Information System (GIS)	Three metro stations with varying land use changes in accordance with their dominating land, as commercial land evolved after the LRT to become a multi-functional center, while the other two stations had fewer changes because they were residential land and industrial land.	This study matches with this research findings, in that the changes in the lands were relying on the number of stations located in the area and the type of land dominated in the district.

Finally, another decisive factor had been previously mentioned, which provision of public infrastructure and financial incentives to attract and support development around stations, which exceedingly depict in Dubai. Concerning population growth and commercialization growth that can be seen. Also, Al-Barsha district having incensement of green space, TOD development, commercial development as well industrial development. The development of economic activities can be solely explained by well-developed transport facilities.

Chapter 6: Conclusion

This chapter summarize the study's accomplishments made in accordance with the research aims. Recommendations highlight additional pertinent studies and topics that should be considered in future decision-making and policy formulation.

6.1 Generalization of Findings

This study thoroughly investigates three Metro stations to highlight the effects of Light Rail Transit on Dubai's urban development. Using GIS and remote sensing techniques, this study estimated the change in urban land use, urban development, and population density associated with the development of the Dubai Red Line Metro from 2008 to 2020. The study's findings indicate that a significant change happened in the three districts following the establishment of the Red Line. The research indicates that Dubai witnessed a high ratio of urbanization during the last 12 years. A boom of urbanization arrived after 2008 and covered almost more than half of the area of Dubai. The results of the urbanization classification demonstrate the built-up area of Dubai in 2008 was calculated to be approximately 371.86 km^2. However, by 2020, this number expanded to 570.60 km^2, a nearly 15% increase. According to the literature, the increase in the built-up area due to natural expansion reflects the natural growth of the commuter and resident populations.

The LRT has a significant redistributive effect on the area, influencing where and how development happens. Along with the Metro line, population density increased by nearly 15% over 12 years. The population density distribution pattern surrounding Dubai Metro is characterized by linear settlements that are more densely packed and concentrated near the stations.

As a result, there was significant demand for residential and commercial space adjacent to the Metro lines. The Dubai Metro's impact on the city, particularly on the growing areas of residential

and economic land, validates the relationship between the development of new Metro lines and the increase in population density. In 2008, the three districts were largely industrial and residential, with very few roads, green spaces, leisure, and commercial land. Additionally, a sizable portion of the land was underdeveloped. The year 2020 brings dramatic changes in land use; the road network became more advanced as the residential area expanded; the road network expanded with minor roads; turning it into a multi-functional center with business, commercial, and recreational uses, as well as commercial land serving as the appealing core in the TOD model. All the development increased in 2020 as a result of the arrival of the Metro System, which has a significant impact on development. That is why land-use change is also population-dependent.

The Metro's surrounding areas also saw an increase in road connectivity because of this enormous development. But the RTA's development of the road network has considered carrying capacity, built-up areas, and all other necessary parameters. This contributes to the sustainability of Dubai by ensuring that transportation and population living in the surrounding area are well-designed, as well as by ensuring that development is precise and controlled.

Due to that, Dubai city and the areas of the Metro station and surroundings accomplishment of more complex urban infrastructures, population density, building density, land uses change, road utility incensement, etc. The presence of the Metro made the city more complex and livable to citizens and visitors. Accessibility changes due to the Metro initiative –accessibility is the quality of being reached or entered. It was the major transportation benchmarking parameter required to study in this scenario. The Metro initiative is making more mobility (speed of movement) by giving access to the public. Therefore, it’s required to understand the transit accessibility change due to the Metro. According to connectivity analysis, it exhibits there is massive change in accessibility in and around the Metro Stations.

The development was mostly attributed to Dubai's rising economic standing and the technology employed in the city, which is named "The City of Innovation". However, population analysis revealed that the population increased mostly near the Dubai Metro, accelerating transportation and connectivity between the surrounding districts and the towns. Along with other developments such as infrastructure, the Dubai Metro has a significant impact on population density, as most people want to live near the Metro as a convenient way of transportation.

The land use change attributable to location factors as commerce has great influence through economies of agglomeration and speculation in focalized clusters. Through the Metro station and surrounding area development, the attraction and agglomeration of commercial land uses can be identified. Due to the Metro, it is identified that the commercialization, mix uses, and business accordingly reduces residential and greenery areas. Population density had a particular development in Dubai and surroundings of Metro stations during the time frame of the present study. As explained in Section 6.2.1, densities within the study area increased less than in the rest of Dubai. The statistics also show a decrease in housing, pointing towards higher densification within existing dwellings to maintain population levels. The Metro stations serve the areas by providing public buses and taxis to connect the people from the stations to their destinations and the Metro line accelerates the connectivity between these selected districts to the rest of Dubai. As illustrated in Chapter 4, the opening of further Metro lines, further land planning and expansion will take place around the Metro stations, which would have a clustering impact on the living of the people.

LRT can a step toward a more sustainable transportation system in terms of cost-effective mass transit options with a lower environmental impact and less likely to cause car accidents. The Dubai Metro enhances the city's transportation system's quality by enhancing urban mobility and

environmental quality while consuming less fuel, resulting in lower pollution emissions. More generally, it consumes less road space, which helps reduce congestion, and has a greater occupancy rate than other modes of travel. LRT should also be supported in other emirates, as it will contribute significantly to the overall reduction of GHG emissions from urban mobility.

This research has paved the way for various future studies to investigate some alternatives for proper land use and focusing exclusively on urban rail line growth does not guarantee noticeable improvements in the district and its surrounding areas. The study's finding will help the RTA and other concerned departments to study and figure the rapid change in urban development and Land use changes and take future steps to upgrade the Red Line to make its more public friendly and environment friendly with its sustainability in the Dubai region.

6.2 Further Transport Related Studies

Future studies have the potential to expand on this study. These are classified into studies focusing on the Dubai Metro specifically, as well as additional research or case studies evaluating the impact of a transportation system on the environment, sustainability and value of land or property in general.

The research concludes that the Dubai Metro is effective to urban development with more stable well-being and more decent living conditions by increased travel times and improving access to basic amenities. Increased population density around Metro stations will also help to promote urban growth by boosting economic development and creating new jobs and the Dubai's Metro system changes the land use and population density redistribution.

The Metro helps relieve Dubai's overall transportation system by reducing (inner city) traffic congestion and the number of cars on the road. Land use evaluations for three stations of three main

areas, including Jebel Ali, Al-Barsha, and Business Bay, can broaden the analysis provided in this study due to the complexity of gathering data for the entire Metro line. Additional studies will be conducted to estimate the economic impact, and buffer assessments throughout the Metro's surrounding areas, in order to identify how the Metro line contributes to the overall network during the lifetime of its service. Conducting interviews with decision-makers and planners at Duba's RTA, as well as administered a survey with local people, to acquire a deeper grasp of another urban development principle. Also, it's essential to have border participatory to get the community perspective regarding the Metro Initiative, like focus group discussions, key informant interviews, community mapping, time series analysis, and mind maps.

At the micro-urban scale, the analysis of transport impact assessment is need with pedestrian flows count. It will depict the walkability improvement and integration of bus terminals around Metro stations that may make more understanding on the subject. Other accessibility measures can be incorporated in future studies as well. Also, closeness centrality variation, space syntax variation, between centrality variation need to be useful to do the analysis. Additional research on the social impact and ramifications of urban density along the Metro line may be valuable. This research enables to comprehend the advantages and disadvantages of LRT, as well as the concerns of local inhabitants, to incorporate them into future phases of the Dubai Metro and spatial planning regulations.

6.3 Recommendations

This study's findings may build and analyses rail transit networks in densely populated cities, as well as to optimize and organize the operation of new and current transit lines. This exploratory study of the Dubai Metro's image revealed that, while it is the newest public infrastructure and one of the Emirate's iconic emblems, it is also one of the newest public infrastructures. Aside from this

feature of Dubai continuously striving to maintain a leading position in the global city network, the Dubai Metro, as a means of public transportation, provides an alternative to the vehicle by optimizing sustainable, reliable, and flexible transit system. The coordination of transportation and land use is crucial for achieving integrated future planning of city development. Following are some recommendations these Dubai governments or RTA departments should adopt:

1. One of the primary difficulties facing Dubai's environmental authorities has been maintaining ambient air quality within acceptable limits. Human activities, such as emissions from fuel combustion for energy, water, and transportation, and industrial operations, all contribute to pollution. The Dubai Metro contributes a major part to these emissions but is comparatively low to other means of transportation. The government should focus on the environmental sustainability of large projects like the Dubai Metro and conduct research regarding this matter.
2. The immediate environmental impact of transportation operations when the cause-and-effect link is typically readily recognized. Noise and carbon monoxide emissions, for example, cause direct damage. But there are indirect causes and effects, both financial and environmental and studies like Environmental Impact Assessments (EIA) should be conducted before implementing large transportation projects like the Dubai Metro.
3. Conducting an Environmental Management Plan (EMP) to monitor environmental elements and mitigation strategies during the operation processes and for future proposed Metro lines such as location of the monitoring (near the Project activity, sensitive receptors, or within the Project influence area); Means of monitoring, i.e., parameters of monitoring and methods of monitoring (visual inspection, consultations, interviews, surveys, field measurements, or internal and external sampling and analysis); and Frequency of monitoring will be (daily, weekly, monthly, seasonally, annually, or during implementing a particular activity).

4. The future population will continue to grow. This will increase the reliance on the transportation system and mainly on cars, resulting in Dubai's road networks experiencing traffic congestion and the environmental burden from Greenhouse Gas (GHG) emissions, consuming energy as well. Therefore, Metro timing should be increased since the Metro operates in a limited time. Hence, raising Metro timing can help to alleviate this flow of traffic.
5. According to this study, the population clusters around Metro lines, making these places ideal for new businesses and hotels. Private developers should pay for cost of the infrastructure requirements resulting from their development. Therefore, the Dubai Authority should take this possibility to boost land values in these areas to fund future Metro services.
6. Three districts (Jebel Ali, Al-Barsha, and Business Bay) have excellent public accessibility and connectivity; hence, public infrastructure improvements should occur concurrently with any new developments. The increased growth should occur in designated urban areas or empty land but not in areas recommended for natural resource or agricultural protection. The upcoming Metro Lines should be at an expressway interchange or along key arterial roads. The neighboring roadways should have sufficient capacity to accommodate the traffic and should provide safe access.

6.4 Limitations

This research experienced several challenges, particularly throughout the exploratory investigation and, more precisely, during data gathering. Due to the study's limited sample size (33 participants), maybe the sample size may not accurately reflect the actual number of passengers on the Dubai Metro. Conducting in-field face-to-face interviews as some passengers declined and rushed to catch their train. Traveling from station to station in search of participants took considerable amount

of time. And there was a weakness in these interviews, which is the absence of local residents (Emiratis), whose feedback is important in this study.

It was more challenging to schedule interviews with local individuals to reach out to all social groups, which was accomplished with eight participants only and done by phone calls. The current global situation, the covid-19 pandemic, has complicated arranging face-to-face interviews and visiting the Dubai Government to request information. And to meet the study's objectives, land use data was required, which might be gathered from secondary sources to save time and effort. Unfortunately, the Dubai Municipality declined to provide the selected districts due to concerns about confidentiality. Finally, after collecting the data, the Author dealt with software errors during the digitization processes and then analyzing using GIS new tools, which was more difficult and required repetition to get to the results. That takes a lot of time and effort for a student with an architectural engineering background to deal with.

This study contributes to advancing knowledge regarding sustainable light rail transit systems and adds information relating to the transportation effects on urban development in the Dubai Metro. Indeed, the method used in this study can be applied in various countries to determine how the land use develops around the Metro lines through time using a variety of sample sizes and periods. Additional studies on activity-based and demand-driven modes of transportation and land use integration may be necessary to clarify the requirements for transportation and land use integration.

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Appendices

Appendix A

The research questionnaire:

جامعة الإمارات العربية المتحدة
United Arab Emirates University

UAEU

MSc in Architectural engineering Program

This survey was prepared for a research within a course in the United Arab Emirates University GIS and Remote Sensing department to asses the effects of Dubai metro on urban land use.
Your participation in this survey will help us understand the overall residents' opinion about the development of land in Dubai.

تم إعداد هذا المسح لبحث ضمن مساق نظم معلومات الجغرافية بجامعة الإمارات العربية المتحدة لتقييم آثار مترو دبي على استخدام الأراضي في المناطق الحضرية. ستساعدنا مشاركتك في هذا الاستطلاع على فهم الرأي العام للمقيمين حول تطوير الأراضي في دبي

Nationality الجنسية

- ☐ Emirate - اماراتي
- ☐ Resident – مقيم

What is your gender? الجنس

- ☐ Male
- ☐ Female

Education المؤهل الدراسي

- ☐ No schooling complete غير حاصل على تعليم مدرسي
- ☐ High school graduate شهادة ثانوي
- ☐ Bachelor's degree البكالوريوس
- ☐ Master's degree الماجستير
- ☐ Doctorate الدكتوراه

What is your Current Status? ما هو وضعك الحالي؟

- ☐ Employed
- ☐ Un-employed
- ☐ Student
- ☐ Retired
- ☐ Housewife

Have you ever been used Metro for traveling - هل سبق واستخدمت دبي مترو للتنقل؟

- ☐ Yes- نعم
- ☐ No- لا
- ☐ Other-

Do you Satisfy with developing Metro rail in Dubai region? هل أنت راض عن تطوير قطار المترو في منطقة دبي؟

- ☐ Very Satisfy
- ☐ Satisfy
- ☐ Dis-satisfied
- ☐ Rather Satisfied
- ☐ Very dis-satisfied

What is your purpose of using the Metro? ما هو هدفك من استخدام المترو؟

- ☐ Office
- ☐ Personal
- ☐ College/university
- ☐ Shopping
- ☐ other

How many times in week do you travel on Metro? كم مرة في الأسبوع تسافر بالمترو؟

- ☐ I'm visitor
- ☐ < 1 day
- ☐ 1-2 days
- ☐ 3-4 days
- ☐ 5 or more days

What mode of transport you were using before Dubai Metro for travel? ما هي وسيلة النقل التي كنت تستخدمها قبل مترو دبي للسفر؟

- ☐ Bus
- ☐ Car
- ☐ Motor Bike
- ☐ other

What is your current mode of transport after developing Metro? ما هى طريقة النقل الحالية لديك بعد تطوير المترو؟

- ☐ Car
- ☐ Bus
- ☐ Metro
- ☐ Other

What would encourage you to use Metro more often? ما الذي يشجعك على استخدام المترو فى كثير من الأحيان؟

- ☐ Comfort and Safety,
- ☐ Less Dependent on a Car
- ☐ Close to leisure Activities
- ☐ Can Walk to Destinations,
- ☐ Congestion in road
- ☐ Other

What are the reasons that you choose not to use the metro to travel? ما أسباب اختيارك عدم استخدام المترو للسفر؟

- ☐ Not Reliable
- ☐ I have car
- ☐ Slow speed and frequent stops
- ☐ Take long to arrive to destination
- ☐ Societal trends
- ☐ other

What time took you to walk towards metro station from your home? ما الوقت الذي تستغرقه فى السير الى محطة المترو من منزلك؟

- ☐ Less than 10 minutes?
- ☐ 11-20 minutes
- ☐ 21-30 minutes
- ☐ More than 30

Do you prefer living near the metro stations and you can use it for your daily trips ? هل تفضل السكن بالقرب من محطات المترو بحيث يمكنك استخدام مترو لرحلاتك اليومية؟

- ☐ Yes
- ☐ No
- ☐ Does not matter

When you visit Dubai do you prefer choosing hotels that are close to metro? عندما تزور دبى هل تفضل اختيار الفنادق القريبة من المترو؟

- ☐ Yes
- ☐ No
- ☐ Does not matter

What other features of metro should Improve?ما الميزات الأخرى للمترو التى يجب تحسينها؟

- ☐ Speed of metro
- ☐ Parking for car owners
- ☐ Other

What is your Age? ما هى الفئة العمرية؟

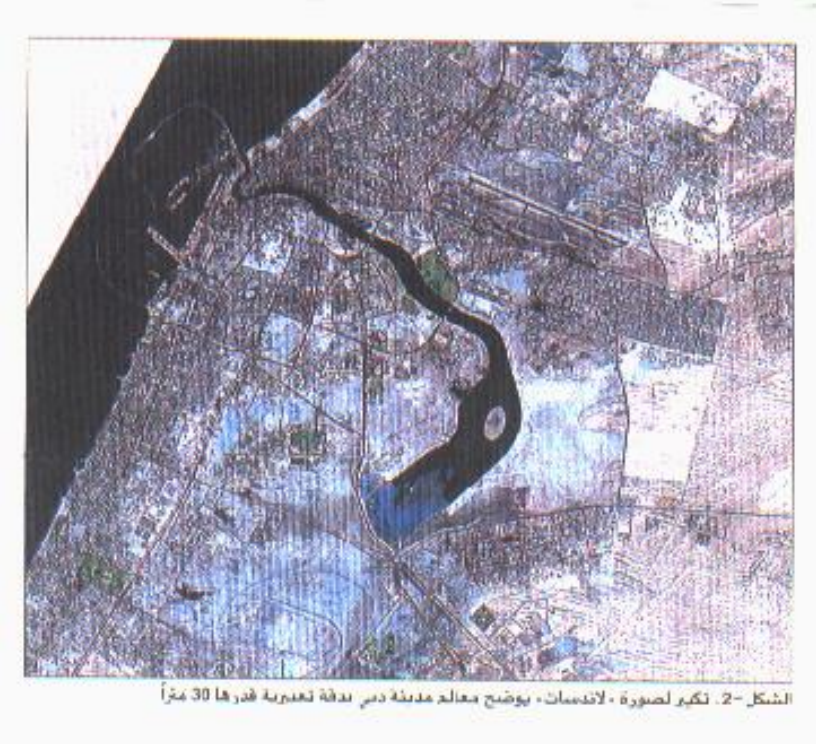
- ☐ Below 18
- ☐ 18-25
- ☐ 26-40
- ☐ 41-60

What is your monthly income level? ما هو مستوى دخلك الشهري؟

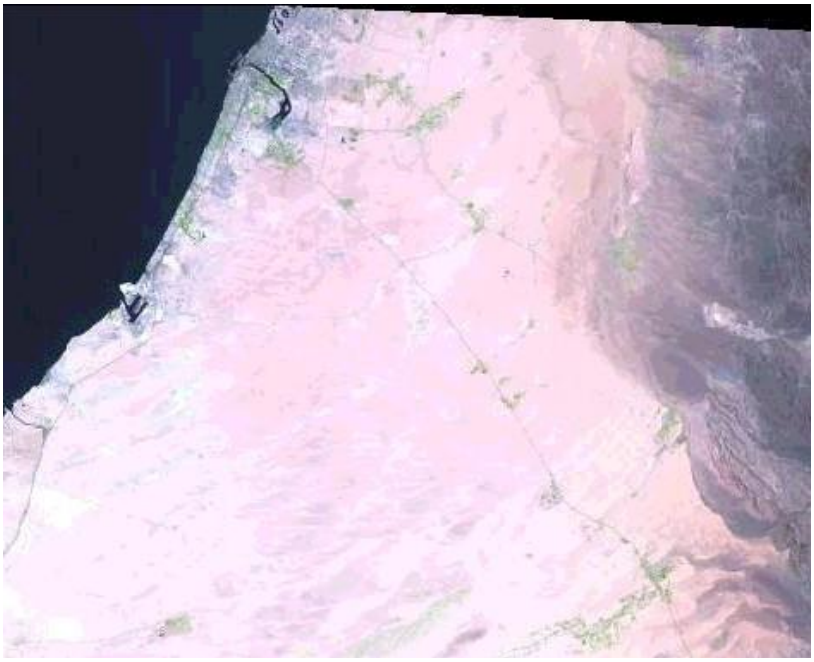
- ☐ Less than 2,000 AED
- ☐ 2,000 to 4,999 AED
- ☐ 5,000 to 9,999 AED
- ☐ 10,000 to 14,999 AED
- ☐ +15,000

Please give your Feedback on Dubai metro?من فضلك أعط ملاحظاتك عن مترو دبى؟

Appendix B



(a)



(b)

Figure 49: Dubai city views in 2008. (a) landsat for Dubai from 30 meters & (b) Landsat image for entire Dubai city in 2008, Dubai Satellite Image from Landsat 7.

Appendix C

Table 13: Proposed Lines and Details

Proposed lines	**Details**	**Number of stations**
Purple line	The purple line is plan along the Al Khail Road. The line will extend from the al Maktoum airport to Muhaisnah. There will be 9 Metro stations and three check-in facilities.	9 new Metro stations
Blue line	The line is proposed to go align the Sheikh Mohammed bin Zayed road with access to the public. The line is planned to open by 2030.	18 new Metro stations
Pink line	While the Pink Line appears to originate in Al Sufouh and link to the Dubai tram in the direction of City of Arabia, the Gold Line originate in the Dubai Marina region, continue north toward Arabian Ranches, and eventually return to the Deira area. This line was planned to open and complete the construction by 2030.	12 new Metro stations
Gold line	This line announced as yellow line 2008 and in 2013 it was changed to gold line. This line connection through the Arabian Ranches, Deira, and Dubai marina. Line planned to open and complete the works by 2025.	

Table 13: Proposed Lines and Details (Continued)

Proposed lines	Details	Number of stations
Red Line extension	The Red Line extension was with more than 15.5 km with new 6 major Metro stations. The extension project connects the axing/connected at the border with Abu Dhabi. The planned date was not confirmed	6 Metro stations
Green Line extension	The line is planned to extend by 11 km by connecting international city and al jabber. Also, expanding another distance to Al Qiyadah station by Green Line by 7.5 km will be a major impact on the urban growth of the area. This project will cost around AED 3 billion and it will impact to reduce 30% of vehicle traffic between this major both cities.	8 Metro stations

Source: Adapted from Data from RTA and (Pugsley, 2014)

Appendix D

Figure 50: Satellite Image Jebel Ali District in 2008

Figure 51: Satellite Image Jebel Ali District in 2020

Figure 52: Satellite Image Al-Barsha District in 2008

Figure 53: Satellite Image Al-Barsha District in 2020

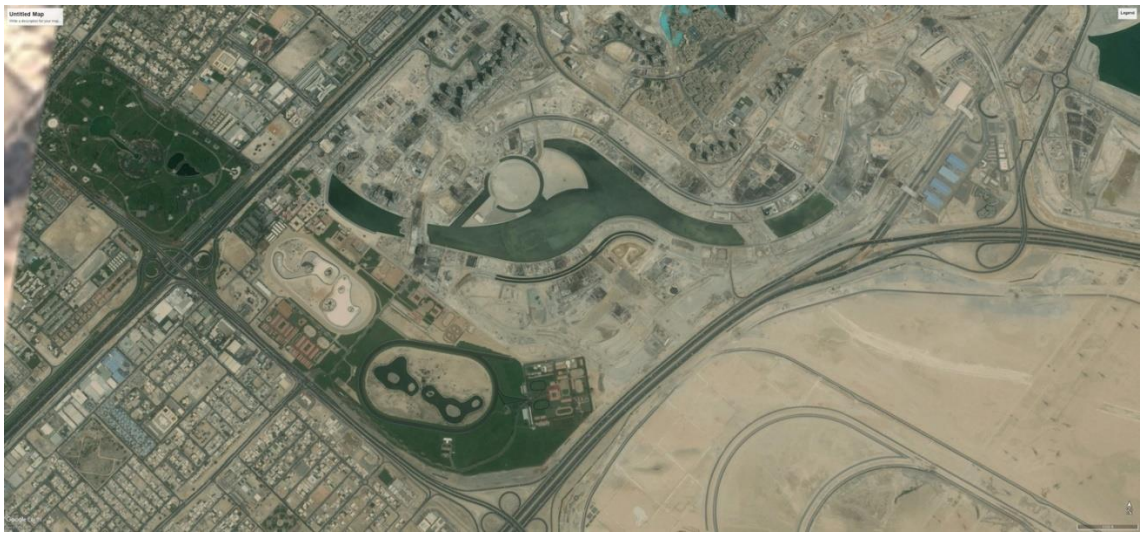


Figure 54: Satellite Image Business Bay District in 2008

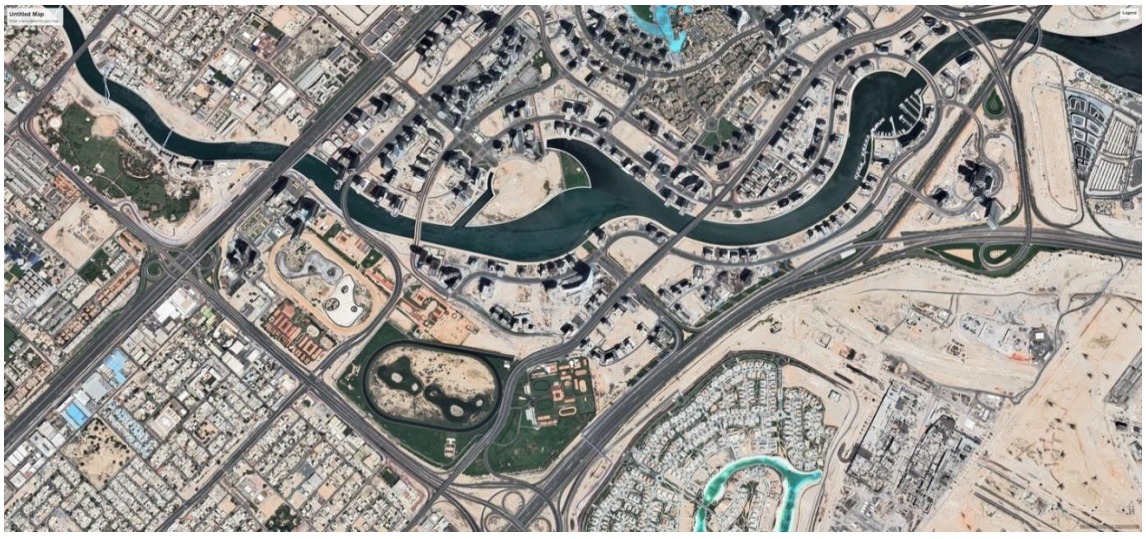


Figure 55: Satellite Image Business Bay District in 2020

UAE UNIVERSITY MASTER THESIS NO. 2022:51

The research context perspectives sustainable transportation as a mode of human development in which resource use aims to meet human needs without increasing the demand for new roads, while protecting the environment from pollution and reducing energy consumption. Therefore, Dubai's Road Transport Authority developed the LRT system, which is the city's Metro. The results indicate that Metro play a vital role in enhancing population density, mixed land use, and connectivity around the Metro stations.

Dhabia Alefari received her Master of Science in Architecture Engineering from the Department of Architecture Engineering, College of Engineering at UAE University, UAE. She received her BSc in Urban Planning from the College of Humanities and Social Science, UAE University, UAE.

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