Selected Indicators of Al-Najaf Road Network: Public Transportation Noise and Pollution

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Abstract. It is urgently necessary to improve the state of transportation and related infrastructure, especially given that the most important indicators of urban development gauge a city's progress. One of the most influential of these indicators is what is known as "smart transport," which refers to transportation that utilizes modern communication and information technology technologies to address various challenges in various transportation sectors. The holy city of Najaf smart transportation strategy seeks to reduce dangerous levels of traffic-related noise and air pollution while enhancing various aspects of mobility and traffic flow indicators. This study aims to evaluate the performance of the existing traffic network and public transport in Najaf City and its interference with noise and air pollution at selected points for data gathering by using field measurements using cameras, noise meters, and pollution measurement devices. The study states that the public transport sector in Al-Najaf city is significantly poor as private cars are dominant by about 65% of traffic mix with values of pollution and noise above the standards. One of the most effective solutions to traffic problems is the implementation of intelligent transportation systems. Part of these strategies is establishing a tram network and raising road classes' strategies by proposing some geometric design editing, U-turns reducing, and raised ramps additions.

Keywords: Najaf city; public transport; traffic noise; traffic flow pollution; travel time.

1. INTRODUCTION

The use of private automobiles has increased significantly during the past few decades. Between 1950 and 1990, the number of motorized cars in the globe increased from approximately 75 million to over 675 million. Around 80% of these automobiles and motorcycles were primarily used for personal transportation. Between 1970 and 1990, the number of kilometers traveled by private car per capita in Western Europe increased by 90 percent, from 4,620 to 8,710 kilometers [1]. The rise in automobile usage has caused many environmental, societal, and economic issues. The release of poisonous and dangerous compounds contributes, among other things, to global warming, and raw materials and energy are required to manufacture and use smog and acid precipitation. Next, scarce automobiles. Expansion of road infrastructure results in the distorting and fragmenting of natural regions, which may disturb natural habitats. On a social level, automobile use harms the quality of life in urban areas since it is noisy, causes annoyance, contributes to local air pollution, and results in traffic accidents. In the Organization for Economic Cooperation and Development (OECD) countries, transportation has been identified as the primary source of environmental noise; around 16% of the population is exposed to noise levels from transportation that can significantly disrupt sleep and communication. In 1998, 42,000 people perished in European Union traffic accidents [2].

Urbanization has led to a decline in services, increasing the demand for transportation among those who remain [3]. Aging populations result in a shift in transportation requirements and a decline in the number of people traveling to education or work. One of the concerns noted in the literature on public transportation is that the automobile has been the primary form of transportation for decades and has overtaken the use of public transport [4,5]. "The car supports the creation of distances and obstacles only it can overcome" [6-8].

Cities are experiencing rapid economic growth because they are the main drivers of national economies. However, these benefits come with significant sustainability challenges because cities account for more than 70% of the harmful emissions that contribute to global warming and consume between 60% and 80% of all consumables. In addition, the world's urban population has reached 4.21 billion people, or 56% of the total population. Urbanization rates are predicted to continue to rise, reaching 68.4% of the total population who will live in cities by 2050, indicating constant global urbanization. The rate of urbanization in Iraq is currently 70.9%, and by 2050, it is anticipated to be 80% [9].

2. LITERATURE REVIEW

2.1 Public Transportation

The families of transit services that are accessible to people in urban and rural areas are collectively referred to as "public transportation." Therefore, not just one mode but a range of conventional and cutting-edge services should work in unison to deliver system-wide mobility [10]. The urban public transportation system includes normal and rapid buses, light rail, subways, ferries, etc. Personal transportation consists of private automobiles, motorbikes, electric vehicles, etc., bicycling, and walking. As a result of the 1973 and 1979 global oil crises, which led to high prices and restricted supply of fossil fuels, public transportation networks were built. As a vital component of the urban passenger, urban public transportation has helped to alleviate traffic congestion, reduce the demand for fossil fuels and environmental pollution, and ensure city accessibility for urban residents (especially urban vulnerable groups such as the disabled, elderly, etc.), thereby contributing to the sustainable development of cities and urban transportation [11].

There are several definitions of public transportation. Walker [12] proposes one of these definitions, stating that public transportation "consists of regularly scheduled vehicle trips, open to all paying passengers, with the capacity to carry multiple passengers whose trips may have different origins, destination, and purposes". The author deconstructs this definition to explain its components. By "regularly scheduled vehicle trips", Walker [12] demonstrates that transportation is provided by a vehicle that follows a set schedule or pattern; however, routes and schedules may vary. Public transportation should be predictable so that different people can plan around it without communicating directly with each other. Walker [12] identifies this as the primary distinction between transportation and other modes of transportation. Public transportation networks are deemed crucial to the sustainability of metropolitan regions for a variety of social, environmental, and economic reasons, such as ensuring access to activities and services, reducing traffic congestion, increasing productivity, and lowering carbon emissions [13].

2.2 Noise Generated From Traffic

A vehicle's engine, exhaust, tire interaction with the road pavement, the contact of moving cars and passing air, road quality and traffic control, vehicle speed, and traffic patterns are just a few variables that lead to increased road traffic noise, particularly on highways. The noise level on the highway grows as the road's width narrows and the buildings' height rises [14]. Using typical outdoor noise exposure indicators, the impact of road traffic noise is determined [15]. The weighted equivalent continuous sound pressure level in the specific daytime or over 24 hours is one of the most used noise indicators. The regulatory agencies use this indication in evaluation guidelines and regulations [16]. On the other hand, standard indicators of traffic noise are insensitive to identifiable traffic noise occurrences. And temporal noise profile variation [17]. International noise limits (Central Pollution Control Board (CPCB)) and World Health Organization (WHO) is 65 dBA and 70 dBA, respectively [18].

2.3 Traffic Flow Pollution

The transportation sector is the reason for around a third of the atmosphere's chlorofluorocarbons (CFCs), 20% of its carbon dioxide (CO_2), and 50% of its nitrogen oxides (NOx) are released by fossil fuel combustion [19]. Air pollution caused by traffic is a significant problem for the general public. Automobile emissions of nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOC), and particle matter (PM) are significant causes of air pollution in Hong Kong and other metropolitan cities. Air pollutants generated by traffic, such as NO_2 and PM, pose a health risk, while greenhouse gases generated by transportation, such as carbon dioxide (CO_2), may contribute to global warming. As motor vehicles are the primary source of urban air pollution, it is necessary to create management measures that reduce environmental impacts while maximizing the efficiency of motorized transport [20]. The air quality index (AQI) is the function to indicate emissions as stated by Environmental Protection Agency (EPA). See Table 1. The US EPA bases its definition of AQI on the five leading pollutants: sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and particulate matter (PM10 and PM2.5) (SO_2). The index of each pollutant individually, as specified in the equation below, is first calculated using concentration data from the linear interpolation formula and reference concentration data [21]:

$$IP = \frac{I_{HI} - I_{LO}}{BP_{HI} - BP_{LO}} (C_P - BP_{LO}) + I_{LO} \quad (1)$$

Where:
IP=Index for any pollutant (P)
C_P= Concentration of pollutant P
BP_{HI}= A breaking point that is equal to or greater than C_P
BP_{LO}= A breaking point that is equal to or less than C_P
I_{HI}= AQI value correlates with BP_{HI}
I_{LO}=AQI value correlates with BP_{LO}

Table 1: EPA standards of AQI and traffic flow emissions [16].

CO (PPM)	SO_2 (PPM)	NO_2 (PPM)	Values of AQI	Health Concern's Level
0 - 4.4	0.0-0.034	0	0-50	Good
4.5 - 9.4	0.035-0.144	0	51-100	Moderate
9.5-12.4	0.145-0.224	0	101-150	Unhealthy for certain individuals
12.5 -15.4	0.225-0.304	0	151-200	Unhealthy
15.5-30.4	0.305-0.604	0.65-1.24	201-300	Very Unhealthy
30.5-40.4	0.605-0.804	1.25-1.64	301-400	Hazardous
40.5-50.4	0.805-1.004	1.65-2.04	401-500	Hazardous

2.4 Travel Time

The time necessary to travel between two points of interest is known as travel time. By following the route(s) that connects any two or more points of interest, it is possible to reach them. It is possible to calculate travel time precisely. Running time, or the amount of time the mode of transportation is in motion, and paused delay time, or the amount of time it is halted (or traveling at a speed slow enough to be stopped, typically less than 8 mph or 5 mph), comprise travel time [22]. When traffic control is present on a section of roadway, vehicle velocities decrease below the average running speed. The average travel speed is the speed factor that best represents the impact of traffic management. The segment length divided by the average journey time is used to calculate this speed. The whole time required to cross a street segment, including any stop-time delays, is the travel time [23].

2.5 Previous Studies

Al-Jameel and Abdabbas [24] studied the existing public transport in Al-Najaf City, and the study came up with conclusions that the current public transportation system has many deficiencies in terms of researched public transportation infrastructure, including individual buses, trams, schedules, and even routes. Their study made suggested plans for BRTs and trams as effective and sustainable means of transit. A study conducted by Mansour [25] on the effect of noise and pollution in a selected urban road network stated that Al-Matar Street had the highest average noise level across all areas, which was 87 dBA, exceeding both WHO and CPCB guidelines. Moreover, Al-Najaf-Kufa Street has the highest CO content at around 8 ppm, below EPA and WHO guidelines. However, CO_2 levels are all within the permitted outdoor limits everywhere. At Al-Hizam Street, SO_2 levels were high (0.9 ppm), exceeding WHO and EPA guidelines. Moreover, Al-Hizam Street's NO_2 content was exceedingly high (1.05), above the restrictions. All sites' Air Quality Index (AQI) revealed a highly hazardous pollution situation.

Abdulkareem [26] studied the evaluation of noise pollution indicators in Najaf City. Their study stated that industrial areas had the most significant value of (Leq), 108.44 dB, followed by commercial areas at 89.55 dB, educational places at 87.1 dB, quiet regions at 80.4 dB, and residential areas at 69.05 dB. The noise assessment for their study highlighted the unsettling situation of noise pollution in the city of Najaf, where the highest values of Leq in all locations were higher than the allowable level in the Iraqi guidelines.

3. STUDY AREA AND METHODOLOGY

Al-Najaf governorate's capital is Al-Najaf City. It is situated in the country's central region, some 160 kilometers south of Baghdad. The city is located at 32°01'33.4°N and 44°20'46.5°E latitude and longitude, respectively. The selected data points in Al-Najaf City have been surveyed, as clarified in Figure 1 and Table 2. Urban structure refers to the city's physical layout or structure, particularly regarding economic and transportation activity [27]. Another definition could be the spatial style or configuration of discrete components, such as structures and land use, as well as economic and social activities, public institutions, the population's distribution, and networks connecting them; conversely, spatial structure is the spatial distribution for the inhabitants and land use in the urban area, or the appearance of the daily trip within urban areas [28]. The transportation network is integrated with the urban structure. Al-Najaf has experienced significant urban development because of the city's religion, position, and connections to neighboring areas. This development is mainly dependent on the possibilities for acceleration that occur in population growth which is either normal growth or growth brought on by immigration from various locations for various causes over time [29]. The following table states the selected streets and their descriptions.

Figure 1: Location of the selected data point.

Table 2: The selected roads in the study area.

Road no.	Local name	lanes/dir.
1	Qanbar street	2
2	Al-Mujamaat street	2
3	Al-Kafeel University street	3
4	Al-Zaytoon street	2
5	Al-Hawly- matar street	3
6	Najaf-Karbala street	3
7	Najaf-Kufa street	3
8	Emad sekr complex street	3
9	Ring road (Elevators street)	3
10	Najaf Technical Institute street	3

The study focused on gathering information about traffic performance for the existing network and its environmental effect at specified locations based on high activities and types of roads. It used the camera to record videos to extract traffic volumes from 6:00 A.M to 9:00 A.M trying to cover peak hours.

Video camera | Bushnell radar device | Noise level meter

HUMA-I (HI-150) | Advanced Sense Environmental Test | AQDPI

Figure 2: Tools used in the study.

The speed gun (Bushnell radar) measures the free flow speed and spot speed data over time. Traffic-generated noise is also measured using a noise level meter at the shoulders, and pollution emissions have been monitored and recorded using Advanced Sense Environmental Test Meter, Air Quality Detector Precision Instrument (AQDPI), and HUMA-I (HI-150). Traffic mix has been computed and listed for each type (Private cars, taxis, minibusses, buses, trucks, MTRs, and Motors) and their percentage to clarify public transport assessment. The existing public transport in the city of Najaf is represented generally by several routes starting from Al-Najaf internal garage (Origin A to Destination B) runs by minibusses; these routes don't cover the entire city, and the actual need for people transit as shown in Figure 3 and Table 3.

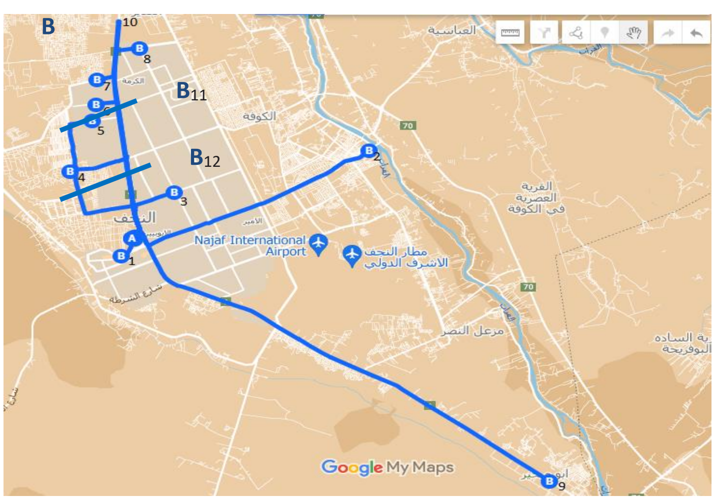

Figure 3: Public transport routes in Al-Najaf City.

Table 3: Existing public transport routes in Al-Najaf City.

Origin	Route	Destination
Najaf Internal Garage (A)	A-B1	To Al-madina Al-kadima (CBD)
	A-B2	To Kufa city
	A-B3	To Al-Zahra'a District
	A-B4	To Al-Muhandiseen
	A-B5	To Al-Nasr- Muhandiseen
	A-B6	To Al-Milad- Faw
	A-B7	To Al-Nida'a Dist.
	A-B8	To Al-Askary Qubal Dist.
	A-B9	To Abu Skher and Al-Manatherah
	A-B10	To Al-Haideryah
	A-B11	To Al-Wafa'a Dist.
	A-B12	To Al-Askary Dist.

4. RESULTS AND DISCUSSION

4.1 Travel Time

Travel time in the study area has been measured to state the network performance and travel delay due to congestion; for the test, the travel time at Najaf-Karbala Road on 3 runs for each direction with a length of 18 km, as shown in Figure 4 and Table 4.

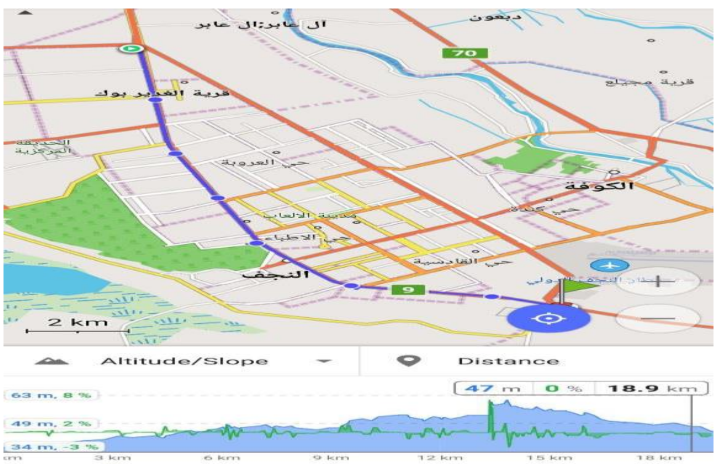

Figure 4: Najaf-Karbala travel time track.

Table 4: Travel Time test at specified segment at Najaf-Karbala Street.

No. of Run	Direction	Travel Time (Min.)	Date
1	Al-Shuhada'a Bridge –Al-Radhaweya Bridge	23:43	Wednesday (29/3/2023) – 7:55 A.M
2	Al-Shuhada'a Bridge –Al-Radhaweya Bridge	28.09	Thursday (30/3/2023) – 7:25 A.M
3	Al-Shuhada'a Bridge –Al-Radhaweya Bridge	28:29	Sunday (2/4/2023) – 7:52 A.M
4	Al-Radhaweya Bridge- Al-Shuhada'a Bridge	24:20	Monday (3/4/2023)- 7:51 A.M
5	Al-Radhaweya Bridge- Al-Shuhada'a Bridge	21:48	Tuesday (4/4/2023) –7:56A.M
6	Al-Radhaweya Bridge- Al-Shuhada'a Bridge	26:40	Thursday (30/3/2023) –7:55A.M

4.2 Traffic Volumes and Flow Rates

Traffic volumes and flow rates have been calculated for every 5 minutes at the study points using video cameras in the morning (6:00-9:00) A.M trying to cover peak hours on different days. Here are some examples. See Table 5. After data analysis, it's obvious that flow rates experience high values starting from 7:15 A.M to 8:45 A.M with an influence reduction in speed as demonstrated in Figure 5 below:

Table 5: Example for traffic volumes and flow rates at Najaf- Kufa Street (Road number 7) To Al-Najaf (Monday-10/10/2022).

Time (A.M)	Private	Taxi	Minibus	Bus	Truck	MTR	Motor	flow rate (veh./hr.)
6:05-6:10	34	7	15	1	5	4	8	888
6:10-6:15	40	7	23	3	9	4	12	1176
6:15-6:20	37	14	22	2	9	4	12	1200

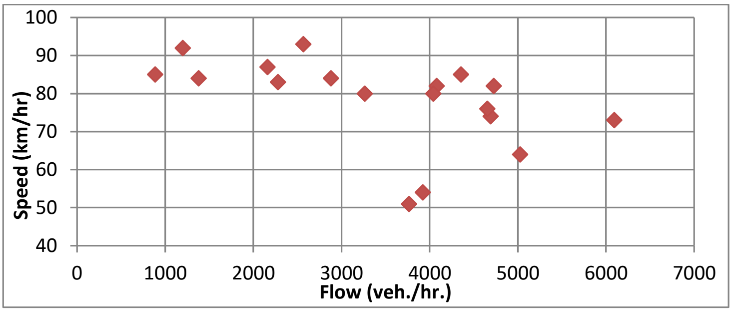

Figure 5: Speed–Flow distribution in Al-Najaf – Kufa Street.

4.3 Traffic Mix

Traffic mix means the variety of vehicles on roads, such as private cars, taxis, minibusses, trucks, motors, and MTRs. The following table represents the noticeable dominant percentage of private cars all over the main roads in Al-Najaf city, see Table 6.

Table 6: Traffic composition percentage for each street.

Road no.	Direction	Private cars%	Taxi%	Minibus%	Bus%	Truck%	MTR%	Motor%
1	To Karbala st.	63.1	12.1	3.6	1.1	7.9	6.2	5.9
1	From Karbala st.	64.2	8.7	7.4	0.6	10.0	5.2	3.9
2	To Karbala st.	70.5	9.0	7.1	0.7	4.5	4.2	7.7
2	From Karbala st	68.8	10.0	6.6	0.5	5.5	4.7	3.8
3	To Karbala st.	66.0	14.0	6.0	0.3	4.0	4.0	6.0
3	From Karbala st	65.0	13.0	6.0	0	5.0	5.0	6.0
4	To Karbala st.	61.33	14.86	6.14	0.24	6.0	6.76	4.67
4	To A-Hawly st.	61.81	14.97	5.0	0.14	6.45	6.0	5.64
5	To Najaf	68.83	11.12	3.74	0.41	7.7	4.0	4.2
5	To Karbala	63.39	11.92	5.71	0.48	9.94	4.35	4.21
6	To Najaf	63.1	10.6	10.0	0.7	5.1	3.6	6.9
6	To Karbala	62.2	11.5	12.8	1.2	5.7	3.9	2.7
7	To Najaf	65.28	10.05	13.02	0.92	3.04	2.29	5.4
7	To Kufa	68.37	10.02	15.4	1.13	0.55	1.81	2.72
8	To Airport	61.61	12.8	9.26	1.26	2.34	5.15	7.58
8	From Airport	64.23	12.88	8.59	0.57	1.70	3.99	8.04
9	To complexes	55.67	11.02	7.74	3.34	11.54	7.61	3.08
9	From complexes	58.43	11.44	8.98	2.63	11.78	4.97	1.77
10	To Najaf	52.3	11.5	19.2	0.8	8.3	5.2	2.7
10	From Najaf	56.0	9.9	19.3	0.7	9.2	3.0	2.0

4.4 Noise Generated from Traffic Flow

Noise values in the study area were measured at daylight in midblock sections by noise level meter and compared within international limits Central Pollution Control Board (CPCB) and World Health Organization (WHO), see Table 7.

Table 7: Noise generated in the study area.

Road	Ave. Highest Noise level (dBA)	Noise limitation (dBA) by CPCB	Noise limitation (dBA) by WHO	Value
1	90.3	65	70	High
2	85.48	65	70	High
3	88	65	70	High
4	88.9	65	70	High
5	93.06	65	70	High
6	89.36	65	70	High
7	88.5	65	70	High
8	88.48	65	70	High
9	82.44	65	70	High
10	76	65	70	Moderate

4.5 Traffic Pollution Emissions

Emissions have been measured at six locations distributed between Najaf and Kufa cities. The results of pollution emissions in the table below stated an unhealthy environment compared to international limits, as shown in Table 8.

Table 8: Example for traffic pollutants at Kufa-Najaf Street in PPM.

Time	O_3	Temp.(C)	SO_2	NO	NO_2	CO	CO_2	TVOC	AQI
6:25	0	12.9	0	0.3	0.08	0.02	528	0.1	0.2
6:30	0	13.2	0	0.2	0.08	0.02	529	0.1	0.2
6:35	0	13.1	0	0.3	0.09	0.02	648	0.4	0.3

Table 9: AQI values in the study area.

Road	AQI Values PPM			Result
	CO	NO_2	SO_2	
Najaf-Kufa	52	112	81	Unhealthy
Al-Zaytoon st.	53	201	0	Very Unhealthy
Ring Road	52	200	0	Unhealthy

5. CONCLUSIONS

The main points resulting from this study can be concluded as follows:

- Road users in Al-Najaf city depend mainly on private cars, within a percent of nearly 65% of the traffic mix.
- The public transport sector is represented by about 10% of minibusses with no schedule and without fixed routes, except the Najaf internal garage.
- Bus transit in the city is less than 1% all over the selected streets; most of it belongs to travel companies.
- Taxi services in the city miss regulations and management as it runs by individual drivers.
- Noise levels due to traffic are very high, reaching 94 dBA at some locations considered above the standards.
- Traffic pollution led to an unhealthy environment and an air quality index above the global limits.
- The study recommends using smart transport with no fuel consumption, almost zero emissions, and a lower effect of noise. One of the modern unique solutions is implementing a tram network in the city.

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