

ASSESSING THE EFFECT OF URBAN GROWTH ON MOBILITY TRANSFORMATION–DUHOK AS A CASE STUDY

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ABSTRACT

Duhok's rapid urban growth with its car-oriented transport system in the recent decades has raised concerns about its future implications on residents and the environment. The increase in the number of cars, a lacking alternative transport system, and investment in car responsive facilities are causing constant issues of traffic congestion and environmental degradation. This study will investigate the impact of the rapid urban growth in Duhok city and the history and problems of the city transport system across decades. Findings show that the previous public transport system disappeared, reportedly, due to political and security reasons, changes in affluence and economic development, trading patterns of private cars and taxis into the region, complications in government revenue, and priorities of development and planning directions. Furthermore, the government prioritized constructing car responsive infrastructure of roads, bridges, and car parks, resulting in degradation of land and resources and gradual replacement of green and open spaces in favor of car-oriented land use. This car-oriented trend is further shown through the city's low vehicle occupancy rate, which shows an average rate of 1.56 and high household vehicle ownership.

KEYWORDS: Urban growth, Car Oriented Development, Public Transportation, Land use, Vehicle Occupancy.

1. INTRODUCTION

Urban growth continues to exist in most urban settings around the world, changing the social and physical aspects of the area. Since they reside at the center of development of communication and economic growth, cities contain functions for the people to make use of (Kuddus, et al., 2020). Historically, movement within cities was solely made by walking, thus how many cities have agglomerated and compact forms. The evolution of transportation impacted urban areas where they become shaped by transportation infrastructure, mainly roads and bridges. City peripheries started to expand and new activities were starting to be dispersed in new centers rather a single city center. A vicious cycle started to emerge as more activities further from the city center required more motorized travel, leading to an increase in the number of cars owned and bringing with its externalities (Rodrigue, 2020).

Most of the production and consumption activities are heavily fixated in cities, leading to major challenges in need of tackling, including

environmental degradation, poverty, inequality, and most importantly for the context of this research, transportation challenges (Kuddus, et al., 2020). Transportation options are continuously affected by land use patterns and development in transportation usually impacts patterns of urban development. The connection between land use and transportation carries with it implications on people's decisions for living and working, since the land use distributions create demand for transport while the supply of it enables land uses to be distributed (Marshall & Banister, 2007). According to Banister (2005) societies around the world are becoming more and more urbanized, where over half the world's population are starting to live in cities, with the year 2025 expected to have 61% global urban population. As cities continue to grow, so the distance between centers of activity, bringing with them investment and migration attraction. The more investment takes place in cities leads to attraction of more human capital, requiring more face-to-face contact, bringing with it more need for transport. As Banister (2005) puts it, sustainable transport systems are those which

consume less resources, utilize less space, reduces externalities to the environment and humans while utilizing renewable energy sources, and offers multiple modes to choose from. This study will investigate the impact of the rapid urban growth in Duhok city and the history and problems of the city transport system across decades.

1.1. Research Problem:

Duhok city is increasingly packed with cars, and when the local government is providing transport infrastructure away from a sustainable transport city policy, it is becoming responsive to the increase in the number of cars used in the city, hence leading to traffic congestions during peak hours of the day. In light of this, response from the government's side has not only been opposite the promotion of an alternative CTS (City Transport System), but rather market oriented as most investment in physical capital is being favored to encourage further car use. Construction is leaning more towards roads and bridges, rapid high-rise tower construction, and complementary transportation facilities like car parks and petrol stations, which further degrade the environment. With that, the city is increasingly dependent on a car-oriented city transport system. Since the year 1987 Duhok city has been relying almost solely on a car-oriented city transport system (CTS), where the city's current CTS is comprised majorly of private cars and taxis, with some degree of mini-buses, may be regarded as wasteful in terms of resources and land use, detrimental to the environment, and fragments the society (Al-Wattar, 2013). This, in turn, places Duhok city's car-based CTS into the territory of a term known as Unsustainable Transport System.

1.2. Research Objectives:

The objectives of this research are:

1. To understand the changes of Duhok city's population growth and its impacts in the natural and built environment overtime.
2. To trace the development history of Duhok's City Transport System over a dedicated period and comprehend its dynamic history.

2. METHODOLOGY

Through using a Case Study Research Design of employing qualitative and quantitative methods of data collection, the researcher will be able to investigate to employ the necessary methods of data collection to study the history of the city's transport system evolution and delve

through the many variables that have enabled such a system to prevail in the city over the years.

2.1. The Study Area

Duhok is one of the cities in Kurdistan region of Iraq. As with other cities in Kurdistan region, urban growth has been going on for decades, which is associated with the continued expansion of the city's built environment as well as the associated economic and social activities. The city is seeing a rise in horizontal and vertical expansion brought about by the natural increase in population, migration, the spread of the limits of Duhok city municipality, and improved affluence of the residents. With this growth, population size and housing units have been increasing and the city has been expanding, leading to the stretch of the city's municipality limits.

The city's population grew from nearly 10,000 inhabitants back in the year 1957 to nearly 280,137 in 2009, and is now sitting at around 450,313 inhabitants (Directorate of Statistics in Duhok, 2023). Recently, urban development in the city has leaned more and more towards road construction and high-rise buildings at a quick pace, while at the same time encouraging car-oriented infrastructure such as parking and fuel stations. All of these have strained the environmental aspects of the city and further aided in shifting the city's transport system to an entirely car-oriented system, with high emphasis being on private vehicles and taxis and neglecting the public modes of transport such as buses and mini-buses.

2.2. Urban Growth of Duhok city

For the purpose of understanding the urban growth process of Duhok city across the years, a detailed analysis was conducted using historical censuses and other secondary data in order to demonstrate an image of the growth of the city across different years, plus the dynamic growth rates. Using data collected from various publications and directorate statistics, the population number and growth rates of Duhok city for a selected number of years has been constructed as seen on Table (1).

Across many periods, Duhok city has been experiencing different growth stages, resulting, often, from a very high natural population growth rate in the region and Iraq as a whole. From different historical circumstances including Revolutions, Wars and conflicts, fleeing and displacement, and migration, the population of the region always fluctuated. In

addition to the aforementioned circumstances, urban growth in Duhok city has also resulted from: the natural population increase; internal migration; and reclassification of rural areas in Duhok city's boundaries.

According to the directorate of Statistics in Duhok (2023), the population number of the years following 2009 has been based on estimates, whereby 2017's population is estimated at around 361,610 persons. Not much difference in growth has been seen in 2023, although the city's population is estimated to have reached 450,313 persons, an increase of nearly 100,000 from 2017. The city's orientation started moving towards vertical development where high-rise buildings are seeing a rise in Duhok. In 2017, investment grew in this sector and more high-rise apartment buildings (locally called Towers) started being planned and constructed. Across these periods, there was significant urban growth observed all across the city. Using ArcGIS, the researcher calculated the change in city area across the periods. Starting from 1957, the area of the city was at around 1.23 km², which grew significantly in the coming decades where it reached 12.06 km² in 1987. In the year 2009, the city had an urban area of around 39.36 km². Currently, it is sitting at around 50.0 km² in the year 2023. Phases of Duhok city's Population and Urban Growth between 1957-2023 can be seen on Fig. (1).

Table (1): Population size and Growth Rate of Duhok city for selected years between 1987 – 2023.

Year	Population	Annual Growth Rate and Period	
		Growth Rate %	Period
1987	114,322	3.6	1987-1996
1996	169,221	3.4	1996-2009
2009	280,137	4.0	1998-2009
2013	319,774	3.4	2010-2013
2017	361,610	3.0	2013-2017
2023	450,313	2.8	2017-2023

Sources of Data: Population size for the years 1987 and 1996 retrieved from the Directorate of Statistics in Duhok (June, 2023), Population size for the years 2013, 2017, and 2023 are estimates retrieved from the Directorate of Statistics in Duhok (June, 2023) based on the Republic of Iraq 2009 building, housings, establishments & household census by the Central Statistics Office in Iraq (CSO).

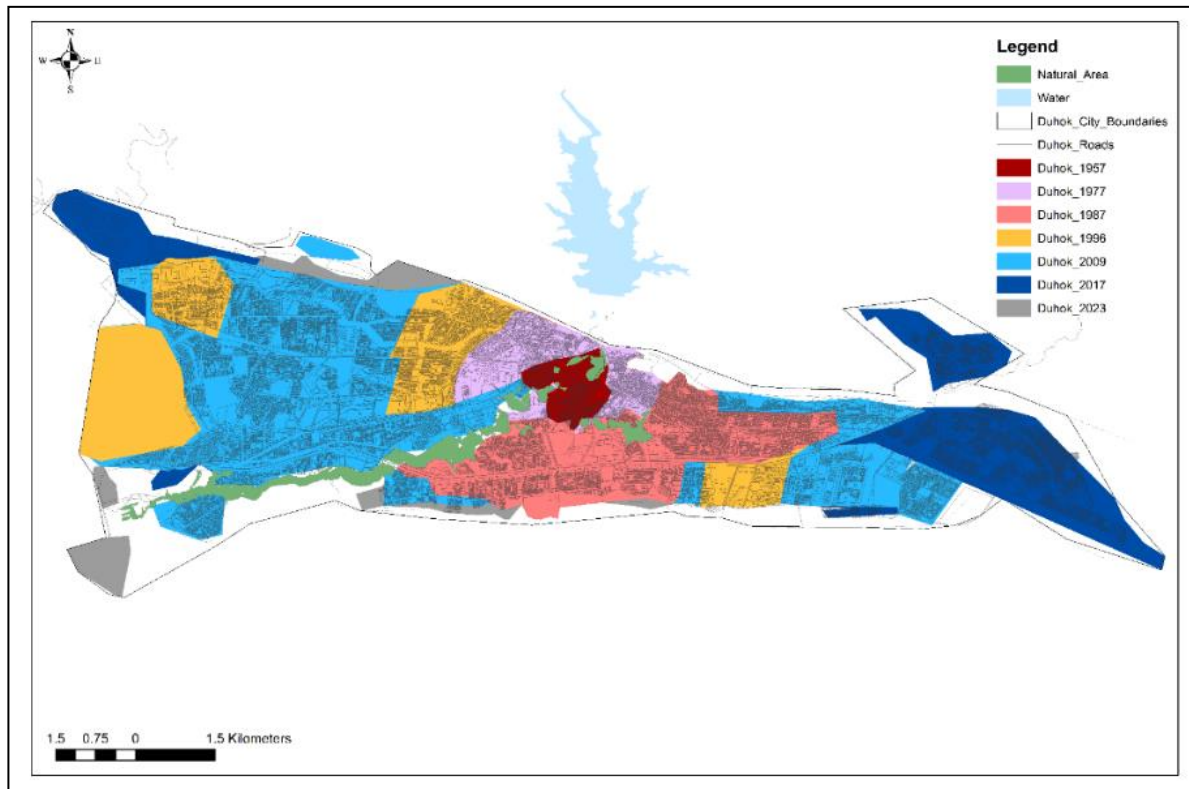


Fig. (1): Urban Growth of Duhok city (1957 – 2023).

Source: Constructed by the Researcher using ArcGIS, based on Hajani (2019) and Google Earth Satellite Imagery.

2.3 Data Collection Methods

For data collection, a Mixed-methods research has been adapted for the purpose of combining both qualitative and quantitative inquiry approaches, enabling the collection of both data sets, and using them together to provide greater strength for the research (Creswell, 2009). This was deemed fit for the purpose of gaining benefit from both methods and reinforcing the study with numerical analysis and prevailing trends along with qualitative responses and observations of the city transport system.

The researcher included both forms of data sources for the purpose of strengthening the data collected and to assure the upmost inclusion of all relevant data that can be of aid to the research. Primary sources encompass observations, interviews, and questionnaires, while secondary sources involve the process of extracting already available data from documents spanning from records, publications, or censuses and statistical reports (Kumar, 2011).

Participant observations were conducted to allow the researcher to passively observe the transportation trends and be an active member on the ongoing activities through driving through the streets and getting an image of how

the city functions. In addition, the researcher explored vehicle occupancy surveys of the traffic flow to determine the vehicle occupancy rate within Duhok city. An online questionnaire form was designed containing 52 open- and closed-ended questions pertaining to specific travel behaviors of Duhok city's drivers and/or passengers. The form sample can be seen in the Appendices on page 15. Regarding interviews, a form of non-probability sampling was used known as Expert sampling where, based on the researcher's judgment, the experts were selected and asked to participate in the interviews. The Key Informant Interviews (KII) were conducted with personnel in Governmental Directorates as well as Academic Staff working in the College of City and Regional Planning in the University of Duhok who were deemed to have knowledge to the scope of the research to further add to the researcher's knowledge and enhance the findings on the important research questions. The questions form used for the KIIs can be seen in the appendices on page 16. The governmental directorates in question included: Directorate of Transportation in Duhok; Directorate of Traffic in Duhok; Municipality of Duhok; and the Directorate of Statistics in Duhok. In addition, to enrich the responses collected particularly

regarding the historical context of the city's transportation system, the researcher tried to fill the gap by interviewing Knowledgeable Persons who have lived through, and have knowledge on, Duhok's transportation system in the 1980s and onwards.

Vehicle occupancy rate indicates the number of passengers that are within a vehicle during a trip. Usually, the higher this rate, the higher the efficiency of energy use and economic resources and an indicator for the efficiency of the public transport system. Low vehicle occupancy rates indicate car reliance, thus a community with a vehicle-oriented land use and dependency on private cars. Occupancy is impacted usually by the time of day, day of the week, trip purpose, and often season. In general, travel purposes for work or education have lower vehicle occupancy than travel for recreation or social gatherings (Sullivan & O'Fallon, 2003)

The researcher conducted a process of surveying vehicle occupancy through self-filling out forms which contained fields for different types of vehicles (car, taxi, bus, and truck/pickup), along with the number of passenger present in each vehicle during the time of observation. This was done over the three main peak hours existing within the street network of the city (8:00 to 9:00 AM, 2:00 to 3:00 PM, and 7:00 to 8:00 PM), which were based on the results of the users survey conducted and shown in the next chapter. The researcher surveyed the traffic flow during these three times (one hour each) and measured the vehicle flow and vehicle occupancy rate. This process was done over two different months of the year (July and December) in order to capture the variations in the vehicle occupancy rate for the time where usual schools and colleges are on summer holiday versus regular college days in Mid-December. The researcher spent 3 days of collecting these data for each month to ensure equitable collection. By using weighted average calculation, it is possible to measure the vehicle occupancy rate for each of the three times of the day:

$$\bar{x} = \frac{\sum x_i f_i}{\sum f_i}$$

Where:

\bar{x} = Vehicle occupancy rate;

x_i = Number of passengers;

f_i = Number of vehicles counted;

2.3. Sample Survey

For the sample survey of users and passengers in the city, the population for the residents aged 18 to 30 years old, being 127,789 persons as acquired from population data from the Directorate of Statistics in Duhok (2023), were included within the sampling process by using the following formula:

$$Sample\ Size = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2 N}\right)}$$

Where:

N = Population Size, Z = z-score, e = margin of error, and p = standard deviation.

An 85% confidence level has been chosen which can allow the researcher to reasonably control and conduct the survey. For a confidence level of 85%, the z-score, acquired from the z-table, is equal to 1.44. The population N is the number of people aged between 18 and 30 out of the total Duhok city population being 127,789 persons. E is the margin of error, a smaller margin of error leads to more accurate results but with larger sample sizes. A standard for margin of error used is 5%, but for the purposes of this research, a 10% value will be used for a more controllable sample size. The standard Deviation (P) refers to how much variation is expected from the responses, which is usually set at 0.5. The sample size formula shows that a sample size of 52 participants needs to be included within the survey.

$$\frac{\frac{1.44^2 \times 0.5(1 - 0.5)}{0.10^2}}{1 + \left(\frac{1.44^2 \times 0.5(1 - 0.5)}{0.10^2 \times 127,789}\right)} = 51.81 \cong 52$$

3. RESULTS AND DISCUSSIONS

The researcher employed various methods of analysis to conduct the research and achieve the objectives set at the start. The data collected were used to construct narrative and explain the themes of analysis which will be discussed accordingly:

3.1 Responses from the Users Survey

When the respondents of the survey were asked on the number of times they drive or become passengers on a daily basis. A relatively high number of private car trips are apparent in the city as indicated by 56% of responses who conduct 2 to 3 times per day trips by the users (Fig. (2)). When asked about the number of passengers in addition to the driver, 52% responded having 1 to 2 passengers, thus lower vehicle occupancies reflect higher energy consumption and less sustainability, posing considerable effects on the transportation network of the city (Fig. (2)). Also, regarding the number of cars each household own, 48% indicated possessing 2 cars, where higher vehicle ownership relates to higher car-reliance in the city (Fig. (3)).

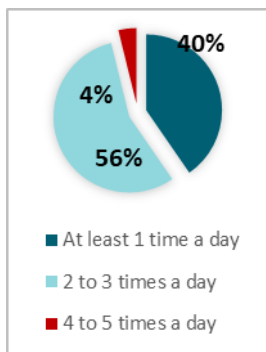


Fig. (2): Number of times a day people are driving or being a passenger in a car on a daily basis.
By the researcher.

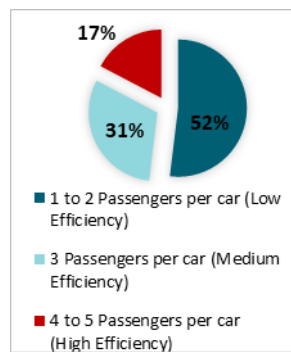


Fig. (3): Passengers per vehicle.
By the researcher.

The respondents were asked about the times of the day where there is traffic congestion on the streets. Based on responses from all 52 respondents, 9:00 AM was the highest chosen time for traffic congestion with 19% (36 times chosen). This was followed by 2:00 PM with 9% (21 times chosen), and 7:00 PM with 11% (27 times chosen).

To analyze congestion and land use activity within Duhok city, two questions on the survey were provided. First, the respondents were asked to indicate on which sections of Duhok city they find the most traffic congestion. According to responses, the most selected area was the KRO/Shakhke zone with 37% (47 times chosen) followed by zone the City Center with 28% (36 times chosen). Other zones also of relevance include Barzan Road and governmental directorates with 10% (13 times chosen) and Baroshke and the Industrial zone with 8% (10 times chosen) (Fig. (4)). Next, when asked on the top three most attractive land uses/destinations in Duhok that people drive to, again the KRO/Shakhke and the City Center areas were regarded as most attractive with 27% (32 times chosen) and 26% (31 times chosen) respectively. Other locations chosen included the Gali/Duhok Dam area with 13% (15 times chosen) and Barzan Road/Governmental Directorates with 9% (11 times chosen).

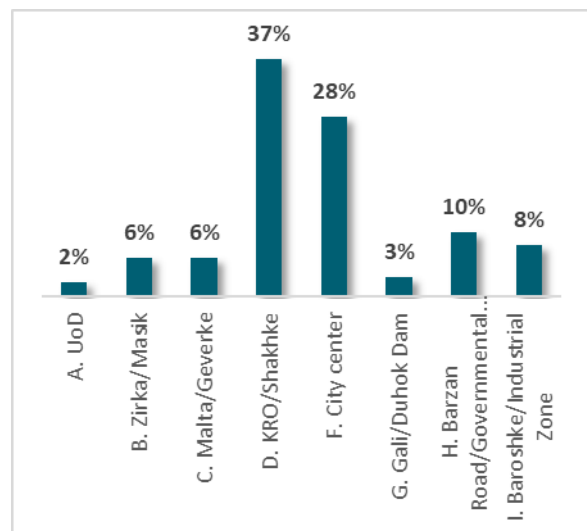


Fig. (4): Sections of Duhok city with the most traffic congestion.
By the researcher.

3.2. Analysis of Duhok CTS

Results of the vehicle occupancy rate survey show that, in July 2023, vehicle occupancy rate in the early mornings is at 1.23, referring to a very low occupancy. By looking at the afternoon time, occupancy is at 1.48, which indicates more passengers are within the vehicles during this time of day as compared to the morning. By looking at the late evening time, occupancy is considerably increasing, reaching to 1.59.

Comparing it to December 2023, occupancy

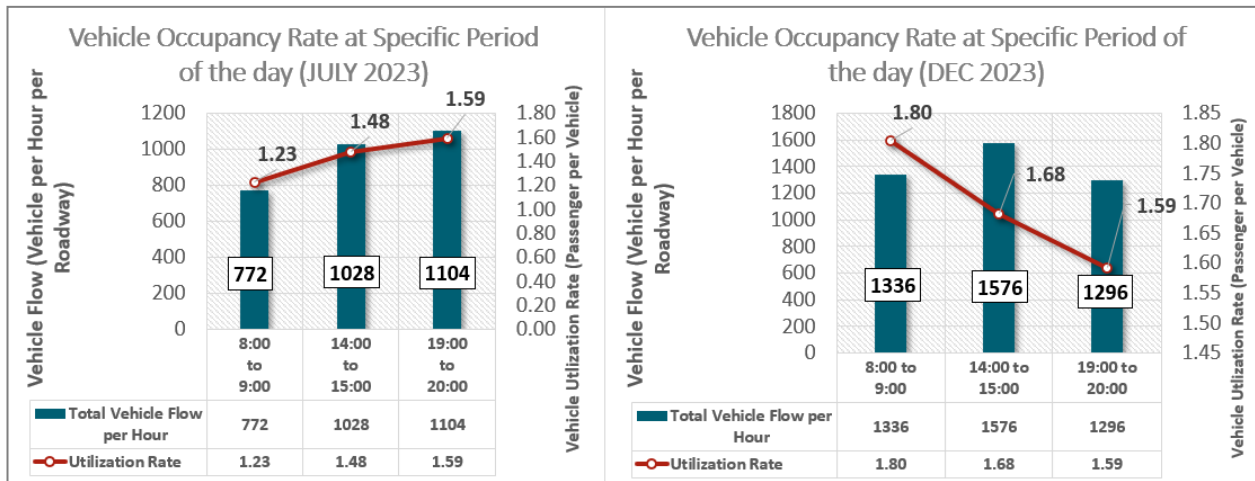


Fig. (5): Vehicle Occupancy Rate during Specific Periods of the day.
Source: By the researcher.

is much higher in the mornings between 8:00 A.M. and 9:00 A.M., reaching to 1.80, which is evidently reflected by the fact that the majority of vehicle rides are towards schools, universities, and governmental offices during the mornings of the winter season, which also accompanies higher ridership by the fact that more people use the vehicles. In the afternoons, occupancy somehow drops but not significantly, reaching to 1.68, which is again higher than it was in July. At late evening, occupancy is at 1.59, holding a similar rate as it was in July, reflecting that people travel out for recreational purposes at night in a similar fashion during both seasons.

In the summer, Duhok city has an average vehicle occupancy rate of 1.43, while in winter, occupancy is higher at 1.69. Thus, overall, it can be inferred that Duhok city has an average vehicle occupancy rate of 1.56. By looking at other countries, this rate is somehow close to the United States occupancy rate being at 1.5 persons per vehicle (Center for Sustainable Systems, 2022).

Duhok city’s vehicle-oriented land use is apparent in the urban development decisions of the past decades. More and more emphasis is being put on the construction of complementary infrastructure to the car which including a plethora of car parking spaces, countless fuel stations, and a road network designed solely to serve the car’s access while neglecting all other modes of transport. This over-dependence on cars has degraded other modes of active and public transportation, along with any future plans to establish them since the cars and taxis of Duhok city are taking the majority of the

traffic.

To further exacerbate the condition, the currently available mode of public transport in Duhok is solely reliant on mini-bus transport, which as discussed in a previous study by the researcher (Othman, 2019) is an inorganized mode that offers low reliability time management wise and low quality of service for passengers. Moreover, the routes the mini-buses travel through do not cover the entirety of the city and there are no set timetables that residents can adhere to, resulting in low ridership.

The dominance of the vehicle-oriented land use within Duhok city is seen in the Shorash Garage which is the main station for mini-buses within Duhok city, is slowly being consumed by cars as more and more space within the garage is being dedicated for private vehicle parking at the expense of mini-buses.

More evidence on the government’s prioritization of car-oriented development lies in the investment side in transportation infrastructure. As mentioned, the government plans have so far been countering the idea of establishing alternative modes of transport to the car and have been prioritizing car travel as the sole mode of transport, thus resulting in the increase in the number of cars in the city.

One plan, the tramway project, was finalized in 2015 and was intended to serve the city with different tram routes across the streets. However, the large budget of over \$1.8 million US dollars was deemed too costly at a time of financial crisis in the region as a whole and thus, did not enter the implementation stage (Municipality of Duhok, 2019).

One recent investment project, described as

one of the most important roads in Duhok governorate, Barzan road which connects to Duhok-Zakho road and towards Turkey underwent immense investment and infrastructure development between 2019 and 2022. With a budget of over 86 billion Iraqi Dinars, the road was designed to decrease road accidents, ease travel for the public, and decrease traffic congestion (Kurdistan Regional Government, 2023). Although there are benefits to these road investments, they directly oppose the promotion of sustainable form of transportation as they increase the desire for car usage. As seen on Fig. (6), Barzan road which was converted from a dominantly residential neighborhood into a corridor with over- and under-passes. The car-oriented land use that the city faced along with weak alternative modes of transport made it so that all investment kept flowing into the development of responsive infrastructure for the car, reinstating the vicious land use-transportation cycle which may continue for more years to come if these trends continue on.

Terminal. While the facility sounded as an opportunity to become a step towards Sustainable City Transport System for Duhok city and its surroundings by providing bus services, but its development direction opted towards increasing car-dependence. The facilities inside the terminal contain a zone for car dealerships, further escalating the car-oriented land use and transportation decisions that are filling the city with more cars. Adjacent to it is a Terminal for Travel Buses which houses travel companies, mainly for passengers wanting to visit cities in Turkey or its airports, and doesn't serve the city as a public transport option at all. Next to it is a fuel station, the third fuel station in this small zone, adding further to how much the city development and its zoning decisions opt for cars.

Another recent investment project implemented is the Duhok International General

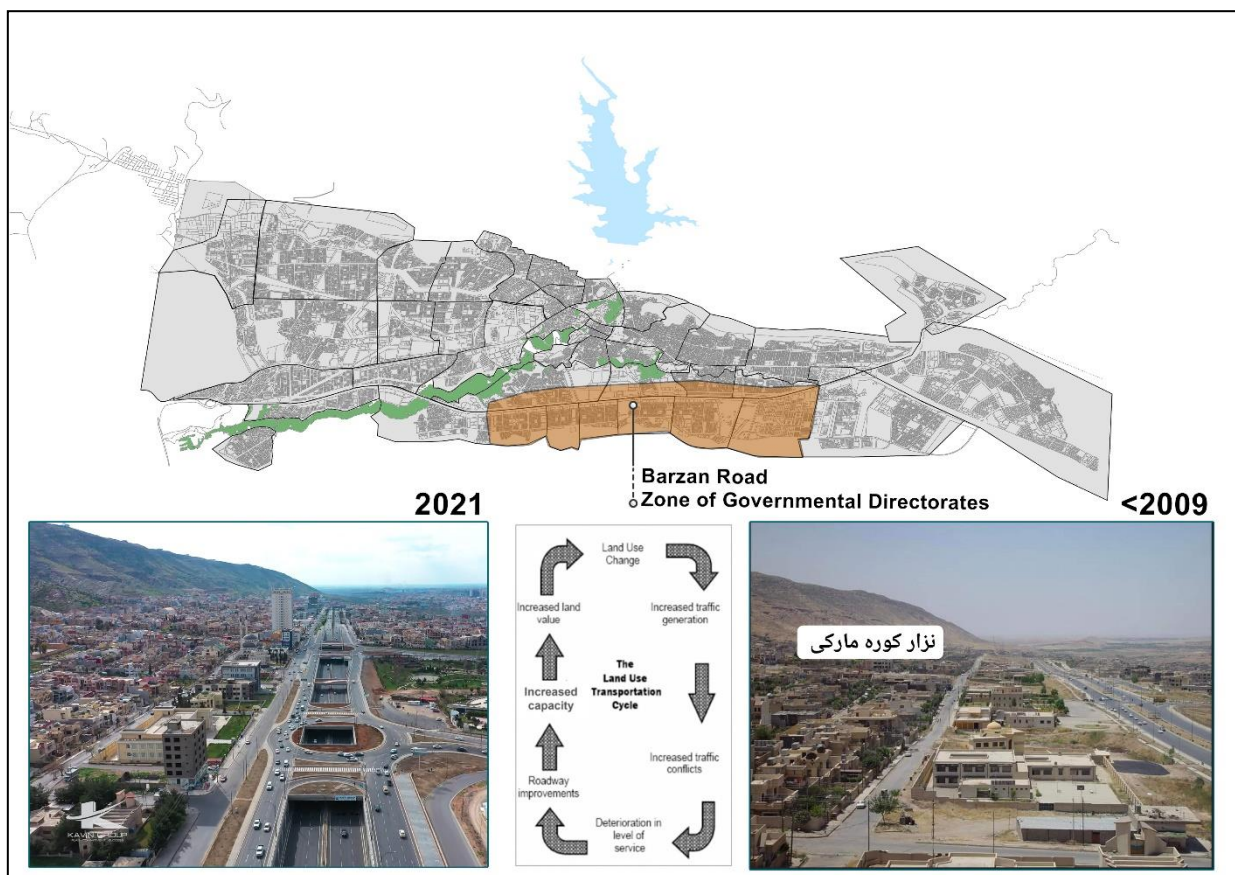


Fig. (6): The Construction of the Barzan Road Overpass-Underpass project as demand increased.

Source: Constructed by the Researcher using ArcGIS and Adobe Photoshop. Images acquired from left to right: Kavin Group (2021); Stafford Regional Planning Commission (2003); Nizar Koramarky (2023).

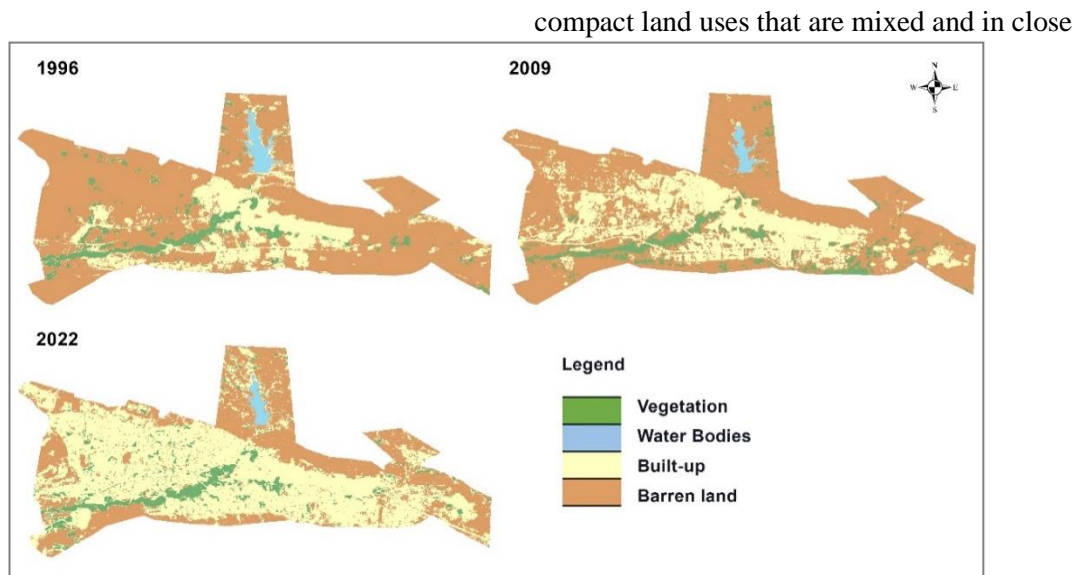


Fig. (7): Land use/Land cover change between 1996, 2009, and 2022.
Source: By the researcher using ArcGIS.

Table (2): Change in LULC Area of Duhok city between 1996, 2009, and 2022.

Classes	LULC 1996		LULC 2009		LULC 2022	
	Area (km ²)	Percentage	Area (km ²)	Percentage	Area (km ²)	Percentage
Vegetation	5	7%	5	7%	5	7%
Water Bodies	1	1%	1	1%	1	1%
Built-up	16	21%	22	29%	43	57%
Barren land	53	71%	47	63%	26	35%
Total	75	100%	75	100%	75	100%

Source: By the Researcher using ArcGIS.

To understand the degree of change of Duhok’s urban growth, a process of Land use/Land cover mapping can be used, which is changing overtime resulting from urbanization characterized by population growth, socio-economic activities, and use of land resources. This process will aid the researcher in mapping out the changes in land use/land cover (LULC) over a period of time and measure the area for changes in these LULC classes. The maps shown on Fig. (7) show the changes in the land use/land cover within Duhok city between 1996, 2009, and 2022. As can be seen, vegetation remained somehow stable with 5 km², however, built-up area continued to grow onwards from almost 16 km² in 1996 to 43 km² in 2022. This comes at the expense of barren land which has been consumed and reduced by built-up area, and to its extension transportation infrastructure, from 53 km² in 1996 to 26 km² in 2022 (Table (2)).

As components of sustainable city transport,

proximity is a necessity to allow people to walk from their homes to their workplaces without relying on motorized travel. This can be seen incredibly absent since the city’s development has been going towards sprawl patterns over the decades, forcing residents on the need for a car travel to their destinations. Another aspect of sustainable CTS indicates the need for the system to conform within the confines of the ecosystem, which the urban growth of the built-up area continued to opt for horizontal single-family housing, causing further sprawl and environmental degradation. This leads to uncontrolled motorization as a result of urban and economic growth and aggravated by a continuous car-oriented development pattern which fragments the society, causing spatial separation, between residents and the workplace. Since not everyone will be able to have access to a private car, impacting a person’s choice of mobility and participation in the society creates higher costs of moving between locations, which

are other arguments of unsustainable transportation.

Vehicles are usually known as one the main causes of CO₂ emissions, as they lead to air, water, and noise pollution. Societies heavily reliant on motor vehicle transportation are bound to experience environmental degradation and thus, residents' health deprivation. The health effects are one of the largest externalities resulting from vehicles, leading to chronic illnesses such as lung cancer (Delucchi, 2000). An important indicator for measuring externalities produced by vehicles is to compare the yearly per capita CO₂ emissions with the increase in the number of vehicles in Duhok city (Fig. (8)). Per capita CO₂ emissions indicate the annual emissions a person in a country produces, which is resulted from dividing total emissions by the total population. The data measures the amount of CO₂ is emitted from fossil fuel burning and other industrial activities. Data for Duhok city was not possible to acquire, so the Per capita CO₂ emission data for Iraq for selected years was extracted from Our World in Data website (Ritchie & Roser, 2020).

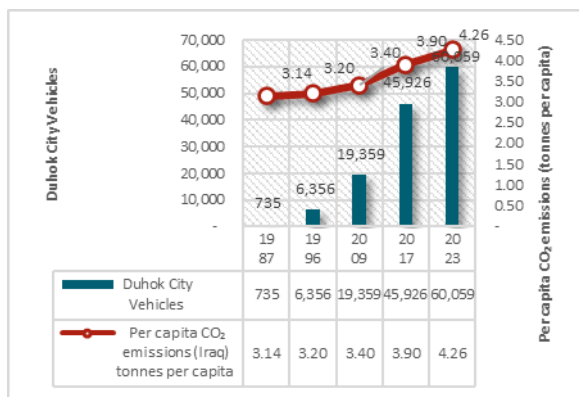


Fig. (8): Duhok city CO₂ Emissions per Capita vs. City Vehicles Increase (1987 - 2023).

Source: Number of Duhok city vehicles adapted by the researcher using data on Duhok Governorate Vehicles (Directorate of Traffic in Duhok (2023); Data of Per capita CO₂ emissions from (Ritchie & Roser, 2020).

3.3. Phases of the City Transport System and its Development in Duhok city

This section will introduce the results of the Key Informant Interviews (KII) that were conducted among 7 personnel from: Governmental Directorates (GD), Academia (A), and Knowledgeable Persons (KP).

Duhok city has gone through different development stages to become the city it is

today. For the scope of the research at hand, the starting phases that the transportation system was explored was from the year 1976 which, according to the Annual Abstract of Statistics 1975 by the Central Statistics Organization of Iraq, is when the public transport system initially started to function in the city.

3.3.1. Phase of Duhok as a Walking City (Pre-1980):

During those years (prior to 1980), the traffic load on the city's streets wasn't as heavy as there were not many vehicles roaming around the streets and the city size was quite small. During this phase, people were able to walk from the furthest points on the city to the city center in around 15 to 20 minutes, reported a respondent. Because of an unfavorable economic condition of the people back then, owning a car wasn't as widespread. Taxies were also pretty rare to find at the time, making public transportation a general common mode used among the residents. However, according to the Annual Abstract of Statistics by the Central Statistics Organization of Iraq (1976), there were seven functioning buses within Duhok, four operating on an external route and three operating internally, having a total capacity of 126 seats.

3.3.2. Phase of the Public Transport (1980-2000):

Between 1976 and 1987, a bus system was functioning in Duhok city called (Almaslaha Al'amma) which translated to the Public Interest. This was branched from the Iraqi public transport system that was functioning at the time. This system was highly desirable by the people due to its low costs. There were three buses operating within the city and four operating on external routes which transported passengers to locations outside of Duhok. Between 1990 and 1998, another type of bus system was established in Duhok city which was locally called the "Reem Buses". These buses were desirable by the people as they were cheaper compared to other forms of transportation at the time. This system was in operation up until the year 1998. Because of a poor economic condition, public transportation saw heavy usage during these years compared to nowadays. Due to possessing the first form of formalized public transport in the area, this phase was titled the Phase of the Public Transport, crossing between 1980 and 2000.

3.3.3. Phase of Gradual Replacement by the Car (2000-2009):

It became apparent to the researcher that prior

to the 2000s, there was a functioning public transport system comprised mainly of buses and it ceased to operate after the 2000s, leading to the formulation of this question to investigate the reasons behind it. One particular reason was because of political reasons, where according to responses, after the Kurdish revolution in 1991, along with the events of Iraq’s invasion of Kuwait, Kurdistan region’s infrastructure was shattered and mostly destroyed, along with many institutions.

After the 2000s, people started experiencing rising affluence and economic development. According to responses, following 2003, and the fall of the previous regime, Kurdistan region gained much decentralized control and started experiencing rapid economic development. This newfound freedom meant that people were now able to spend money for the purposes of improving their livelihoods and investors were able to explore economic growth and trade with outside countries. This led to easier and cheaper import of cars and taxis into the region, making cars affordable for families to purchase and through time, households were starting to afford their own cars. Another reason was lack of government revenue where the government was

electricity, waste management, roads, bridges, and other complementary infrastructure to the car, and other investment projects. Public transport was basically left out of all government projects.

In the year 2009, the number of vehicles within Duhok city was around 19,359 (from a total of 76,798 in the entire Governorate), serving a population of around 280,137. According to the respondents, the Gradual Replacement of the Car period was the start of what is seen today in terms of traffic congestion, parking demand and on-street parking, and the gradual degradation of the green cover in expense of the expanding urban growth.

3.3.4. Phase of Duhok as a Car-oriented city (2009-Present):

Between 2009 and 2023, the population of the city grew from 280,137 persons to around 450,313 persons. The implications of the factors that led to the disappearance of the previous public transport system and the gradual increase in private vehicles and taxis were seen in this phase of Duhok as a Car-oriented city. Because all vehicles are registered in Duhok for the entire governorate, and not for individual cities, a specific set of calculations need to be done

Table (3): Population Number, Number of Families, and Approximate Number of Vehicles of Duhok city

Duhok City			Duhok City Vehicles (Vehicle/Family) x (City Families)	Vehicle / Family	Vehicles / 100 Persons	Number of Taxi and Buses/Mini-buses (for Duhok Governorate)
Years	Population	Families				
1987	114,322	15,275	735	0.05	1	---
1996	169,221	25,631	6,356	0.25	4	3032
2009	280,137	41,584	19,359	0.47	7	6248
2017	361,610	53,971	45,926	0.85	13	17,503
2023	450,313	64,067	60,059	0.94	13	17,945

Source: Population data acquired from the Directorate of Statistics in Duhok (2023); Vehicles data acquired from the Directorate of Traffic in Duhok (2023). Number of Duhok city Vehicles and Vehicle per family ratios worked out by the researcher as mentioned in the text.

not gaining much revenue from operating the system and was reportedly facing losses. As the responses indicated, the bus system was majorly subsidized to provide cheaper prices for passengers, making keep up and operation costly for the regional government to sustain. Finally, low priority in the government's plans meant that private cars started to be given the utmost priority in investment and the government basically started focusing all infrastructure and investment projects towards the enhancement of essential service delivery such as water,

where the total number of persons within the Governorate was divided by the average family size. After reaching the total number of families in the governorate for each of the concerned years, the total number of vehicles (private cars, taxis and buses, and trucks) was divided by the number of families. This resulted in the average number of vehicles per family for Duhok governorate during each year. This was multiplied by the number of families in Duhok city to know how many vehicles, in average, there are in the Duhok city. Following this

process, the results on **Table (3)** were reached which show the approximate number of vehicles within Duhok city as compared to its population and families.

In 2009, the number of vehicles owned by each family was 0.47, which means for every two families, there was one vehicle. This almost doubled as in 2023, there is an average of 0.94

car-reliant. A summary of the phases along with the increase in the number of vehicles and families in Duhok city can be seen on the timeline on Fig. (9).

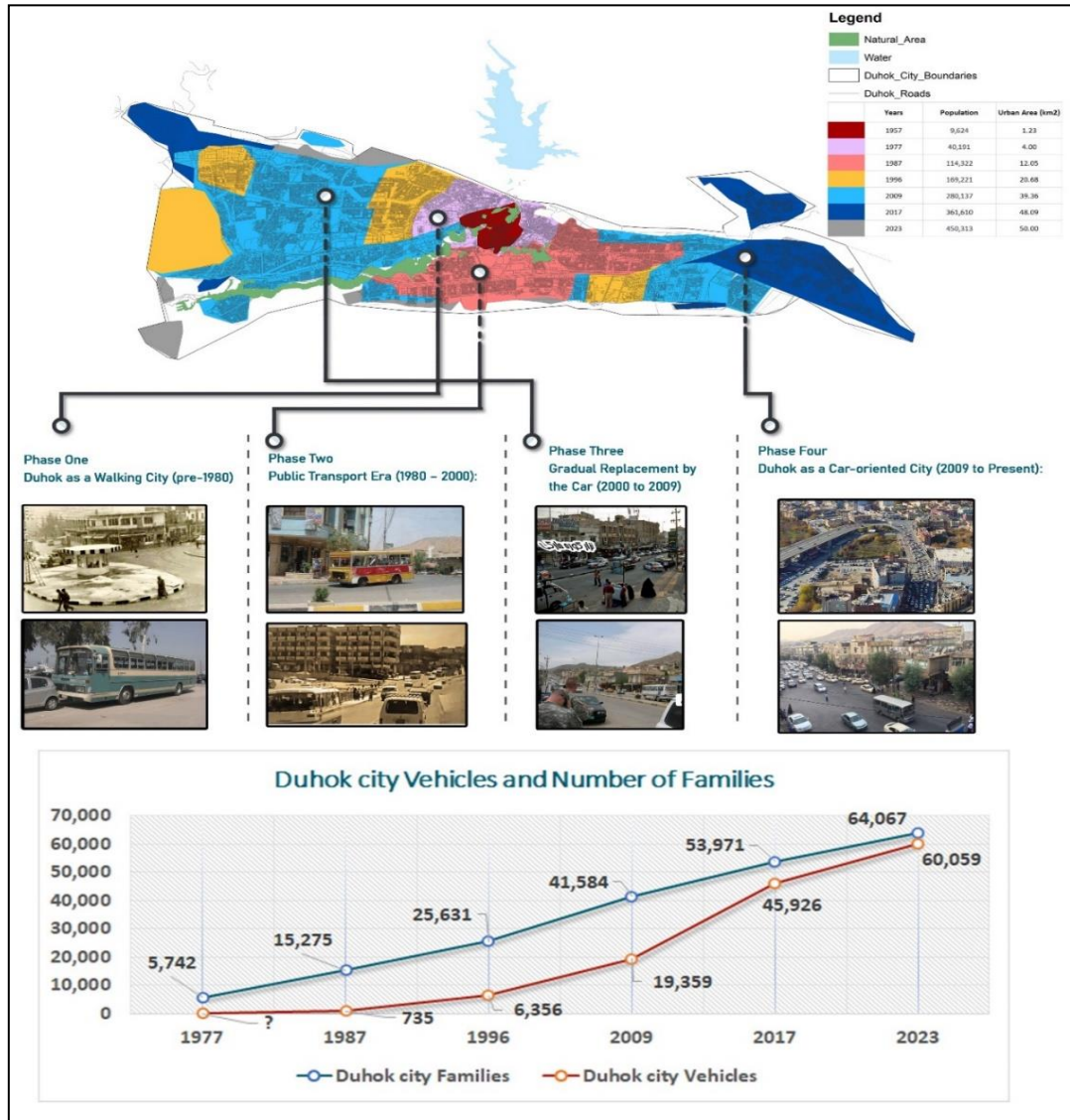


Fig. (9): Timeline of Duhok City Transport System Transformation over the period 1976 to 2023.

Source: Constructed by the Researcher using ArcMap and Adobe Photoshop.

vehicles per each family in Duhok. The number of vehicles imported into the region rose to an all-time high, which can be seen that between 2009 and 2023, the number of Duhok city vehicles tripled (from 19,359 to 60,059). This illustrated the extent by which the city has reached, starting from a walking and public transport reliant city to an almost entirely car-oriented city. The fact that every family owns a car shows that the city's infrastructure is entirely

4. CONCLUSIONS

The expansion of Duhok city across decades coupled with a car-based transport system and an ineffective public transport system raised the concern on the creation of an Unsustainable Transport for the future of the city and the implications they have on the natural and built environment and the residents overall.

Duhok's city transport system went through

different development phases, categorized as eras, from the period of 1976 to 2023. Pre-1980, Duhok city was a predominantly walking city with some extent of cars and buses, which then transitioned to the Public Transport Era, and unfortunately saw slow dismantlement and replacement by the car caused by political reasons, rising affluence and economic development, import of cars and taxis, lack of government revenue, and low priority within the government's plans. Backed up by the increase in the number of vehicles from 736 in 1987 to around 60,059 in 2023, the city saw a shift from a walking and public transport reliant city to an almost entirely car-oriented city.

The dominance in the car-oriented development is resulting in the degradation of public and active transportation modes and is shifting away budget from constructing a sustainable city transport system towards favored building construction and supporting infrastructure for the car. The replacement of many open and green spaces by car parks and fuel stations highlights the environmental impacts of this growth in the number of cars in Duhok city.

Without reliable alternative transportation modes, residents will heavily rely on their private cars, causing hundreds and thousands of further vehicles enter the daily traffic fleet, and leading to unimaginable traffic congestion, parking space problems, degraded quality of life and access for people, and substantial environmental concerns in the near future. Responses also showed that 56% of the participants drive 2 to 3 times a day, indicating a somehow high number of trips conducted using private cars on a daily basis within Duhok city. Responses also show 52% having 1 to 2 passengers per vehicle, referring to lower vehicle occupancies which reflect higher energy consumption and poses considerable effects on the transportation network of the city. Also, 48% indicated possessing 2 cars, an indicator of higher car-reliance in the city. With an average vehicle occupancy rate of 1.56, Duhok city's cars are being ineffectively utilized for single-passenger car trips and making the roads crowded with cars.

REFERENCES

- Al-Wattar, O. (2013). *Urban Growth and the Need for an Alternative Passenger Transport System in Duhok city*. Duhok.
- Banister, D. (2005). *Unsustainable Transport City*

transport in the new century. New York: Routledge.

- Center for Sustainable Systems. (2022). *University of Michigan*. Retrieved from Personal Transportation Factsheet: <https://css.umich.edu/publications/factsheets/mobility/personal-transportation-factsheet>
- Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Method Approaches*. Los Angeles, London, New Delhi, Singapore: SAGE Publications, Inc.
- Delucchi, M. (2000). Environmental Externalities of Motor-Vehicle Use in the US. *Journal of Transport Economics and Policy*, 135-167.
- Hajani, I. (2019). *PROMOTING URBAN SPATIAL PLANNING GUIDANCE FOR ACHIEVING PHYSICAL SUSTAINABLE URBAN DEVELOPMENT IN DUHOK CITY - KURDISTAN REGION / IRAQ*. PhD Thesis, TU Dortmund University - Germany, Faculty of Spatial Planning, Dortmund.
- Kuddus, M. A., Tynan, E., & McBryde, E. (2020). Urbanization: a problem for the rich and poor? *Public Health Reviews*, 1-4.
- Kumar, R. (2011). *Research Methodology: a step-by-step guide for beginners*. London, California, New Delhi: SAGE.
- Kurdistan Regional Government. (2023, April 6). *Barzan road connects Kurdistan directly to Turkey*. Retrieved from Kurdistan Regional Government: <https://gov.krd/dmi-en/activities/news-and-press-releases/2023/april/barzan-road-connects-kurdistan-directly-to-turkey/>
- Marshall, S., & Banister, D. (2007). *Land use and Transport*. Oxford and Amsterdam: Elsevier.
- Othman, A. (2019). *Strategizing a Transit-Oriented System through improving Bus System in Duhok city*. Department of Spatial Planning, Duhok: University of Duhok.
- Ritchie, H., & Roser, M. (2020). *Iraq: CO2 Country Profile*. Retrieved from Our World in Data: <https://ourworldindata.org/co2/country/iraq>
- Rodrigue, J. P. (2020). *The Geography of Transport Systems*. Oxon and New York: Routledge.
- Sullivan, C., & O'Fallon, C. (2003). Vehicle occupancy in New Zealand's three largest urban areas. *26th Australasian Transport Research Forum*, (pp. 1-17). Wellington, New Zealand.


OTHER REFERENCES:

- Data on the Old System of Public Transport functioning in Iraq acquired from the Annual Abstract of Statistics 1975 by the Central Statistics Organization of Iraq.
- Data on the Tramway plan for Duhok city acquired from the Municipality of Duhok (2019).
- Image of Barzan road in 2009 acquired from Nizar Koramarky (2023).
- Image of Barzan Road in 2021 acquired from Kavin Group (2021).
- Population Numbers and Statistics acquired from the

Directorate of Statistics in Duhok (2023).
 Statistics about Vehicles in Duhok Governorate
 acquired from the Directorate of Traffic in
 Duhok (2023).

5. APPENDICES


1- Online Survey Form:




Survey for M.Sc. Thesis: The Impact of Transportation System Transformation on Sustainable Built Environment: Duhok as a Case Study

My Name is Aland Kamal Othman. I am a Masters student in the College of City and Regional Planning at the University of Duhok. I am currently conducting my Thesis on the Sustainability of Duhok City Transport System (CTS) with the aforementioned title, supervised by Asst. Prof. Dr. Layla M. Raswol.

Your acceptance and responses to the survey questions would be greatly appreciated and immensely helpful in developing my findings. All responses will be kept anonymous.

aland.kamal@uod.ac [Switch account](#) 

 Not shared

Age:

Your answer

Occupation (Job)

Your answer

Next
Clear form

Section 1: The nature of Duhok's current City Transport System and its development:

How many times a day are you driving or being a passenger in a car on a daily basis?

At least 1 time a day
 2 to 3 times a day
 4 to 5 times a day
 More than 5 times a day

How many passengers are usually in the car?

Your answer

What is your usual driving destination?

Your answer

How many cars does your household own?

Your answer

Section 2: The Car-Based city transport distortions on Investment and the natural environment:

During what times of the day is there traffic congestion on the streets? (Please state all times of day)

Your answer

On which sections of Duhok city do you find the most traffic congestion? (State as many as possible)

Your answer

What are the top three most attractive land uses/destinations in Duhok that people drive to? And why?


Please state your response like the following:

1. Reason:

2. Reason:

3. Reason:

Duhok City Activity Land uses



Your answer

Back
Submit
Clear form

2- Key Informant Interview Form:

University of Duhok
College of City and Regional Planning
M.Sc. in Spatial Planning



tu technische universität
dortmund

M.Sc. Thesis Title: |

The Impact of Transportation System Transformation on Sustainable Built Environment: Duhok as a Case Study

My Name is Aland Kamal Othman. I am a Masters student in the College of City and Regional Planning at the University of Duhok. I am currently conducting my Thesis on the Sustainability of Duhok City Transport System (CTS) with the aforementioned title, supervised by Asst. Prof. Dr. Layla M. Raswol.

Your acceptance and responses to the interview questions would be greatly appreciated and immensely helpful in developing my findings. The interview consists of 8 open-ended questions. All responses will be kept anonymous.

Interview Questions for Key Informants (KII)

Date:

Interview Code:

1. **Can you briefly explain how the transportation network, especially public transport, functioned in Duhok city before the 2000s?**
2. **What factors influenced the disappearance of the previous transport system?**
3. **In what way will the new high-rise apartment buildings (towers) impact the future traffic flow of Duhok city?**
4. **How is the current city transport system serving people to access their destinations?**
5. **What may be some plans that can promote alternative modes of transportation within the city?**