Environmental and social sustainable operation for parking lots within the Hilla central business district (CBD)

Sadiq G. Medlol¹ and Ali A. Alwash²

¹ M.Sc. Student, College of Engineering, University of Babylon, Iraq
² Prof. Doctor, College of Engineering, University of Babylon, Iraq
*Corresponding Author: Sadiqghazi1981@gmail.com

Abstract. Central Business District (CBD) is the undisputed center of traffic development resulting from growing industry and economic activity. Attracts people from various parts of the city as well as its area to shop and leisure services. To achieve the objective of this research the Central Commercial Area, Sector 2 in Hilla, was selected to evaluate the sustainability process on the basis of environmental and social indicators for car parks (20 parking lots), as well as identifying the level of service for the pedestrian sidewalks for three roads (Street 60, Street 40 and Bab al-Hussein). The methodology of this research can be summarized by obtaining field data for the volumes of pedestrian traffic using the imaging process, and vehicle parking data (air pollutants from vehicle exhausts, noise level and a number of accidents) through collaboration with relevant government institutions. This work is developing a method for achieving a sustainable composite index for the available information. The indicators are incorporated into environmental, social and economic indicators in a composite sustainable index in a way that overcomes the restrictions of normalization, weight, and aggregation. The results of the composite sustainable transportation index for car parking sustainability range from very low level (2 parking), low level (4 parking), moderate level (12 parking) and high level (2 parking). While the study concluded that the level of service for pedestrian sidewalks is of type (D) for Bab Al-Hussein Street and type (A) for Street 60 and Street 40.

1. Introduction
Parking plays a significant role in delivering service to people by enabling them to park and stops their vehicles before they take part in practices. Often parking issues arise in the central business district, where there isn't enough space. Vehicle drivers have difficulty in finding parking places in that area. To address this issue, the proposed approach is to run the current parking facilities to maximum capacity. That can be achieved by the use of the proper engineering design of parking spaces and appropriate traffic control [1]. Parking, an important part of the transportation network, is a significant problem facing the urban designer and transport engineer, as it plays a vital role in handling traffic and reducing congestion. These a problem emerges with the random increase in car ownership, increasing population growth, CBD economic activity, and land-use change, hence the difficulty of finding suitable solutions. Therefore the availability of parking spaces is an integral aspect of the means of transportation. Parking in center commercial areas is of considerable significance in the principle of preference with respect to transit use for sustainability transport strategy. Parking affects every transport and land use but sometimes overlooks or misunderstands its influence. Multiple individuals see congestion, emissions, noise and injury issues – and even the most vehement opponents of automobiles still fail to associate...
these issues to parking policy [2]. CBDs are places with strong economic and social activities and spaces for pedestrian operations, however, facilities for pedestrians was not included in the design of CBDs. Pedestrian infrastructure is usually implemented as an add-on to the key design of the CBDs and often creates lots of problems than they were meant to address them, where there are insufficient sidewalks/walkways across main roadways, disproportionately controlled by road vendors, occupied by shop premises, or obscured by stopped vehicles, motorcycles, and bikes [3]. This study aims to evaluate the environmental and social sustainability process of parking vehicles (20 parking lots) within the Central Commercial District, Sector 2 of Al-Hilla through the calculation of the composite sustainable transportation index, as well as to assess the level of service for pedestrian sidewalks within the study area for three roads (Street 60, Street 40 and Bab al-Hussein).

2. Parking problems in the central business district

The central commercial area is a traffic attraction due to increased commercial and economic growth leading to a large rise in vehicle movement, and transportation research is invested efforts in the environmental issues caused by vehicles while neglecting the significant part of the parking problems. Congestion issues, delays, and mass transportation inadequacies have driven residents to opt with private cars [4]. The private car demands parking of the vehicles is an integral component of the transport network. This condition has boosted competition for Center Commercial Area car parking spaces [5]. The issue with parking in the center of town stems from a dispute among demand and supply. Most business and public locations in CBD attract cars and pedestrians but lack sufficient parking spaces. The transport designers face difficulties in addressing the problem of parking, particularly in business districts. Finding an empty car park place in the city center’s business district is a period-consuming operation [6]. Parking lots may also have adverse effects on urban areas. Environmental pollutants and roadway congestion are amongst these effects. This has created environmental contamination, because cars are stopped and started while the car is parked and stopped, resulting in noise and pollutions [7].

3. Environmental and social sustainability operation

Sustainability is a matter of growing significance for the transport network in urban areas, and congested traffic flows, deteriorating air quality and demands for better access to livable transportation services are popular in more and more regions about the world [8]. Generally, sustainability is assessed using a range of measurable indicators (environmental, social, and economic) to track patterns, analyze areas and operations, determine different policy and planning choices, and set quality goals [9]. Motor vehicle pollutions comprise carbon monoxide (CO), carbon dioxide (CO₂), nitrogen oxide (NOₓ) in the form of nitrogen oxide (NO) and nitrogen dioxide (NO₂), hydrocarbons (HC), sulfur oxides (SOₓ) in the form of sulfur dioxide (SO₂) and sulfur trioxide (SO₃), and particulate matter (PM10) [10]. A traffic collision usually defined as a traffic accident or crash that occurs when an automobile crashes with another it, pedestrians, animals, roadways barriers or other fixed obstacles such as a wall or utility pole. Collisions in traffic can result in injury, death, damage to the vehicle and damage to property [11]. Traffic noise is a critical environmental issue, given its steady growth in developed states, this issue is not adequately recognized. Now that noise is a significant threat to the safety and social life activity. Become an unwarranted intrusion and burden on the convenience, safety, and efficiency of the life of peoples. Vehicle traffic can be seen as the primary cause of noise pollutants [12].

4. Description of the zone of study

Hilla is situated in the south of Iraq, the governorate of Babylon was bounded by the capital city of Baghdad from the north, by the governorate of Kerbalah from the west, by the governorate of Al-Anbar from the northwest, by the governorate of Wasit from the east and northeast, and by the governorates of Najaf and Diwaniyah from the southwest and southeast respectively. It lies among 44° 22’ 12.426 ”–44° 22’ 12.554” E and 32° 24’ 23.54”–32° 31’ 57.4767” N and occupies an area of approximately 161 km² [13]. The study region lies in the center of the city in which describes sector 2 of the CBD zone as
seen in figure 1. All parking spaces for the vehicles in the study area were covered by 20 parking lots, the off-street parking was highlighted in this study. The study also chose three main roadways within CBD sector 2, namely 60 roadway, 40 roadway, and Bab Al-Hussein roadway, to find the level of service for pedestrian sidewalks, outlined in table 1 and figure 2.

![Figure 1. The Location of Study Area (Hilla City).](image)

5. Data collection for assessment of the sustainability
To meet the research goals, data must be collected in the study area for off-street parking lots and pedestrians. The following explains the data-gathering procedures.

5.1. Traffic data for off-street parking
5.1.1. Accident data for off-street parking
Accident data were collected for parking in the study area via a questionnaire with the garage official, including incidents that occur when a car collides with another, the vehicle's rear collision when parking, and a collision with fixed barriers. As seen in table 2.
Table 1. Information off-street parking in the study area.

| Parking Name                          | Location            | Parking Type | Parking Area m² | Maximum Capacity |
|---------------------------------------|---------------------|--------------|-----------------|------------------|
| 1- Al tejara room park (P1)            | Imam Ali Roadway   | Surface      | 850             | 80               |
| 2- Al rahmaa park (P2)                 | Imam Ali Roadway   | Surface      | 2000            | 195              |
| 3- Saad bridge park (P3)               | Imam Ali Roadway   | Surface      | 1750            | 180              |
| 4- Al mustafa park (P4)                | Imam Ali Roadway   | Surface      | 600             | 55               |
| 5- Al sadiq park (P5)                  | Imam Ali Roadway   | Surface      | 400             | 37               |
| 6 Al amin park (P6)                    | Imam Ali Roadway   | Surface      | 725             | 68               |
| 7- Al sadiq park (P7)                  | Imam Ali Roadway   | Surface      | 275             | 20               |
| 8- Al sundbad park (P8)                | Imam Ali Roadway   | Surface      | 300             | 27               |
| 9 Al nisa garden park (P9)             | Alatibba Roadway   | Surface      | 800             | 75               |
| 10 Al hilal alahmar park (P10)         | Alatibba Roadway   | Surface      | 275             | 22               |
| 11- Al mudinih park (P11)              | Alatibba Roadway   | Surface      | 325             | 25               |
| 12 Alameen park (P12)                  | Alatibba Roadway   | multistory   | 300 per floor   | 125              |
| 13- Babil aluwlaa park (P13)           | Alatibba Roadway   | Surface      | 600             | 50               |
| 14 Al fayhaa park (P14)                | Alatibba Roadway   | Surface      | 350             | 30               |
| 15- Al akhwaan park (P15)              | Alatibba Roadway   | Surface      | 450             | 40               |
| 16- Multi-story park (P16)             | Alatibba Roadway   | multistory   | 300 per floor   | 120              |
| 17 Bab Alhussain park (P17)            | Bab Alhussain Roadway | Surface   | 4250            | 350              |
| 18- Al baghdadi park (P18)             | Bab Alhussain Roadway | Surface   | 250             | 20               |
| 19- Al azzawi park (P19)               | Bab Alhussain Roadway | Surface   | 350             | 30               |
| 20- Al hilla municipality park (P20)   | Al baladayh Roadway | Surface      | 500             | 45               |

Figure 2. Locations of Study in the Central Business District (Sector 2).
Table 2. Accident data for off-street parking.

| Parking number | The number of accidents |
|----------------|-------------------------|
| P1             | 3                       |
| P2             | 30                      |
| P3             | 20                      |
| P4             | 2                       |
| P5             | 5                       |
| P6             | 20                      |
| P7             | 10                      |
| P8             | 25                      |
| P9             | 12                      |
| P10            | 10                      |
| P11            | 3                       |
| P12            | 1                       |
| P13            | 1                       |
| P14            | 5                       |
| P15            | 2                       |
| P16            | 1                       |
| P17            | 2                       |
| P18            | 3                       |
| P19            | 2                       |
| P20            | 1                       |

The table indicates that incidents in the car parks vary from one park to another, as these garages are not regulated and lack preparation and supervision as well as stopping at random, which contributes to a reduction in safety standards and therefore raises the risk of incidents. In addition, the entrances and exits of the parking lots are not separate, the weak design of the entrance dimensions does not commensurate to the large number of vehicles that use the parking lots, and carelessly parking maneuvers lead to crashes.

5.1.2. Noise data for off-street parking

Traffic noise value was collected in coordination with the Babylon City Environment Department. Depending on the peak hour volume, from (5-7) PM for a period of February month. For this purpose, the noise values were measured using a digital sound level meter (SVAN 955) portable in decibels, as shown in table 3, plate 1 represents a photo of the instrument.

The proposed specification for air quality for the Environmental Protection Agency (EPA) (2009) Ministry of the Environment as follows [14]:

- Noise $L_{eq}$ (Iraqi limit = 55 dB).
- Lead (Iraqi suggested limit = 2 microgram/m$^3$).
- $SO_2$ (Iraqi suggested limit = 40 ppb).
- $CO$ (Iraqi suggested limit = 35 ppm).
- $NO_x$ (Iraqi suggested limit = 5 ppb).
- $CO_2$ (Iraqi suggested limit = 300 ppm).
Plate 1. Digital sound level meter (SVAN 955), portable.

Table 3. Noise data for off-street parking.

| Parking number | Noise dB(A) |
|----------------|-------------|
| P1             | 70.1        |
| P2             | 66.3        |
| P3             | 64.4        |
| P4             | 67.6        |
| P5             | 65.8        |
| P6             | 68.3        |
| P7             | 63.2        |
| P8             | 70.5        |
| P9             | 63.4        |
| P10            | 68.2        |
| P11            | 62.7        |
| P12            | 69.1        |
| P13            | 68.7        |
| P14            | 66.9        |
| P15            | 67.5        |
| P16            | 65.3        |
| P17            | 79.8        |
| P18            | 77.5        |
| P19            | 73.2        |
| P20            | 66.4        |

The table shows that the noise level of the study area exceeded the allowed limit for the suggested air quality specification for EPA (2009) environmental ministry obtained from the environmental office at Hilla city [14].

5.1.3. Air pollution data for off-street parking

Air pollutant data obtained by measuring directly at the site through coordination with the Ministry of Science and Technology – Department of Chemical and Biological Waste Treatment – Quality Control and Occupational Safety Center, the air pollutants (CO₂, CO, NO, SO₂, NO₂) for car park were measured using a digital Gasmet DX4040, Portable FTIR ambient gas analyzer, Plate 2 represents an image to the device, It is an instrument capable of measuring multiple gases (organic and inorganic) at low concentration simultaneously in real-time. As shown in table 4.
Table 4. Air pollution data for off-street parking.

| Parking number | CO₂ (ppm) | CO (ppm) | NO (ppm) | SO₂ (ppm) | NO₂ (ppm) |
|----------------|-----------|----------|----------|-----------|-----------|
| P1             | 265       | 27.7     | 0.05     | 0.01      | 0.24      |
| P2             | 283       | 26.3     | 0.07     | 0.04      | 0.23      |
| P3             | 270       | 24.6     | 0.07     | 0.06      | 0.21      |
| P4             | 260       | 27.5     | 0.04     | 0.03      | 0.18      |
| P5             | 255       | 26.5     | 0.04     | 0.05      | 0.21      |
| P6             | 290       | 28.5     | 0.03     | 0.09      | 0.17      |
| P7             | 265       | 28.8     | 0.06     | 0.05      | 0.15      |
| P8             | 288       | 26.2     | 0.19     | 0.23      | 0.26      |
| P9             | 310       | 32.4     | 0.11     | 0.18      | 0.36      |
| P10            | 302       | 29.8     | 0.09     | 0.07      | 0.19      |
| P11            | 288       | 30.2     | 0.16     | 0.21      | 0.21      |
| P12            | 315       | 30.9     | 0.12     | 0.17      | 0.5       |
| P13            | 297       | 32       | 0.09     | 0.14      | 0.43      |
| P14            | 305       | 34.2     | 0.03     | 0.14      | 0.48      |
| P15            | 295       | 29.3     | 0.03     | 0.18      | 0.48      |
| P16            | 280       | 28.4     | 0.08     | 0.13      | 0.33      |
| P17            | 334       | 36.8     | 0.13     | 0.20      | 0.14      |
| P18            | 327       | 31.2     | 0.1      | 0.15      | 0.11      |
| P19            | 295       | 33.6     | 0.11     | 0.36      | 0.38      |
| P20            | 297       | 30.4     | 0.15     | 0.19      | 0.13      |

The table indicates that air pollutant levels in the study area were found some of them were within the acceptable limits, while others show values higher than the adopted limit the Ministry of the Environment's (2009) allowable air quality requirements [14].

5.2. Traffic data for pedestrians

Includes volumes of pedestrian traffic for a specific location of the road, defined as the number of volumes of pedestrian traffic that traverse a certain section of the walkway over a 15-minute period, as shown in table 5. In addition, data were collected on the sidewalks and obstructions affecting the effective width of the walkway, such as trees, storefronts, lighting poles and stairways for pedestrian crossing, and others, as shown in table 6. Traffic data was obtained using the imaging method and depending on the traffic peak hour.
Table 5. Pedestrian volume in the study area.

| Roadway name                           | Peak hour | Time                  | Pedestrian flow P/15min. |
|----------------------------------------|-----------|-----------------------|--------------------------|
| Sixty Roadway (Al tahmaziah bridge-Al thawrah intersection) | 8:00-9:00 | 8:0-8:15              | 157                      |
|                                        |           | 8:15-8:30             | 243                      |
|                                        |           | 8:30-8:45             | 188                      |
|                                        |           | 8:45-9:0              | 139                      |
| Forty Roadway (Intersection of 40- Abu Khumrah Intersection) | 8:00-9:00 | 8:0-8:15              | 117                      |
|                                        |           | 8:15-8:30             | 129                      |
|                                        |           | 8:30-8:45             | 194                      |
|                                        |           | 8:45-9:0              | 154                      |
| Bab Al Hussein Roadway (Bab Al Hussain-Bab Al Hussain bridge) | 8:00-9:00 | 8:0-8:15              | 420                      |
|                                        |           | 8:15-8:30             | 458                      |
|                                        |           | 8:30-8:45             | 437                      |
|                                        |           | 8:45-9:0              | 385                      |

Table 6. Pedestrian walkway obstacles in the study area.

| Roadway name                           | Total walkway width(WT) (ft) | Obstruction Type | Obstruction distances in walkway(W0) (ft) |
|----------------------------------------|------------------------------|------------------|------------------------------------------|
| Sixty Roadway                          | 26.4                         | 1. Stairways     | 7+4+6+2=19                               |
|                                        |                              | 2. Trees         |                                          |
|                                        |                              | 3. Shops         |                                          |
|                                        |                              | 4. Parking       |                                          |
| Forty Roadway                          | 23.1                         | 1. Shops         | 6+4+3.5+2=15.5                           |
|                                        |                              | 2. Trees         |                                          |
|                                        |                              | 3. Electricity poles |                                     |
|                                        |                              | 4. Parking       |                                          |
| Bab Al Hussein Roadway                  | 4.95                         | 1. Traffic signs | 2                                       |
|                                        |                              | 2. Trees         |                                          |
|                                        |                              | 3. Electricity poles |                               |
|                                        |                              | 4. Parking       |                                          |

6. Results and Analysis

The results can be summarized in two parts, the first section to assess the sustainability of off-street parking lots and the second section to find the standard of service for pedestrian side walkways as in the sub-sections below:

6.1. Sustainability assessment for off-street parking

Transportation indicators consist of many kinds of information (social, economic and environmental), and therefore there may be a difference among the indicators in the units. Therefore, it is must be to transfer them into numbers without measurements before grouping indicators. These steps are known as normalization. Using Equation (1) [15], to normalize Indicators, I_{accident}, I_{noise}, I_{CO2}, I_{CO}, I_{NO}, I_{SO2}, and I_{NO2} are as shown in table 7.

\[
I_i = \frac{I_{\text{max}} - I}{I_{\text{max}} - I_{\text{min}}} \tag{1}
\]

I_i = any calculated normalized indicators.
I_{min} = Minimum Indicator Value.
I_{max} = Maximum Indicator Value.
I = indicator value which its increase effects negatively on sustainability.
A key method of sustainability evaluation is to combine single indicators into a composite index. It assesses the different parameters of sustainability which can not be fully captured by individual measures alone. Opponents of the compound indicator think the Compound index is inaccurate because of its subjective construction. However, there is no individual index that can address all questions and that needs several indicators [15].

Standard weighting has the advantage of assessing how significant each parameter is compared to the other parameter. Some of the weighting approaches refer to the guidelines used for this reason by the decision-makers. The approach of evaluating trade-off is more useful in terms of accumulation and the triple base. Weights are typically set to 1, and the weight category is identified as $W = (w_1, w_2, w_3, w_n)$ and $\sum w_i = 1$ is, as G. Malczewski (1999) described.

In order to measure the composite sustainability index for parking lots in the study area using the equation (2), the following weights were proposed on the basis of the trade-off analysis approach and on the basis of the harmful effects by evaluating the results of the questionnaire for which specialists had made. The ICST (Composite Sustainable Transport Index) values range from zero (worst case) to one (best case), the ICST results are shown in table 8.

$$I_{\text{CST}}(\text{Parking}) = 0.6 I_{\text{accident}} + 0.184 I_{\text{noise}} + 0.0432 I_{\text{CO2}} + 0.0432 I_{\text{CO}}$$
$$+ 0.0432 I_{\text{NO}} + 0.0432 I_{\text{SO2}} + 0.0432 I_{\text{NO2}}$$

Table 8 indicates the variability in the index of sustainable composite transport for parking, and the overall sustainability operation evaluation varies from the very low to the high level. From (0.00-0.35) it represents a very low level, from (0.36-0.65) is low and from (0.66-0.85) a moderate level and from (0.86-1.00) it represents a high level.

Thus, parking lots P2 and P8 have a very low level and that P3, P6, P9, and P17 have a low level while P1, P5, P7, P10, P11, P12, P13, P14, P15, P18, P19, and P20 have a moderate level and finally P4 and P16 they have a high level.
Table 8. Composite Sustainability Transport Index ($I_{CST}$) for parking within the CBD sector.

| Parking number | $I_{CST}$ |
|----------------|-----------|
| P1             | 0.82      |
| P2             | 0.31      |
| P3             | 0.54      |
| P4             | 0.88      |
| P5             | 0.83      |
| P6             | 0.48      |
| P7             | 0.75      |
| P8             | 0.30      |
| P9             | 0.62      |
| P10            | 0.66      |
| P11            | 0.83      |
| P12            | 0.77      |
| P13            | 0.82      |
| P14            | 0.73      |
| P15            | 0.80      |
| P16            | 0.87      |
| P17            | 0.63      |
| P18            | 0.68      |
| P19            | 0.69      |
| P20            | 0.84      |

6.2. Finding level of service for pedestrian sidewalks

In order to estimate the level of service for pedestrian sidewalks in the study area, this requires finding pedestrian flow rate ($V_P$) based on per (15 minutes), using Equation (3) and Table 9 [16].

$$V_P = \frac{V_{15}}{15 \times W_E}$$     \hspace{1cm} (3)

$V_P$ = pedestrian unit flow rate (P/min./ft).

$V_{15}$ = peak 15 min. flow rate (P/15min.).

$W_E$ = effective walkway width (ft).

Table 9. The criteria for the pedestrian level of service[16].

| Level Of Service | Flow Rate (P/min./ft) | V/C Ratio |
|------------------|-----------------------|-----------|
| A                | <5                    | <0.21     |
| B                | >5-7                  | >0.21-0.31|
| C                | >7-10                 | >0.31-0.44|
| D                | >10-15                | >0.44-0.65|
| E                | >15-23                | >0.65-1.0 |
| F                | variable              | variable  |

To calculate the effective width of the walkways, using Equation (4), after subtracting the width of all the obstructions in it, such as trees, storefronts, lighting poles, special stairways [16].

$$W_E = W_T - W_0$$     \hspace{1cm} (4)
$W_T = \text{total walkway width (ft).}$  
$W_0 = \text{The sum of the width and shy distances on the walkway (ft) from obstruction.}$

Using the above equations, $a$ ($V_P$) is calculated for all roadways in the study area, through which the required service level will be inferred, as shown in Table 10.

**Table 10.** Shows the level of service for pedestrian sidewalks in the study area.

| Roadway Name       | effective walkway width($W_T$) (ft) | Flow Rate ( P/min./ft ) | level of service | V/C Ratio |
|--------------------|------------------------------------|-------------------------|------------------|-----------|
| Sixty Roadway      | 7.4                                | 2.189                   | A                | <0.21     |
| Forty Roadway      | 7.6                                | 1.701                   | A                | <0.21     |
| Bab Al Hussein     | 2.95                               | 10.350                  | D                | >0.44-0.65|

7. Conclusions

This following inference emerges in this study:

1. The values for Composite Sustainability Transport Index ($I_{CST}$), for calculated data to parking lots in the study area, the comprehensive assessment of the sustainability operation level is from moderate (12 parking) to low (4 parking) and very low (2 parking) with two parking representing a high level.

2. The noise level for all off-street parking in the study area exceeded the allowed limit for the suggested air quality specification for EPA (2009) Environmental Ministry.

3. The levels of air pollutants (CO$_2$, CO, NO, SO$_2$, and NO$_2$) for off-street parking in the study area, where some of them were found within the acceptable limits, while others show values higher than the adopted limit for the suggested air quality specification for EPA (2009) Environmental Ministry.

4. The level of service for pedestrian sidewalks is of type (D) in street (Bab Al Hussein), and this explains the poor performance of these sidewalks and their lack of suitability in terms of design. While the level of service in the street (sixty, forty) is of type (A) due to the width of the sidewalks in these streets.

8. References

[1] Ahmed L A 2009 A Study of Parking Characteristics in a Central Part of Basrah City *J. Eng. Sustain. Dev.* **13** 143–65

[2] Manville M and Shoup D 2005 Parking, People, and Cities *J. Urban Plan. Dev.* **131** 233–45

[3] Rumar K 1999 Transport safety visions, targets and strategies: beyond 2000 1st Eur. Transp. Saf. Lect. Eur. Transp. Saf. Counc. Brussels, Tech. Rep

[4] Yue W L 2004 Parking management in Saudi Arabia: is there any solution? *AUSTRALASIAN TRANSPORT RESEARCH FORUM (ATRF), 27TH, 2004, ADELAIDE, SOUTH AUSTRALIA, AUSTRALIA* vol 27

[5] Juremalani J Review of Parking Problems in CBD Area of Urban Cities in Developing Countries

[6] Rodrigue J-P, Comtois C and Slack B 2016 The Geography of Transport Systems

[7] Kadiyali L R 1987 Traffic Engineering and Transportation Planning Khanna Publishers *New Delhi*

[8] Mihyeon Jeon C, Amekudzi A A and Vanegas J 2006 Transportation System Sustainability Issues in High-, Middle-, and Low-Income Economies: Case Studies from Georgia (U.S.), South Korea, Colombia, and Ghana *J. Urban Plan. Dev.* **132** 172–86
[9] Gilbert R, Irwin N, Hollingworth B and Blais P 2003 Sustainable transportation performance indicators (STPI) Transp. Res. Board (TRB), CD ROM
[10] Pratama A R, Arliansyah J and Agustien M 2019 Analysis of Air Pollution due to Vehicle Exhaust Emissions on The Road Networks of Beringin Janggut Area J. Phys. Conf. Ser. 1198 82030
[11] Garber N J and Hoel L A 2009 Traffic & Highway Engineering-SI Version (Cengage Learning)
[12] Al-Ghonamy A I 2010 Analysis and Evaluation of Road Traffic Noise in Al-Dammam: A Business City of the Eastern Province of KSA J. Environ. Sci. Technol. 3 47–55
[13] Elnaggar A A, Elmwafi M and Ismael M R Road Network and its Evaluation for Sustainable Development in Al-Hilla City, Iraq
[14] Ali Al-Anbari M, Hadi Abedali A and Abdul Ameer Alwash A 2018 TRANSPORT SUSTAINABILITY INDEX OF MAIN ARTERIALS AT HILLA CASE STUDY (SAFETY AND ENVIRONMENTAL ASPECTS) J. Eng. Sustain. Dev. 22 106–17
[15] Reisi M, Aye L, Rajabifard A and Ngo T 2014 Transport sustainability index: Melbourne case study Ecol. Indic. 43 288–96
[16] Manual H C 2000 Special report no. 209 Transp. Res. Board, Washingt. DC, USA