Economic, Social, and Environmental Sustainable Operation of Roadways within the Central Business District (CBD) sector at Hilla City Incorporated with Public Transport

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Abstract. The maintaining of sustainability is a constant challenge. Sustainability can be achieved by maintaining road traffic safety or preventing collisions and using pollution-free vehicles and safe transporting of goods. This research addresses the assessment of measuring transport sustainability based on economic, social, and environmental indicators for public transport routes. The methodology of this research can be described by collecting data (air pollution, noise, number of incidents, and volumes of traffic) from 15 public transport links within the central business district (sector 2) in the city of Hilla through collaboration with the departments concerned. To avoid the problem of utilizing several evaluation indicators, this research is developing a procedure to obtain a sustainable composite index to available data collection. The indicators of sustainability for urban transportation addressing the economic (delay), social (safety), and environmental (noise, air pollution) aspects depend on existing data. Indicators are combined in the economic, social, and environmental indicators into a composite sustainability index, in a way that overcomes the restrictions of normalization, weight, and aggregation. It is an attempt to estimate the sustainability of transport within the CBD sector No.2 in Hilla, which is integrated with public transport. According to the ICST (Composite Sustainability Transportation Index) value for roads associated with public transportation in Sector No.2 of the CBD Hilla City, the overall assessment for sustainability operation is from moderate level (9 links) to low (5 links) and a high level (1 link).

Keywords: Indicators, Noise, Public Transport, CBD, Sustainable Operation, Traffic Safety

1. Introduction
Transport is an essential part of daily life and a basis for the development of societies, and it is the link that unites all parts of the city. The significant increase in the movement of people and goods that cities have witnessed in recent years has significantly contributed to many problems in these cities. Especially cities that are moving towards sustainability and its adoption of the concept of sustainable transport and its planning in cities, as one of the essential concepts in preparing comprehensive transport plans that achieve livable cities and sustainable. Achieving sustainability in transportation

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systems is to ensure that social and economic as well as environmental considerations, are taken into account in decisions affecting the effectiveness of transport [1]. An efficient transportation network is the primary driver of the city's economic, social, and environmental development. Transport systems have been described as a "lifeline" for cities in recognition of this crucial role. Expanded transport networks have fostered urban growth, but have also produced a number of challenges to achieve sustainable [2]. A significant factor in creating a sustainable transport network is the provision of a wide range of public transportation services. In terms of efficiency and roadway space usage, user costs, and pollution production, public transportation is more actively than private transportation. Public transportation systems will effectively meet much of urban passenger transport requirements. Public transport is the main driver for sustainability achieving in the transport sector [3].

Some authors have conducted studies inside Iraq similar to this paper method, but have relied on the part of the indicators. Jrew et al., 2017 were studied on assessing and analyzing the causes of traffic incidents of major urban roadways in the city of Erbil, Iraq, utilizing statistical analysis techniques. The results of the research showed that certain geometric and traffic factors are correlated with roadway accidents, as well as the rising numbers of segments in the main urban roadways will raise the number of incidents [4]. Salman, 2013 studied predict traffic noise on the Muhammad al-Qasim road in Baghdad using the technique of multiple regression analysis. After the information was collected, the data were analyzed to find the prediction model. Statistical analyzes showed that the model was convincing and gave acceptable values [5].

This research aims to study the assessment of transport sustainability based on incorporating environmental indicators (air pollutants and noise), social (traffic accidents), and economic (delay) for public transport paths in the central commercial area of Hilla by calculating the composite sustainable transport index. This research is unique in this region, because the region is located in the centre of the city of Hilla, where most of the social and economic activities are located, and the traffic is highly dense.

2. Environmental, social and economic sustainability aspects

In general, sustainability is explored in terms of the theories of sustainable development. A usually utilized definition of sustainability came from the Brundtland board report our combined Future - sustainable development is a development that meets the needs of the present without compromise the ability of future generations to meet their own needs [6].

2.1 Traffic Congestion Delay

For most people, individual trip time is the most related standard when layout and operating a road of specific origins for a specified goal. National roadway planners and economics are concerned with the total travel period in a specific region through a specific period. The overall delay produced by congestion is of particular importance [7]. Congestion is an inevitable aspect of most urban cities. Further, there is a level at which congestion begins to diminish the ability to live, increases transportation costs and impact the reliability of travel on public transport [8]. Traffic congestion is usually associated with a decrease in normal road capacity due to high traffic volumes, traffic accidents, bad weather, and roadworks. There is no individual, easy solution to congestion management. Sustainable congestion management will demand an incorporated approach that includes major use of public transportation and higher occupation vehicles, far-sighted land-use planning, changes in behaviour by roadways user and corporate, and changes in how roads are managed [9].
2.2 Traffic Safety

Traffic incidents are a big problem for the transport system. Incidents can result in loss of life, injury, or harm to property and none of those are all appropriate. Moreover, incidents have an economic impact. Including 2-5% of the GDP [10]. The different sustainability characteristics, advantages, and disadvantages of the current transportation system are analyzed, providing a clear recommendation for efficient and sustainable transport preparation aimed at maintaining traffic safety, which in turn leads to sustainable transportation systems [8]. Accidents of traffic decrease road capacity and contribute to congestion. The value of delay depends on the type/period of the accident, the number of the pathway that has been blocked due to the accident, response times to reach and remove the accident, the time required to resume ordinary road operation [11].

2.3 Traffic Noise

Environmental pollution directly or indirectly affects human health and daily activities. One of these pollutants is the traffic noise resulting from the increase in the number of cars and heavy vehicles inside the cities, as well as from the sounds of engines and friction between the car and the surface of the pavement. One of the most common sources of noise pollution is the noise resulting from the movement of vehicles, as it contributes (60-80)% of city noise, and the noise rate in major cities may reach high levels [12].

2.4 Traffic Gas Pollutants

Vehicles are among the most important sources the energy-consuming. Automobiles produce around one-fifth of a CO2 in the atmosphere that rises by human actions, one-third of the CFCs, about half of the nitrogen oxides. Such three important gasses become significant contributors to climates changes. Emissions from vehicles are based on traffic, roadway and automobile properties, weather conditions and driver behaviours [13]. CO emissions from heavy-duty vehicles, buses, and trucks (diesel fuel) equal just 1/11 of those for the small vehicle (benzene) [14].

3. Definition of the study region

The city of Hilla is located in southern Iraq, located on the Shatt al-Hilla, the eastern branch of the Euphrates, about 110 km south of Baghdad, about 60 km north of the holy city of Najaf and about 40 km southeast of the holy city of Karbala. The city is located approximately in the middle of Mesopotamia. It is located among 44° 22' 12.426" – 44° 22' 12.554" E and 32° 24' 23.54" – 32° 31' 57.4767" N. The city of Hilla developed close to the ancient city of Babylon, whose ruins are 8 kilometres north of the current city centre.

The study area is the Central Business District (CBD) is the city's high focus area. It is the city's commercial, office, and cultural centre. It has high-density traffic, a large number of transportation and a lot of activities during the day. CBD is a fixed site where sales and trade took place and were usually near the main transportation route and the side of the river. The location of the study area is represented in CBD Sector No. 2 in the city of Hilla, as shown in Figure (1).
4. The Current Reality of Public Transport in CBD

The city of Hilla witnessed a population growth and expansion in urban areas and economic activities, which requires extensive traffic between the areas of Hilla, which led to congestion and heavy traffic on the roads, as there was a heavy dependence on private cars. Effective public transport is essential to achieving sustainability. In order to increase performance, politicians and planners must be informed of the current weaknesses in public transport systems in order to become targets of future interventions. The Public Transport Survey (PT) in the CBD sector in Hilla is useful for studying future planning, including selecting operational strategies and accessibility, Figure (2) shows the public transportation links in the study area (CBD Sector2). The following observations were made through the questionnaire:

- Public transportation is random and disorganized.
- The restriction of passenger vehicles to a maximum of (8-14) passengers and the absence of transport vehicles that hold more numbers, reflecting the trend towards smaller vehicles that increase their numbers and increase the pollutants, congestion, and noise due to the rise in the number of journeys.
- The current situation of public transport in the city of Hilla does not have a clear identity because there is no real public transport system that can be relied upon as a major transporter within a rapidly evolving city.
- Most of the buses used on the network lines are old and need constant maintenance.
- There are fifteen links for the public transport routes of buses starting from the central commercial area (study area) and ending in other neighbourhoods of the city.
- There are no specific stations for the ascent and descent of passengers, the way allowed by these buses seems random on length of the route.
5. Data Collection for Sustainability Evaluation

5.1 Traffic volume data for public transport links

Traffic volume data is collected based on the video image from the Police office in Hilla city and measurement and monitoring. The delay time is determined using the equation (1 and 2) [15]; all of this data can be seen in Table 1 and Figure 3.

\[
\text{Delay} = T_{\text{congested}} - T_{\text{free flow}} \quad \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots (1)
\]

\[
T_{\text{congested}} = T_{\text{free flow}} \times \left[ 1 + \alpha \times \left( \frac{V}{C} \right)^{\beta} \right] \quad \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots (2)
\]

Where:

- $T_{\text{congested}}$ = Congested travel time.
- $T_{\text{free flow}}$ = Freeflow travel time.
- $V$ = Assigned traffic volume.
- $C$ = Capacity.
- $\alpha$, $\beta$ = Volume / Delay coefficients.

**Table 1.** Information Public Transport Routes and Delay in the CBD (Sector 2)

| Roadway Name | Length (m) | Width (m) | Speed (km/hr) | Traffic Volume(vph) | Delay (sec) |
|--------------|------------|-----------|---------------|---------------------|-------------|
| L1           | 1526       | 30        | 60            | 3500                | 192.34      |
| L2           | 693        | 30        | 60            | 2300                | 13.65       |
| L3           | 825        | 40        | 60            | 5000                | 83.04       |
| L4           | 440        | 40        | 60            | 2200                | 23.48       |
| L5           | 1341       | 40        | 60            | 4050                | 86.71       |
Figure 3. Delay in Public Transport Routes

The figure above shows that the delay in the study area varies from one roadway to another, due to heavy traffic congestion.

5.2 Accident data for public transport links

Traffic accident data were monitored for public transport routes in the study area by cooperation with the traffic police office in Hilla city. This data can be seen in Table 2 and Figure 4.

| Roadway Name | The number of accidents |
|--------------|------------------------|
| L1           | 3                      |
| L2           | 1                      |
| L3           | 4                      |
| L4           | 3                      |
| L5           | 4                      |
| L6           | 3                      |
| L7           | 4                      |
| L8           | 12                     |
| L9           | 3                      |
| L10          | 3                      |
| L11          | 3                      |
| L12          | 3                      |
| L13          | 4                      |
| L14          | 3                      |
| L15          | 3                      |
Figure 4. Accidents rates in Public Transport Routes

The figure above shows that traffic accidents in the study area differ from one route to another and that these accidents result from a vehicle collision with another, collision with fixed obstacles, and (vehicle-pedestrian) incidents.

5.3 Noise data for public transport links

The noise values for public transport routes in the study area were measured in cooperation with the Hilla Environment Office utilizing the digital sound level meter (SVAN 955), portable in (dB). As shown in Table 3 and Figure 5, plate 1 is a picture of an instrument.

The suggested specification for air quality for the (EPA) (2009) Ministry of the Environment as follows [16]:

- 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 public transport links

| Roadway Name | Noise dB(A) |
|--------------|-------------|
| L1           | 81.6        |
| L2           | 83.3        |
| L3           | 84.7        |
| L4           | 78.4        |
| L5           | 78.5        |
| L6           | 80.6        |
| L7           | 82.3        |
| L8           | 85.2        |
| L9           | 69.2        |
| L10          | 72.9        |
| L11          | 73.4        |
| L12          | 78.3        |
| L13          | 80.3        |
| L14          | 78.6        |
| L15          | 80          |

Figure 5. Noise Values for public transport routes

The figure above indicates that the noise values for all public transport links in the study region exceeded the permitted limit for the environmental ministry's (EPA) (2009) proposal air quality specification [16].

5.4 Air Pollutants data for public transport links

Air pollutants such as (CO₂, CO, NO, SO₂, and NO₂) for public transportation routes in the study area were measured in cooperation with the Ministry of Science and Technology - Quality Control and Occupational Safety Center. For this purpose, Use the Gasmet DX4040 portable digital device. The data are seen in Table 4, and Figure 6, 7, and plate 2 shows a device picture.
Plate 2. Digital Gasmet DX4040, portable FTIR.

| Roadway Name | CO₂ (ppm) | CO (ppm) | NO (ppm) | SO₂ (ppm) | NO₂ (ppm) |
|--------------|-----------|----------|----------|-----------|-----------|
| L1           | 290       | 39       | 0.06     | 0.30      | 0.42      |
| L2           | 250       | 35       | 0.12     | 0.32      | 0.48      |
| L3           | 315       | 30.8     | 0.08     | 0.09      | 0.10      |
| L4           | 265       | 29.6     | 0.14     | 0.39      | 0.59      |
| L5           | 285       | 36.3     | 0.06     | 0.08      | 0.39      |
| L6           | 340       | 38.7     | 0.09     | 0.14      | 0.23      |
| L7           | 310       | 29.3     | 0.08     | 0.11      | 0.17      |
| L8           | 375       | 39.4     | 0.11     | 0.36      | 0.38      |
| L9           | 225       | 23.3     | 0.17     | 0.06      | 0.47      |
| L10          | 218       | 22       | 0.13     | 0.11      | 0.47      |
| L11          | 283       | 31       | 0.1      | 0.27      | 0.41      |
| L12          | 273       | 24.5     | 0.16     | 0.25      | 0.52      |
| L13          | 297       | 31.2     | 0.14     | 0.53      | 0.41      |
| L14          | 260       | 28.9     | 0.12     | 0.47      | 0.38      |
| L15          | 345       | 33.7     | 0.11     | 0.31      | 0.32      |
Figure 6. CO$_2$, CO Values for public transport links

Figure 7. NO, SO$_2$, NO$_2$ Values for public transport links

The above figures show that the values of air pollutants for public transportation routes in the study region, some of them are within the permissible limits, whereas others have higher values than the proposed specifications for air quality for the Ministry of Environment [16].

6. Result and Analysis

The results can be divided into two groups; one for Sustainable Indicators and the other for the Sustainability Index as illustrated in the following:

6.1 Sustainable Indicators for public transport routes in CBD

Indicators of transport include various types of information (social, economic, and environmental). Therefore there may be some discrepancy between the indicators in the units. Therefore, it is important to convert these into numbers without any dimension before compiling indicators. This procedure is called normalization. Using equation (3) [17], normalized indicators data: I$_{\text{delay}}$, I$_{\text{accidents}}$, I$_{\text{noise}}$, I$_{\text{CO}_2}$, I$_{\text{CO}}$, I$_{\text{NO}}$, I$_{\text{SO}_2}$, and I$_{\text{NO}_2}$ are shown in Table 5.

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

(3)

I$_i$ = Any calculated normalized indicators.
I_{min} = \text{Minimum Indicator Value.}
I_{max} = \text{Maximum Indicator Value.}

### Table 5. Normalized data indicators for public transport within the CBD sector

| Roadway Name | $I_{\text{delay}}$ | $I_{\text{accident}}$ | $I_{\text{noise}}$ | $I_{\text{CO}_2}$ | $I_{\text{CO}}$ | $I_{\text{NO}}$ | $I_{\text{SO}_2}$ | $I_{\text{NO}_2}$ |
|--------------|-------------------|-----------------|-----------------|-----------------|----------------|----------------|-----------------|----------------|
| L1           | 0                 | 0.82            | 0.23            | 0.54            | 0.023          | 1              | 0.49            | 0.35            |
| L2           | 0.94              | 1               | 0.12            | 0.79            | 0.25           | 0.45           | 0.45            | 0.22            |
| L3           | 0.57              | 0.73            | 0.03            | 0.38            | 0.49           | 0.82           | 0.94            | 1               |
| L4           | 0.89              | 0.82            | 0.43            | 0.70            | 0.56           | 0.27           | 0.30            | 0               |
| L5           | 0.55              | 0.73            | 0.42            | 0.57            | 0.16           | 1              | 0.96            | 0.41            |
| L6           | 0.68              | 0.82            | 0.29            | 0.22            | 0.04           | 0.73           | 0.83            | 0.73            |
| L7           | 0.04              | 0.73            | 0.18            | 0.41            | 0.58           | 0.82           | 0.89            | 0.86            |
| L8           | 0.92              | 0               | 0               | 0               | 0.54           | 0.36           | 0.43            |                 |
| L9           | 0.80              | 0.82            | 1               | 0.95            | 0.92           | 0              | 1               | 0.24            |
| L10          | 1                 | 0.82            | 0.77            | 1               | 1              | 0.36           | 0.89            | 0.24            |
| L11          | 0.91              | 0.82            | 0.74            | 0.58            | 0.48           | 0.64           | 0.55            | 0.37            |
| L12          | 0.92              | 0.82            | 0.43            | 0.65            | 0.85           | 0.09           | 0.59            | 0.14            |
| L13          | 0.87              | 0.73            | 0.31            | 0.49            | 0.47           | 0.27           | 0               | 0.37            |
| L14          | 0.92              | 0.82            | 0.41            | 0.73            | 0.6            | 0.45           | 0.13            | 0.43            |
| L15          | 0.92              | 0.82            | 0.33            | 0.19            | 0.33           | 0.54           | 0.47            | 0.55            |

#### 6.2 Sustainability Index for public transport routes in CBD

The Sustainability Index contains indicators (accidents, delays, noise, and air pollutants like CO$_2$, CO, NO, SO$_2$, and NO$_2$). To measure the sustainable operation of roads within the CBD sector 2 in Hilla, which is integrated with public transportation. The $I_{\text{CST}}$ (Composite Sustainable Transport Index) values range from zero (worst case) to one (best case) to compare each situation with another.

A practical way of assessing sustainability is to collect individual indicators into a composite index. It measures the multidimensional aspects of sustainability that individual indicators alone can't fully capture. Composite index opponents believe the index of the composite is unreliable because of its subjective construction. In addition, there is no single index capable of answering all questions, and multiple indicators are needed [17].

The aim of the criterion weighting is to determine the relevance of each criterion relative to the other. Many of the weighting methods comply with the provisions of the decision-makers used for this purpose. These methods comprise ranking, classification, and trade-off analysis, which differ in accrual, and the degree of ease of use and use by design makers. The trade-off analysis method is more appropriate when it comes to accumulation and triple basis. However, weight can be defined as an appraisal value, and most importantly it is a more important method in the overall tool. Weights are usually set to 1, and the weight group is defined as $W = (w_1, w_2, w_3, w_n)$ and $\sum w_i = 1$ is as explained by G.Malczewski (1999).

The trade-off analysis approach utilizes direct evaluations of the trade-offs that the decision-maker wishes to make among alternatives. It is proposed that trade-off procedures be used roughly only with objective quantitative assessment criteria. The process becomes difficult when utilizing the criteria for subjective assessments. One weakness is that the decision-maker is supposed to obey the axioms and can make judgments of subtle apathy [18].

To calculate the composite sustainable transport index ($I_{\text{CST}}$) for public transportation paths within the CBD sector 2 in Hilla utilizing the equation (4), the weights were provided depended on criteria
weighting (trade-off analysis) and based on their harmful effect through assessing the questionnaire outcomes, which was made by specialists. Composite transport sustainability index data is presented in Table 6, and ICST results are represented in Figure 8.

\[
I_{CST(Links)} = 0.43 I_{delay} + 0.355 I_{accident} + 0.099 I_{noise} + 0.0232 I_{CO2} + 0.0232 I_{CO} + 0.0232 I_{NO} + 0.0232 I_{SO2} + 0.0232 I_{NO2} \quad \ldots \quad (4)
\]

**Table 6.** Composite Sustainability Index (ICST) for public transport links within the CBD sector 2

| Roadway Name | ICST |
|--------------|------|
| L1           | 0.37 |
| L2           | 0.82 |
| L3           | 0.59 |
| L4           | 0.76 |
| L5           | 0.61 |
| L6           | 0.67 |
| L7           | 0.83 |
| L8           | 0.43 |
| L9           | 0.81 |
| L10          | 0.88 |
| L11          | 0.82 |
| L12          | 0.78 |
| L13          | 0.70 |
| L14          | 0.78 |
| L15          | 0.77 |

**Figure 8.** ICST of public transport routes within Hilla CBD (Sector – 2)
Figure 8 shows the contrast between public transport links I_{CST}. Black colour represents a very low level of sustainability, red represents a low level while green represents a moderate level and blue is for a high level. From the data measured for the delay, accidents, noise, and air pollutants observed in the I_{CST} account for CBD public transport paths, the overall assessment for sustainability operation are from low level to moderate and high-level for one link. Thus, public transport links L1, L3, L5, L7, and L8 has a low level, and L2, L4, L6, L9, L11, L12, L13, L14, and L15 has a moderate level and L10 high level.

7. Conclusions
The conclusion that has been summarized within this study:

1. Central Business District (CBD) represents Sector No. 2 in Hilla because this region meets all operating and land use requirements. The CBD has public transportation with 15 links, the measured data for public transport routes include delays, incidents, noise, and air pollutants like (CO₂, CO, NO, SO₂, and NO₂).
2. The overall assessment of the sustainability operation within the study region (CBD) for public transport links is among low level (5 links) to a moderate level (9 links) and a high level (1 link).
3. The noise values in the study region for all public transport links higher the adopted limit for the suggested air quality specification for EPA (2009) Environmental Ministry.
4. The values of air pollutions (CO₂, CO, NO, SO₂, and NO₂) for all public transportation routes in the study zone, 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.
5. Current condition of public transport in the city of Hilla does not have a real identity because there is no clear public transport system that can be relied upon as a prime carrier within a rapidly developing city.
6. Continued expansion and growth of the study area provided an opportunity for the increase of a number of problems within the central commercial area, as well as the increase in ownership of public and private vehicles that had the effect of the emergence of the problem of traffic congestion that causes delays, accidents, noise, and air pollutants.

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