Road Network and its Evaluation for Sustainable Development in Al-Hilla City, Iraq

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Abstract— Al-Hilla city is the capital of Babil governorate, which is one of the most important governorates in Iraq. It represents the central link point between the northern and southern governorates. In general, road network in Iraq is suffering from many problems due to mismanagement, decline in governmental support and confusing political situation. Therefore, there is a real need to study its current situation to provide more accurate information that is required for its development. The main objective of this work was to evaluate the spatial and temporal changes in road network within Al-Hill city from 1999 to 2015. Both spatial and attribute data about road network in Al-Hilla city were integrated under the GIS environment. Also, six indices (TIEI, PDI, AUSEI, RDI, RADI and Moran) were used to study the interrelationships between road network and urban growth in the city. This was in addition to using the Kernel density analysis to study road density in the city. It was found that the total length of road network in Al-Hilla city was 201.91, 424.94 and 591.51 km in 1999, 2007 and 2015; respectively. However, that expansion was mainly in secondary roads followed by main roads, whereas the expansion in highways was limited. This road network in Al-Hilla city took a random pattern according to the Moran Analysis. Estimated road areas were about 613, 889 and 1157 km^2 in the same sequence of years. Also, urban areas were about 1685, 3109 and 4185 km^2 in previous sequence of years. The AUSEI index indicted that the annual spatial expansion in urban areas was higher between 1999 and 2007 than between 2007 and 2015. The PDI Index indicates the rate of population growth was lower than the expansion in urban areas. Based on the road density index the road length was increased with increasing the population and urban areas. However, the road areas were decreased with increasing urban areas. The person share of road areas reached its maximum in 2007. Kernel density analysis of road network in 2015 indicated that road density in the center city of Al-Hilla was high. This indicates that the area does not suffer from lack of roads and traffic difficulties. The estimated road network in 2030 is expected to decrease from 3.4% in 2015 to 2.76% in 2030, which indicates a decrease in transportation infrastructure. In conclusion road network has to be expanded and maintained in Al-Hilla city to meet the expected increase in population.

Index Terms— Road network, sustainability, Kernel density analysis, and transportation and urban growth indices.

1. Introduction

Transportation plays an essential role in urban development (**Carvalho et al., 2010**). Transportation networks provide mobility systems for people and goods. They work on improving traffic growth and economic activity through easy access **(Meyer and Miller 2001; Singh and Kaish, 2013).** Urban transportation systems are complex networks associated with various geographical, social, economic, and environmental factors **(Wang et al., 2008).** Transportation corridors play an integral role in urban expansion **(Fan, et al., 2009).**

Successful planning is always the result of intensive studies based on accurate information. The primary stage of making an urban planning is the investigation of present situation, which needed lots of effort, people, materials and money in the past. Nowadays, GIS has been used as a new tool to get spatial information and their attribute information in more accurate, time-wise and less-expensive ways (**Wang, et al., 2008**). GIS database offers inclusive framework and organization of spatial and non-spatial data in order to proficiently aid planners and decision makers **(Hite, 2006).**

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Making maps and analyzing spatial data is very helpful in all phases of public service management, from policy development to program implementation to final evaluation **(Mavoa et al., 2012).** Remote Sensing (RS) data and analysis are now providing detailed information for detecting and monitoring changes in land cover and land use **(Franklin, 2001)**.

Some indices have been developed to quantify and analyze spatial–temporal urban growth. Examples of these indicators include the annual urban spatial expansion index (AUSEI) (**Fan et al., 2009; Tian et al., 2005)**, the population growth index (PDI) (**Jat et al., 2008; UNCHS, 1995; Zhang and Guindon, 2006)**, the urban land use/land cover change index (**Xie et al., 2005; Zhang and Guindon, 2006)**, the urban population density change index **(Feng, 2009; Zhang and Guindon, 2006)** and Moran autocorrelation index (**Moran, 1950; Cliff and Ord, 1973)**. The proximity of growth to the transportation infrastructure index (TIEI) **(Fan et al., 2009; Müller et al., 2010; Zhu et al., 2006)** is the only index that has been developed and commonly used to analyze the spatial-temporal relationship between urban growth and transportation.

The objectives of this work were to evaluate spatial and

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temporal changes in road network within Al-Hilla city from 1999 to 2015. This is in addition to studying the interrelationships between the road network and urban growth in the same period of time. This is in order to provide decision makers with more accurate and reliable information about that sector to be used in its sustainability and future development.

2. Materials and Methods

2.1 Study Area

Al-Hilla city is the capital of Babil governorate in Iraq. It is located between these coordinates 44° 22′ 12.426″ – 44° 22′ 12.554″ E and 32° 24′ 23.54″ – 32° 31′ 57.4767″ N and it covers an area of about 161 km² as illustrated in Figure (1). It has a population of about 465524 in 2015, according to the Iraqi Ministry of planning statistics. It has a very hot, dry weather in summer and cold, wet weather in winter. Maximum temperature varied from 19 °C in January to 46 °C in July and August (about 32.5 °C in average). Minimum temperature ranged between 5 °C in January and 27 °C in August (about 16 °C in average). The mean annual rainfall is about 112 mm. These data were downloaded from this website (http://www.meteoblue.com/ar…/ modelclimate/9822).

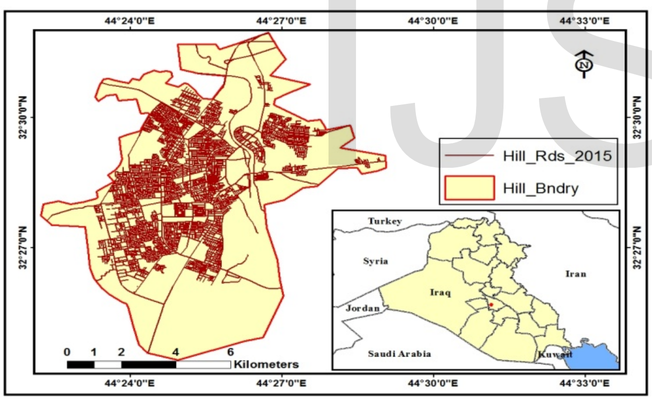

Figure (1): Location map of Al-Hilla City and its road network in 2015.

2.2 Sources of Data and their Analyses

2.2.1 Spatial Data

Multi-temporal aerial photographs and satellite images were used in this study during 1999, 2007 and 2015. Spatial and census data about the road network in Al-Hilla city were obtained from the municipalities of Babil Directorate, the Directorate of Roads and Bridges of Babil and the Directorate of Urban Planning in Babil. These data were used to study the temporal and spatial changes in urban growth and transportation within Hilla city. Figure (2) illustrates the flowchart of data analyses and manipulations that were used in studying spatial and temporal changes in the road network and urban growth within Al-Hilla City.

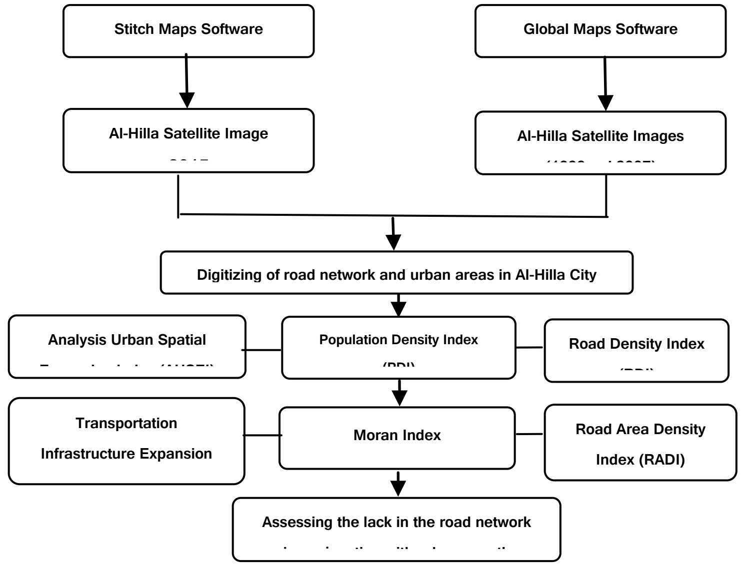

Figure (2): Flowchart used in studying temporal and spatial changes in the road network and urban growth in Al-Hilla City.

2.2.2 Indices of Road Network and Urban growth

Spatial indices were used for evaluating the efficiency of the road network in Al-Hilla city in combination with urban growth. In this work, six indices were used to determine the spatial and temporal changes in the transport and urban growth. These indices are explained in the following:

2.2.2.1. Transportation Infrastructure Expansion Index (TIEI).

The TIEI is one of the commonly used spatial indices in studying spatial and temporal changes in transportation system. It takes into account the changes in the lengths of transportation infrastructures (km) within the city. It is calculated from the following equation **(Tian et al., 2005):**

$$\mathbf{TIEI_t = \frac{TIL_{1,t} - TIL_{1,t-1}}{TIL_{1,t}} \times 100} \qquad \mathbf{(1)}$$

Where, $\mathbf{TIL_{1,t}}$ is the total length (km) of the transportation infrastructure in current year and $\mathbf{TIL_{1,t-1}}$ is the total length in former year.

2.2.2.2 Road density index (RDI)

The RDI provides an indication of the intensity of road networks within cities taking into account the total urban areas and population density. It is used to depict the change in road infrastructure through certain period of time. It is computed by dividing the total length of all roads within Hilla city either by the total urban area or the total number of citizens. The RDI is calculated according the following equation (**Tian et al., 2005**):-

$$\mathbf{RDI\_A_t = \frac{RL_t}{UA_t}} \qquad \mathbf{(2)}$$

Where, $\mathbf{RDI\_A_t}$ is the road density index per area [km/ha], $\mathbf{RL_t}$ is the total length (km) of roads in time (t), and $\mathbf{UA_t}$ is the total urban area in time (t).

$$\mathbf{RDI\_CAP_t} = \frac{\mathbf{RL_t}}{\mathbf{UA_t}} \qquad (3)$$

Where, $\mathbf{RDI\_CAP_t}$ is the road density index per capita (km/person), $\mathbf{RL_t}$ is the total road length in km at time t, $\mathbf{UA_t}$ is the total urban area in hectares at time (t), and $\mathbf{UP_t}$ is the total urban population in the study area at time t.

2.2.2.3 Road area density index (RDAI)

RDAI is another spatial index that is used to study the spatial and temporal relationships between urban development and transportation. In this index, the total area assigned to transportation infrastructure is calculated relative to both the urban population and the total urban area. The RADI is calculated according to the following equations **(Tian et al., 2005; Fan et al., 2009)**:

$$\mathbf{RADI\_A_t} = \frac{\mathbf{RA_t}}{\mathbf{UA_t}} \times \mathbf{100} \qquad (4)$$

$$\mathbf{RADI\_CAP_t} = \frac{\mathbf{RA_t}}{\mathbf{UP_t}} \qquad (5)$$

Where, $\mathbf{RADI\_A_t}$ [%] is the road area density index based on urban area, $\mathbf{RADI\_CAP_t}$ [ha/person] is the road area density index based population of urban area, $\mathbf{RA_t}$ is the total road area in hectares at time t, $\mathbf{UA_t}$ is the total urban area in hectares at time t, and $\mathbf{UP_t}$ is the total urban population in the study area at time t.

2.2.2.4 Population Density Index (PDI)

The PDI provides a great help in the analysis of the spatial and temporal changes in urban-growth and transportation**.** It depicts the pattern of urban growth and transportation efficiency. It was calculated according to the following equation described by (**Zhang and Guindon, 2006; Feng, 2009**):-

$$\mathbf{PDI_t} = \frac{\mathbf{P_t}}{\mathbf{U_t}} \qquad (6)$$

Where: $\mathbf{PDI_t}$ is the index of Population density (persons/km^2), $\mathbf{P_t}$ is the number of the total population at time t, and $\mathbf{U_t}$ is the total urbanism (km^2) at time t.

2.2.2.5 Annual Urban Spatial Expansion Index (AUSEI).

The AUSEI describes the temporal changes in an urban area based on its annual rate of urban growth. It was used to study the annual changes in urban growth within Hilla city. The AUSEI was computed by using the following equation **(Tian et al., 2005; Fan et al., 2009)**:-

$$\mathbf{AUSEI_t} = \frac{\mathbf{U_t - U_{t-1}/U_t}}{\mathbf{N_t - N_{t-1}}} \qquad (7)$$

Where: $\mathbf{AUSEI_t}$ is a spatial index for the annual expansion in Urban area [%/year], $\mathbf{U_t}$ is the total urban area (hectares) in current year (t), $\mathbf{U_{t-1}}$ is the total urban area in the former year (t-1), and **N** is the whole number of years from current year (t) to the former year (t-1).

2.2.2.6 Spatial Autocorrelation Analysis (Moran's index)

Moran Index is one of the most important metrics in identifying the extent of spatial autocorrelation between the features of the studied phenomenon (**Moran, 1950 and Cliff & Ord, 1973**). It is also used to assess the pattern of spatial distribution either if it is regular or random based on both the (Z) and (P) scores. The index value ranges between -1 and +1. When the guide value is close to +1, it indicates a clustered pattern, but when it becomes closer to -1, it indicates a random pattern.

2.2.3 Traffic Analysis Using GIS Framework

Figure 3 illustrates the general framework that was used in studying and analyzing road density and traffic volume in Al-Hilla city. In the first stage, road network maps were digitized from the satellite imagery acquired in 2015 using ArcGIS program (ver. 10.3). Then the entrances to Al-Hilla city were identified on the road network map. The traffic volume was studied at these entrances and also at the city center. Traffic intersections that had high traffic volumes were identified on that map. Finally, Kernel analysis was used for testing density of road network within Al-Hilla city.

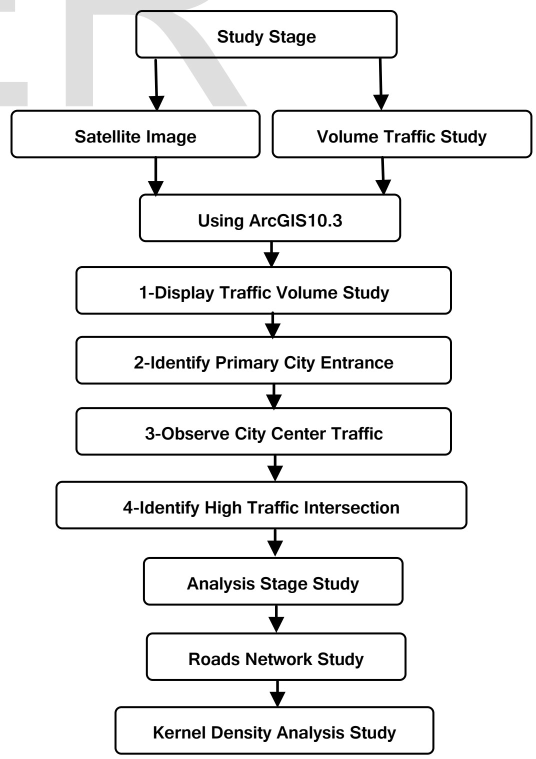

Figure (3): Framework of spatial data for road network in Al-Hilla city and their analyses.

3. Results and Discussions

3.1. Analyses of spatial and temporal expansion in road and urban areas

3.1.1. Temporal and spatial expansion.

Al-Hilla city has witnessed an obvious spatial expansion in its urbanized area during the studied period from 1999 to 2015 as represented in Table (1) and illustrated in figures (4 to 6). This is due to several factors including the end of the Gulf war, stop of the economic blockade, rise in oil prices, increase in the standard of living per capita income and fast growing economy. Most of the expansion was noticed in western side of Al-Hilla city, whereas little expansion happened in the eastern side of the city. Also, the increase in urban areas from 1999 to 2007 was higher than that from 2007 to 2015. Urban area during the first period was about 1424 hectares and about 1076 hectares during the second period. The annual increase rate in urban areas was about 5.73% between 1999 and 2007, whereas it was 3.21% between 2007 and 2015. This urban expansion was evident around the old city, especially toward the western side of the city.

Table 1
Annual Urban Spatial Expansion Index (AUSEI) in Al-Hilla city from 1999 to 2015.

Year	Urban Area (ha)	Spatial expansion (ha)	\AUSEI (%)
1999	1685	--	--
2007	3109	1424	5.73
2015	4185	1076	3.21

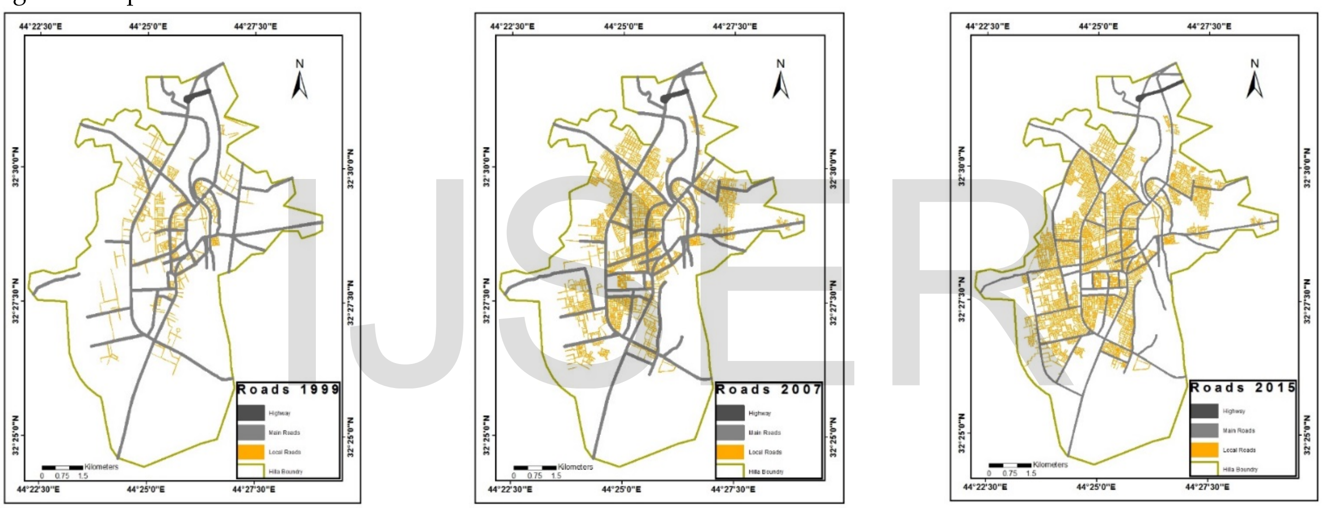

Figure (4): Road network within Al-Hilla city in 1999, 2007, and 2015

Figure (5): Urban areas within Al-Hilla city in 1999, 2007, and 2015

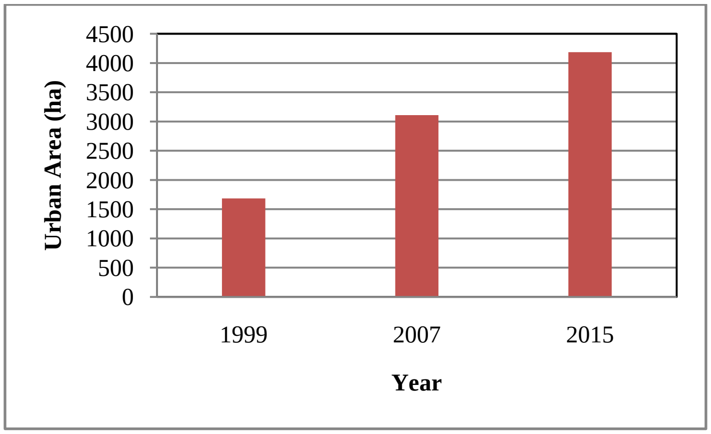

Figure (6): Spatial expansion of urban areas in Al-Hilla city between 1999 and 2015.

3.1.2 Population density index (PDI).

Population of Al-Hilla city grew rapidly from 277428 in 1999 to 465524 in 2015 (about 4.2% higher than that in 1999) as represented in Table (2). This population growth was accompanied by a reduction in population density from 16465 person/ km^2 in 1999 to 11657 person/ km^2 in 2015. This increase in population growth could be due to internal immigration from the countryside to the main cities, rapid economic growth, and natural increase in population. It could be concluded that the urban growth in Al-Hilla city was associated with growth in population; however, the population density was decreased during the studied period of time from 1999 to 2015.

TABLE 2
URBAN AREA, POPULATION GROWTH, AND POPULATION DENSITY INDEX (PDI) IN AL-HILLA CITY FROM 1999 TO 2015

Year	Urban Area (km^2)	Population	PDI (Person/km^2)
1999	16.85	277428	16465
2007	31.09	362415	11657
2015	41.85	465524	11124

3.1.3 Transportation infrastructure expansion index (TIEI).

Analysis of the expansion in transportation infrastructure was based on the three categories of roads in Al-Hilla city: highways, main roads and secondary roads. Table 3 and figure 4 indicate an obvious expansion in road infrastructure within Al-Hilla city from 1999 to 2015. However, the most noticeable increase was observed during the period from 1999 to 2007. The road length was increased rapidly from 202 km in 1999 to 425 km in 2007 (about 52.5% increase in road infrastructure with an annual rate of 6.56%). The road length was also increased from 425 km in 2007 to 585km in 2015 (about 27.3% increase in road infrastructure with an annual rate of 3.40%). Secondary roads were rapidly increased during studied period. Most of these secondary roads serve as main access points for residential development, when they have with good connectivity with the main roads. It can be concluded that although road length in all road infrastructure categories was permanently increase after 1999, the most significant increase was observed in the secondary roads. Highways and main roads remained relatively steady from 1999 to 2007, with only minor changes in main roads.

TABLE 3
TRANSPORTATION INFRASTRUCTURE EXPANSION INDEX (TIEI) OF AL-HILLA CITY FROM 1999 TO 2015

Year	TIL (km)	Change in TIL (km)	TIEI (%)	Annual growth (%)
1999	201.91	--	--	--
2007	424.94	223.03	52.5	6.56
2015	584.89	159.95	27.3	3.4

3.1.4 Road density index (RDI)

The road density index explains the intensification of transportation infrastructures. Table 4 and Figures (7 and 8) show the change in road density in relation with the urban areas and population in Al-Hill from 1999 to 2015. Road density relative to urban areas changed from 0.1198 km/ha in 1999 to 0.1398 km/ha in 2015. On the other hand, road density in comparison with the population in Al-Hilla was increased from 0.0007 km/person in 1999 to 0.0012 km/person in 2007. It was slightly increased to 0.0013 km/person in 2015.

This change reflects the rapid increase in both urban areas and population in Al-Hilla city since 1999. It also indicates that the speed of road infrastructure provision has coincided with population growth. In the last fifteen years, the population of Al-Hilla has grown rapidly with an annual growth rate of 4.2%. Accordingly, the demand has increased for public services, especially transportation infrastructure.

Table 4
Road density index (RDI) based on urban areas and population of Al-Hilla city from 1999 to 2015.

Year	Urban Area (ha)	Population	Roads Length (km)	RDI (km/ha)	RDI (km/person)
1999	1685	277428	201.91	0.1198	0.0007
2007	3109	362415	424.94	0.1367	0.0012
2015	4185	465524	584.89	0.1398	0.0013

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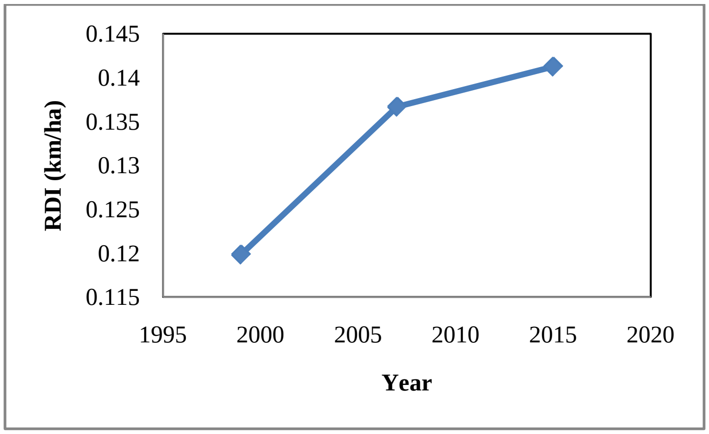

Figure (7): Road density index (RDI) relative to urban areas from 1999 to 2015.

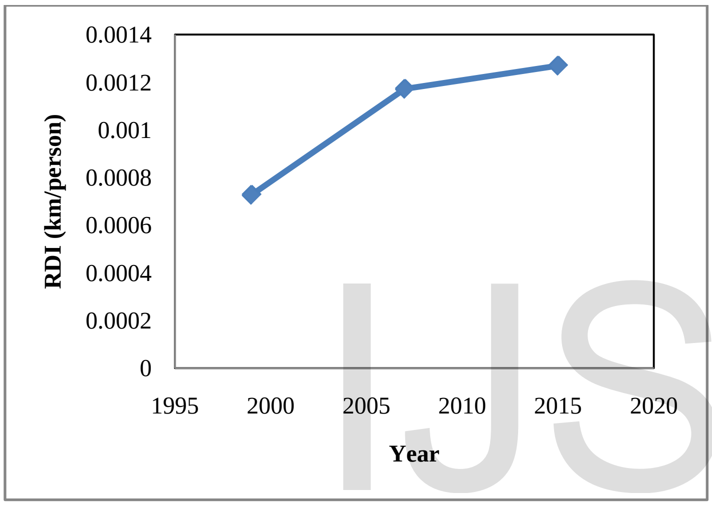

Figure (8): Road Density Index (RDI) relative to population from 1999 to 2015.

3.1.5 Road Area density index (RADI).

The road area density index was designed to explore the spatial and temporal changes among urban growth, population and transportation. The total road area was calculated based on the length and width of the three identified types of roads in Al-Hilla city. Table (5) and figures (9 and 10) shows the change in road density in Al-Hilla city from 1999 to 2015. The proportion of road areas relative to urban areas was significantly decreased from 36.40% in 1999 to 28.60% in 2007. However, there was slight decrease in 2015 (26.83%).

On the other hand, the road area density relative to population was increased from 0.0022 ha/person in 1999 to 0.0024 ha/person in 2015. These results reflect the gap between the rapid increase in Al-Hilla population and expansion in transportation infrastructure. They also reveal the real need to develop and expand transportation infrastructure in Al-Hilla city to meet the rapid increase in population.

TABLE 5
ROAD AREA DENSITY INDEX (RADI) BASED ON POPULATION AND URBAN AREAS OF AL-HILLA CITY FROM 1999 TO 2015.

Year	Population (person)	Road area (ha)	Urban area (ha)	% of Road area	RADI (ha/person)
1999	277428	613	1685	36.40	0.0022
2007	362415	889	3109	28.60	0.0025
2015	465524	1157	4185	26.83	0.0024

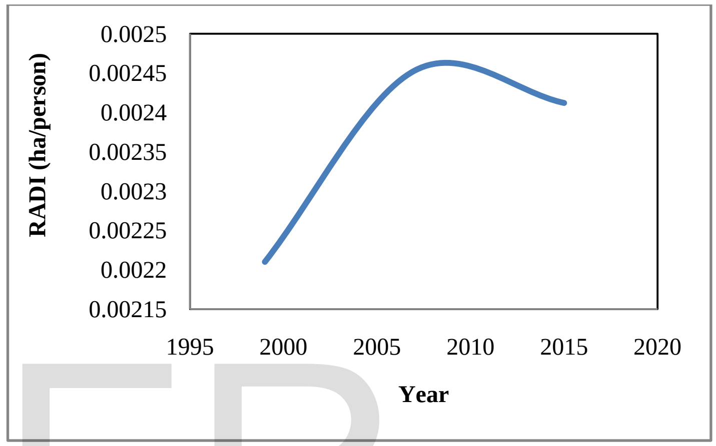

Figure (9): Road Area Density Index relative to population (RADI) from 1999 to 2015.

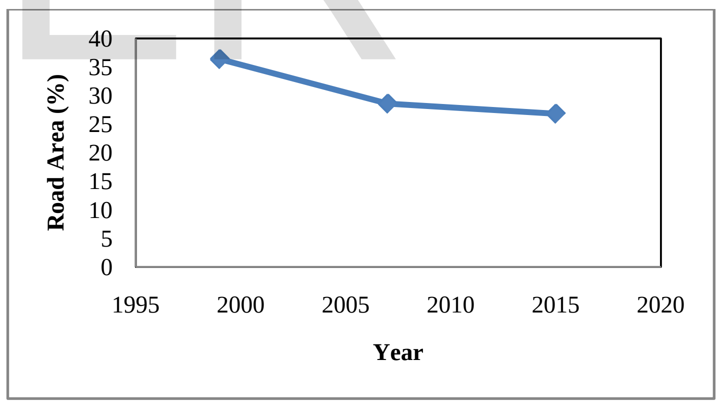

Figure (10): Road area density index relative to urban areas (RADI) in Al-Hilla city from 1999 to 2015.

3.1.6 Anselin Local Moran's I statistic (Moran Index).

Spatial Autocorrelation Analysis (Moran's I statistics) was used to study the spatial distribution pattern of streets within Al-Hilla city in 2015. Data in Table (6) show that the majority of streets (82.2%) were taking a random pattern, about 3.1% dispersed, and about 1.5% of the streets were highly dispersed. On the other hand, only about 12.2% of the streets were highly clustered. Figure (11) illustrates the types of spatial distribution pattern for road network in Al-Hilla city.

TABLE 6
SPATIAL AUTOCORRELATION ANALYSIS (MORAN'S I STATISTICS)

Z-Score	-1 to 1	>2	<-2	-2 to -1	1 to 2	Total
Road Length (km)	480	9	71	18	6	584
%	82.2	1.5	12.2	3.1	1.0	100
Pattern	Random	High Clustered	High Dispersed	Dispersed	Clustered	--

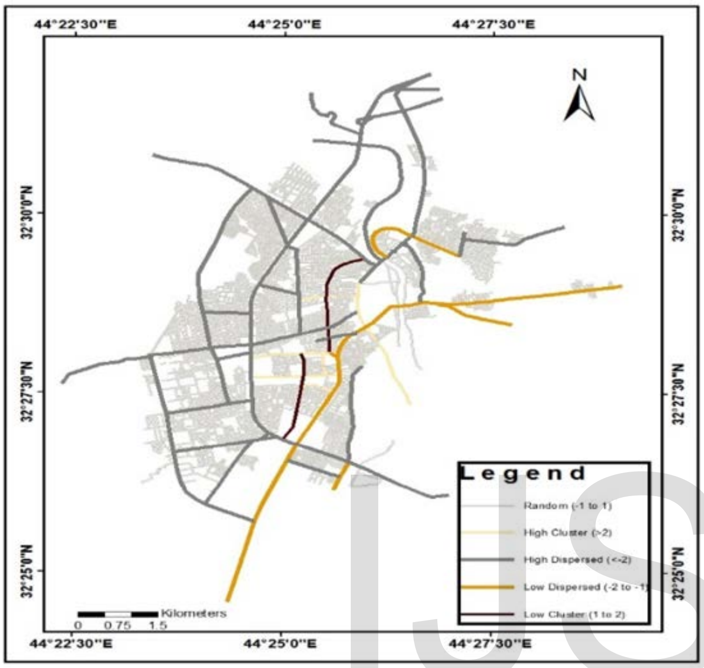

Figure (11): Spatial distribution pattern of road network in Al-Hilla city.

3.2 Analysis of traffic volumes at Al-Hilla city entrances and its city center

GIS plays an effective role in different traffic analysis and applications. In this section, traffic volumes at Al-Hilla city entrances, city center, and city intersections were analyzed and visualized. These analyses were based on the comprehensive traffic statistics obtained from the traffic office of Al-Hilla.

3.2.1 Analysis of traffic volumes at Al-Hilla city entrances

There are four main entrances (EX1, EX2, EX3, and EX4) for Al-Hilla city as illustrated in figure 12. This is in addition to four other subordinate entrances (EX5, EX6, EX7, and EX8), which link the city traffic by the traffic coming from cities and governorates in the vicinity of Al-Hilla city. The first entrance (EX1) lies at the northeast of the city and it is called "Baghdad Main Entrance". This entrance links the city traffic axes with the traffic coming from the north of Iraq and the city of Baghdad. The second entrance (EX2) lies at the northwest and it is called "The Entrance of Karbala". It links the axes of the city traffic with the traffic coming from the city of Karbala. The third entrance (EX3) lies at the southeast and it is called "Entrance of Najaf ". It links of the city traffic with the traffic coming from the city of Najaf. The fourth entrance (EX4) lies at the southeast part of the city and it is called "Entrance of Diwanya". This entrance links Al-Hilla traffic with the traffic coming from Al-Diwanya city and the southern governorates. The fifth entrance (EX5) lies in the west and it is called "Entrance of Tohmazea". It links the city traffic with the traffic coming from the areas of Tohmazea and Aoofy. The sixth entrance (EX6) lies in the east and it is called "Entrance of Seaf Saad". It links the city traffic with the traffic coming from Seaf Saad and the Highway. The seventh entrance (EX7) is called "Entrance of Al-Seahy", which links the city traffic with the traffic that comes from the southern cities district of Al-Hashemea. The eighth entrance (EX8) is called "Baghdad Secondary Entrance”. It links the city traffic with the traffic coming from the northern areas and the city of Baghdad.

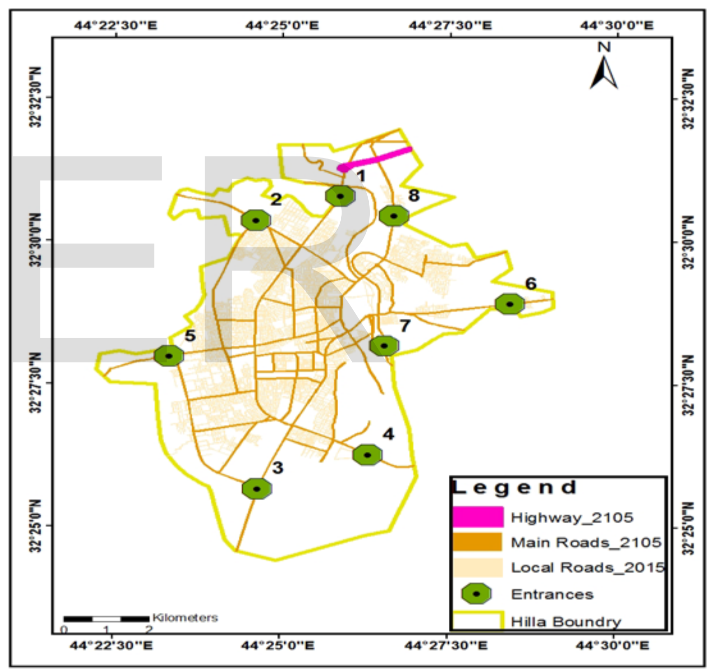

Figure 12: Locations of external entrances to Al-Hilla city.

3.2.1.1. External traffic load flow into Al-Hilla city

The highest traffic load that flows into Al-Hilla city at main external was observed at (8:15 – 9:15 am). There wasn’t any other observable peak period throughout the survey time, which lasted for 12 hours. The same traffic peak was observed at the other external main gates at the same period of time. However, there were two peak traffics at the gate of Baghdad one between 7:00 to 8:30 am for the traffic coming from the nearby districts. The other peak was observed from 2:00 to 4:00 pm for the traffic that leaves the city. From the obtained statistics, we may estimate the outlet city traffic volume at around 50% of all the external traffic coming from the north to south of the city as illustrated in figure 13 and table 7.

TABLE 7
TRAFFIC VOLUME OUT OF AND INTO AL-HILLA CITY AT ENTRANCE GATES.

Location	Out of	Into	Total
EX1	5440	12120	17560
EX2	17320	14500	31820
EX3	19200	13300	32500
EX4	6480	7200	13680
EX5	3415	3620	7035
EX6	4520	3600	8120
EX7	3500	3200	6700
EX8	4000	7500	11500
City	48370	43966	92336

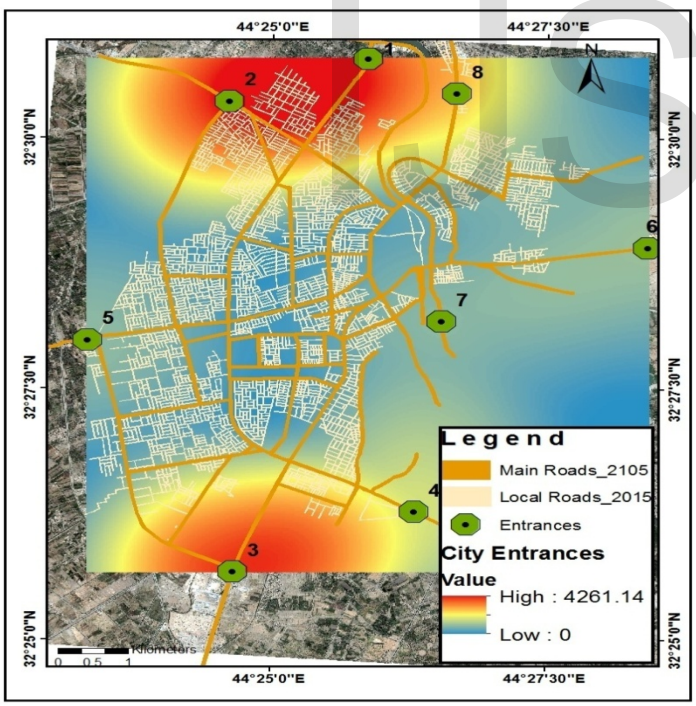

Figure 13: Spatial distribution of traffic volume at Al-Hilla city entrances.

3.2.2 Analysis of Traffic Volume at the City Center

Traffic volumes were also analyzed at the center of Al-Hilla city., which is also known as the “Historic City Core". It covers an area of about two square kilometers. It is encircled from one side by the Euphrates River and from another side by inhabited neighborhoods. Most of the government offices and constructions are located in the city center. This is in addition to the Hilla city main commercial high street. The layout of the main streets is grid orientated and is densely advanced. In general, there is a major traffic problem concerning the historic city core that needs serious solutions. The majority of streets at the city center are narrow and are commonly overcrowded with parking, trucks, private cars that obstruct others access and movement.

Accordingly, traffic data were collected at four internal cordon Stations around the city center as represented in Table 8 and Figures 14 and 15. At the first station (EN1), we noticed that the city center has more attraction rate of about 42%, likewise the traffic flow that leaves the city center was around 45% of all traffic flow that passes the center of Al-Hill city. The peak period for traffic flow through the center was almost two hours. Firstly, we observed that the concentration of traffic volume at the center of the city is in Al-Hussein entrance region that connects Baghdad, Karbala and city neighborhoods with the city center. Another crowded center with traffic flow was observed in the side of the city center that contains the shopping stores, which attract many visiting trips. It was also observed the rate of vehicles that leave the center of the city was higher than that enters it.

TABLE 8
TRAFFIC VOLUME AT AL-HILLA CITY CENTER.

Location	Out of	In to	Total
EN1	22000	18400	40400
EN2	10550	7200	17750
EN3	8620	9616	18236
EN4	7200	8750	15950
City center	48370	43966	92336

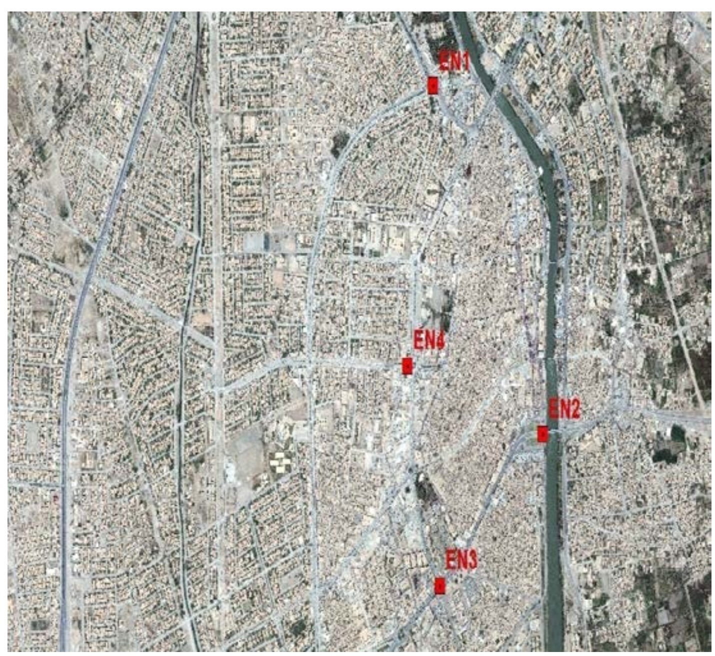

Figure 14: Internal Cordon Stations in Al-Hilla city

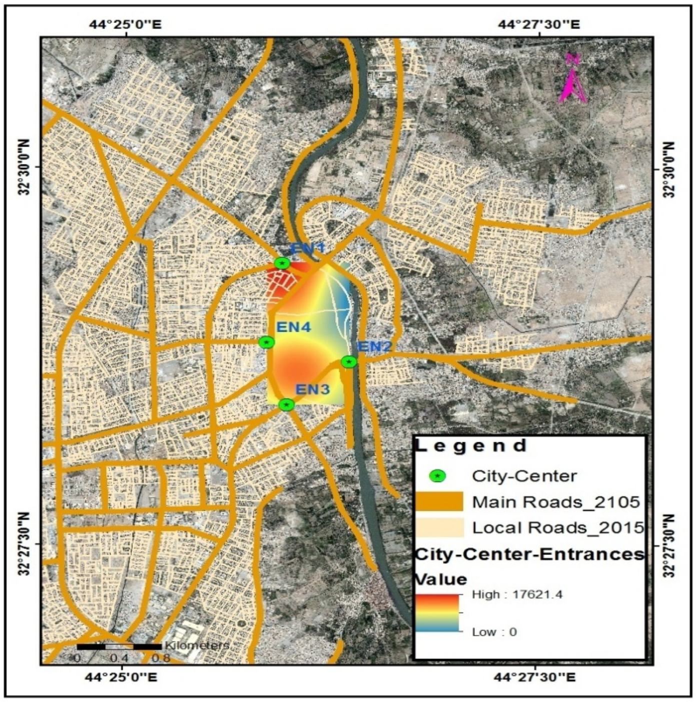

Figure 15: Traffic flow through the old city center

3.2.3 Traffic volumes at the intersections of Al-Hilla City

There are sixteen high traffic intersections in Al-Hilla city. One of them is a quadruple intersection; three dribble intersections and the rest are ground intersections. These intersections were designed and studied according to traffic flow. Traffic volumes at only five of the most active intersections were considered in this study. Figures 16 and 17 illustrate traffic volumes that flow through these five studied intersections and their spatial distribution among them.

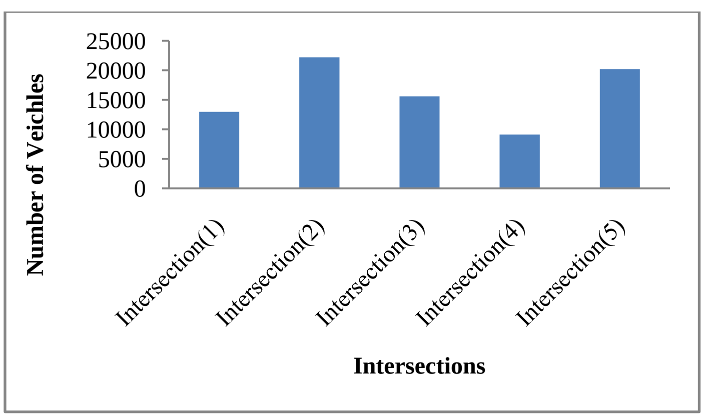

Figure 16: Traffic volumes at the five studied intersections in Al-Hilla city.

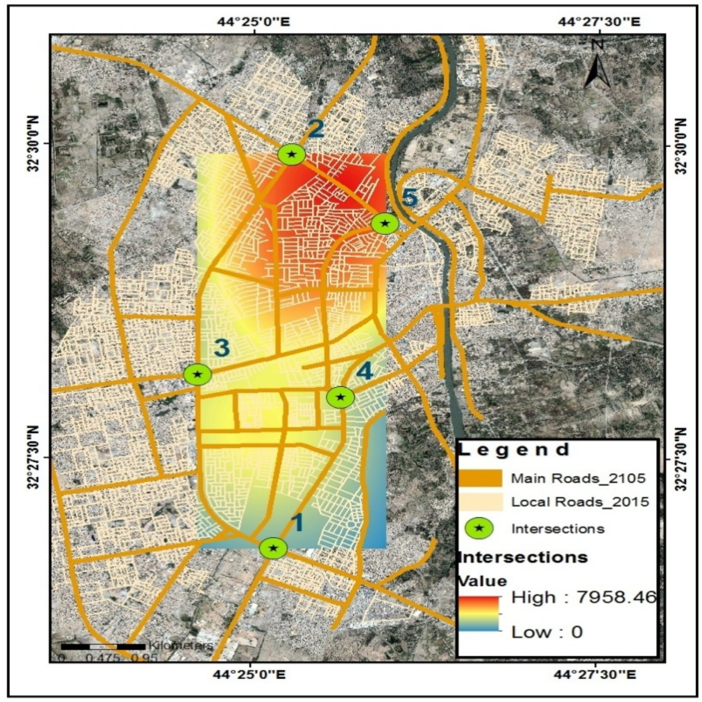

Figure 17: Spatial distribution of traffic flow among the five studied intersections in Al-Hilla city.

3.3. Kernel Density Analysis

Kernel density is 3D analysis tool that makes a calculation of a magnitude per unit area from point or poly-line features utilizing a kernel function. It is used for fitting a smoothly pointed surface to every point or poly-line. The Kernel tool computes the features density in a neighborhood near these features. It could be computed for both point and line features. Potential usages include finding a density of houses, roads or utility lines that influence a town, crime reports, or wildlife habitats. The population field could be utilized to weight certain features which are more influential than others. This is depending upon what they mean, or to let one point signify many observations. For example, some crimes could have a higher weight than others in the determination of general levels of crimes. Regarding line features, a highway that is divided may have a stronger influence than a narrow dirt road (**ESRI, 2013)**. Figure 18 indicates the illustration above showing a line segment and the kernel surface tailored over it. The line segment contribution to density equals the kernel surface value at the center of the raster cell. By default, the selection of a unit is grounded on the projection definition either linear unit of the input poly-line feature data or as stated in the output coordinate system in the environment settings.

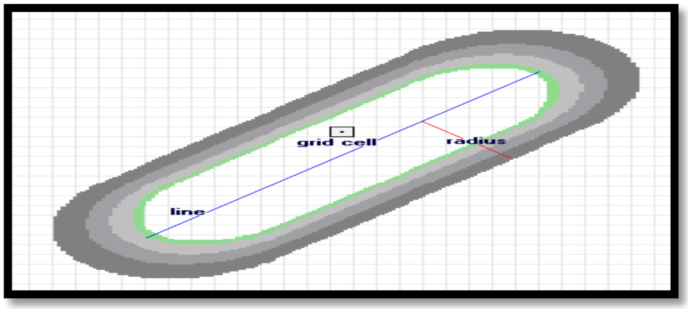

Figure 18: A line segment and the kernel surface fitted over it.

Figure 19 illustrates the results of applying kernel density analysis on the road network in Al-Hilla city center. It shows a high density of roads in the city center of Al-Hilla city. This indicates that the area does not suffer from lack of roads and traffic difficulties may be caused by other factors.

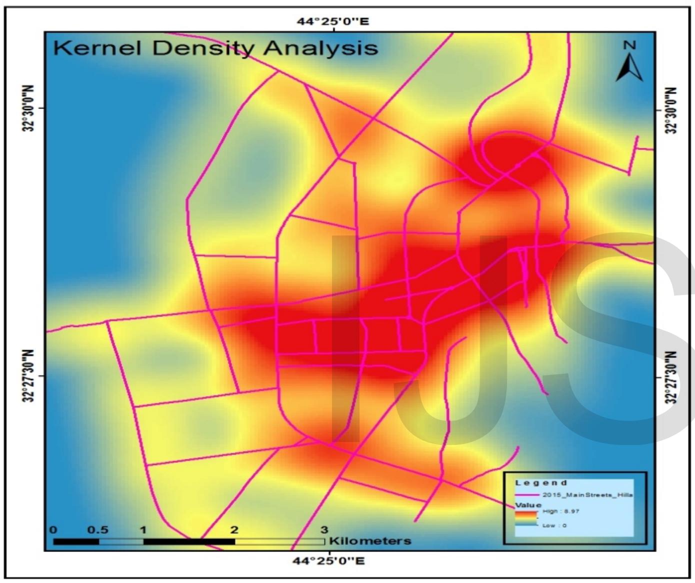

Figure 19: Kernel density analysis of road density in Al-Hill city center.

3.4 Sustainability of road network in Al-Hilla city

In order to sustain road network in Al-Hilla city for future generations, the rate of annual change in road length, road area, and urban area were calculated for the last 8 and 16 years as represented in Table 9. These rates were used to make an estimation of the number of population, road length, RDI, TIEI, road area, urban area and RADI in 2030 as compared with that in 2015.

The results reveal that transportation infrastructure will decrease in 2030 to about 2.76% after it was 3.4% in 2015 as represented in Table 10. The expected total road length in 2030 will be about 998 km after it was about 585 km in 2015. Road area will be about 16.79 km² after it was 11.23 km² in 2015. Also, urban area will be about 68.8 km² in 2030 after it was about 41.85 km² in 2015.

The results show a harmony between urban area and population growth in Al-Hill city based on the RDI index. However, there was a lack of harmony between the expansion of urban areas and the increase in road areas based on RADI index. Accordingly, there is an urgent need to increase the road areas, especially for the main ones. This is in addition to equally distribute road network within the city as it currently has a random distribution. Also, proper maintenance of current roads, good planning and use of modern technologies could help in solving transportation problems in AL-Hilla city.

TABLE 9
RATE OF ANNUAL CHANGE IN ROAD LENGTH, ROAD AREA AND URBAN AREA DURING THE STUDIED PERIOD OF TIME.

Year	Road length (km)	Rate of annual change (%)
1999	201.91	13.80
2007	424.94	11.85
2015	584.89	4.71
Year	**Road area (km²)**	**Rate of annual change (%)**
1999	6.13	5.6
2007	8.89	5.2
2015	11.23	3.3
Year	**Urban area (km²)**	**Rate of annual change (%)**
1999	16.85	10.6
2007	31.09	9.3
2015	41.85	4.3

TABLE 10
EXPECTED POPULATION, ROAD LENGTH, RDI, TIEI, ROAD AREA, URBAN AREA AND RADI IN 2030 AS COMPARED WITH THAT IN 2015.

year	Annual change in road length %	Population	Road length km	Urban Area km²	RDI km/ha	RDI km/person	TIEI %
2015	--	465524	584.89	41.85	0.14125	0.001256	3.4
2030	4.71	768830	998.11	68.8	0.14908	0.001298	2.76
Year	**Annual change in road area %**	**Annual change in urban area %**	**Population**	**Urban area km²**	**Road area km²**	**RADI %**	**RADI ha/person**
2015	--	--	465524	41.85	11.23	26.83	0.0024
2030	3.3	4.3	768830	68.8	16.79	24.40	0.0022

4. Conclusions

From our work, it could be concluded that the application of both remote sensing data and GIS techniques could provide more accurate, low-cost, time-effective information about road network in Al-Hilla city. By evaluating the spatial relationships between urban growth and transportation the results showed that road areas in Al-Hilla city were decreased with increasing population and urban growth. There was a shortage in the main roads and highways; however, there was an increase in the intensity of secondary or local roads which have a narrower width.

The road network was highly dense at the center of Al-Hilla city in year 2015, which indicates no lack in roads. It was found there will a decrease in road areas, TIEI in 2030 than that in the current years. This reveals an urgent need to sustain current road network and increase the main road areas. This is in addition to equally distribute road network within the city as it currently has a random distribution.

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