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Traffic Congestion Measures and Sustainability Evaluation of Urban Street

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ABSTRACT

Traffic congestion become a serious problem that traffic engineers still face. This research explains the sustainable indicators and congestion index for urban streets and their implementation to evaluate the performance measures proceeding toward sustainable roads. Congestion measures in terms of speed reduction and sustainable indicators; mobility (congestion index, travel time, and delay), costs (vehicle operating cost), socio-economic effect (in terms of an estimated factor called User Satisfaction Index (USI), and air pollution (Fuel emissions) are estimated. Link 3 has the highest delay value of approximately (2 minutes) for the evening peak period in the north-south direction due to a large number of vehicles dense traffic and mixed land use of the study area that produce many attraction trips daily. Congestion is distributed more spatially during the morning peak periods, while in evening periods is relatively concentrated on a specific link. The reduction in travel speed due to the congestion effect induced higher vehicle operating costs of an average unit of 2.9 per Km for links 1, 2.6, and 2.4 for links 2 and 3, respectively, at peak time from (8 a.m. to 12 a.m.). Generally, traffic congestion is mainly concentrated on Links 1 and 3 of Palestine's urban street segments. The overall user satisfaction index (USI) is 2.209 and about 44.18%, meaning user satisfaction is less than 50%. This illustrates that the selected segment of the study area is unsustainable regarding the social and commuter opinions aspect.

Keywords: Congestion index, Sustainability indicators, Urban street, Delay, User satisfaction.

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مقاييس الزحام المروري وتقييم الإستدامة للشوارع الحضرية

زينب احمد القيسي *، على ناصر حسين، مرتضى حسن محمد

قسم الهندسة المدنية، كلية الهندسة، الجامعة المستنصرية، بغداد، العراق

الخلاصة

أصبح الزحام المروري من أهم المشاكل المهمة التي مازال يواجهها مهندسي المرور. هذا البحث يوضح مؤشرات الاستدامة والزحام المروري للشوارع الحضرية وكيفية تطبيقها لتقييم مقاييس الأداء لتحقيق شوارع مستدامة. مقاييس الزحام المروري بدلالة انخفاض السرعة ومؤشرات الاستدامة، الحركة (مؤشرات الزحام المروري، زمن الرحلة، زمن التأخير)، الكلفة (الكلفة التشغيلية للمركبة)، الخصائص الاقتصادية الاجتماعية (بدلالة المعامل يطلق عليه رضى المستخدم USI)، وتلوث الهواء (انبعاث الغازات) يتم حسابها. الوصلة رقم 3 كان لها أعلى زمن تأخير حوالي 2 دقيقة لفترة الذروة المسائية في الاتجاه الشمالي–الجنوبي بسبب زيادة عدد المركبات والكثافة المرورية العالية واستعمالات الأرض المختلفة في منطقة الدراسة والتي تولد عدد كبير من رحلات الجذب يوميا". يتوزع الزحام المروري مكانيا" خلال فترة الذروة المسائية بينما فترة الذروة الصباحية تتمركز في مناطق محددة. يتمركز الزحام المروري بصورة عامة في الوصلة رقم 1 و3 من مقاطع شارع فلسطين الشرياني المدروس. إن معامل الرضى المستخدم الإجمالي 2.209 بما يقارب 22.18% وهذه القيمة أقل من 50 %. هذا يلخص إن المقاطع الختارة في منطقة الدراسة لا توفر متطلبات الاستدامة بناءا" على وجهات النظر الاجتماعية والاقتصادية.

الكلمات المفتاحية: مؤشر الزحام، مؤشرات الاستدامة، شوارع حضرية، التأخير، رضى المستخدم.

1. INTRODUCTION

Big cities suffer from traffic congestion, which becomes a serious problem. The traffic engineer tries to alleviate congestion and improve mobility and the level of service and evaluate the efficiency of transportation systems. Therefore, it is necessary to develop an evaluation indicator that explains how the urban street is efficient and sustainable, contributing to the design and operation methods to ensure a sustainable urban street. Mobility is a significant parameter that displays the congestion level regarding speed reduction, travel time, and delay. Several studies estimated running time and delay in peak periods and non-peak periods for different working days **(Faghri and Hamad, 2002)**. The moving car techniques with an observer measure delay, travel time, and traffic flow. The delay was measured by field measurements, simulation software, analytical methods, or a combination of the above-mentioned methods **(Shatnawi and Khliefat, 2018)**.
(Jia et al., 2011) the average vehicle speed was used to estimate the urban traffic state, considering the network’s capacity and residents’ travel characteristics. **(Zhu, 2006)** evaluated the urban road congestion using the system's congestion index and velocity distribution by applying the Gaussian mixture model (GMM). **(Robert et al., 2002)** made a comparison between travel time and distance by discussing the impact of various indicators on the quantification of congestion. They presented classification methods based on measured travel time. The benefit of calculating travel time for the evaluation of transportation network performance and discussed the different techniques of aggregating travel time and speed in the field. No unified evaluation measure exists for congestion conditions and traffic operation states. There are different evaluation indicators for different

regions. For instance, the Taxes Transportation Institute utilized the Roadway Congestion Index (RCI) in 1994 and published a report on congestion in 2006, which indicated average travel time **(Bar-Gera, 2007)**. The Highway Capacity Manual (HCM) in 1985 stated to use of the level of service as an indication for evaluation of urban street performance, which is defined in terms of six levels (From A to E) in the United States **(HCM, 2000)** and three grades in Japan. In China, the average travel speed of a city is chosen as an evaluation indicator to depict the conditions of congestions of road traffic.

The congestion reflects the difference between the travel time required to traverse road segments during peak periods and free flow time, indicating that excess travel time occurred under free flow time conditions. It illustrated the severity of congestion in terms of intensity and expressed as a rate. Duration reflects the time the system suffers from congestion **(Falcocchio and Levinson,2015)**. Traffic congestion metrics that are commonly used include the travel time index and the vehicle travelled mile, vehicle hours travelled, volume-to-capacity ratio (v/c), and duration of peak periods **(Schrank and Lomax, 2005; Rao and Rao, 2012; Rahman et al., 2022)**.

Applying deep learning techniques to avoid congestion based on proactive notification for congestion will help alleviate traffic jam problems **(Kang et al., 2020)**. The free flow speed is used to estimate and evaluate traffic congestion by considering the association parameters of traffic flow, such as the travel speed of road segments in the network. The travel speed is applied to estimate the traffic congestion index based on the optimization algorithm of the subgraph **(Tu et al., 2021).** Different techniques based on the model-driven approach, such as the RatioCut algorithm and hyperparameters automatic steering, are modified to characterize traffic clusters on the road map **(Yu et al., 2022)**. Different strategies include the detection of congestion depending on the measuring indices, average travel speed, speed reduction, and speed ratio. Aspatial analysis using ArcGIS application to present digitized street maps of congestion evaluation. Applying the Fuzzy inference system approach to depict the traffic parameters and demonstrate analytical solutions to uncertain problems **(Alkaissi, 2024)**. The operational analysis of a local roundabout named Ahmed Urabi indicated a poor level of service with a control delay of 300 seconds per vehicle during rush hours. A proposed circulating width for the roundabout of 16 m is suggested, with three lanes for each side of the underpass and four for all rest legs **(Al–Azawee, 2018)**. **(Mohammed et al., 2006)** presented the evaluation and traffic operation improvement of AL-Motanabi square in Kut city to demonstrate the best proposal for performance enhancement from the capacity point of view. Significant elements such as social history and culture, there are fewer studies on the quantifiable spatial indicators of urban development. Therefore, it is not easy to control urban planning directly. Several research developed a sustainable methodology to the prediction of small cities through a quantitative approach and investigated the effect of the functional distribution of urban form **(Yang et al., 2022; Jiao and Fu, 2021).**

In addition, taking into account that urban improvement plans are rarely applied, and when they are implemented, the initiative is carried out in a disjointed and limited manner **(Montoya et al., 2020). (Mesa García, 2021)** proposed a methodology for measuring and evaluating six criteria of urban sustainability (scale, accessibility, connectivity, density, diversity, nodal), specifically for the Bucaramanga municipality; these approaches showed only morphological prospects, and the approaches are not capable to generalize for other similar cities in local study. A sustained design included the index of performance for Bogota city was implemented by **(Carrillo-Rodríguez and Toca, 2013)**. A group of indicators consisting of five dimensions (technology, institutional, economic, innovation,

environmental, and social) were illustrated to assist construction companies in making decisions **(Gaviria, 2013)**. The development of indicators for the economic assessment of the entire life cycle of roads points to a group of criteria that ensure a comprehended evaluation of the economic costs and benefits during the road planning full cycle, construction, maintenance, traffic operation, and final decommissioning or restoration **(Nogueira et al., 2023)**. The triple bottom line is defined as an estimating approach applied for sustained evaluation. It is considered a principle framework where attainment is provided By load balancing the efficiency of the economic, environmental, and social dimensions **(Elkington, 2006; Law, 2015; Nevado-Peña et al., 2015)**.
Preceding studies on this task have given additional consideration to the definition of urban sustained indicators in urban areas oriented towards peculiarity national or provincial, the critical review of sustainability estimation methods, the comparison of weights designated indicators, and discussion of common standardization of indicators **(Sharifi and Murayama, 2013; Pires et al., 2014; Wangel et al., 2016; Berardi, 2013; Kaur and Garg, 2019; Balaras et al., 2018; Balaras et al., 2021)**.
This research aims to demonstrate the main indicators related to the sustainable assessment of urbanized streets. Indicators include the measures of mobility, costs, socioeconomic effects, and air pollution.

2. METHOD

The methodology of this work is based on congestion measures regarding speed reduction and evaluation of the urban street with sustainable indicators chosen based on the literature review. These indicators include mobility (congestion index, travel time, and delay), costs (vehicle operating cost), socio-economic effect (in terms of an estimated factor called User Satisfaction Index (USI), and air pollution (Fuel emissions). The congestion measures, besides the sustainability indicators, have been implemented and investigated to evaluate urban street performance progress to sustainable urban streets in Baghdad city as a case study. Then, the Congestion index was estimated based on gathered traffic field data and GIS data. The methodology includes the following:

- Define the study area and select urban streets to evaluate and implement the sustainable indicators. The case study was selected based on congestion problems that arise according to local studies **(Alkaissi and Yousuf, 2020; Alkaissi, 2022; Alkaissi, 2023; Alkaissi, 2024).**
- Estimate the sustainable indicators: congestion index (speed reduction index), delay and travel time, vehicle operating costs, fuel emissions, and the last User Satisfaction Index.
- Spatial analysis of congestion measures using ArcGIS application to display traffic congestion.

3. STUDY AREA AND DATA COLLECTION

The Palestine urban street is one of the most urban arterials in Baghdad, located east of Baghdad. It runs parallel to the west of the Army Canal from Mustansiriyah University and Mayslone intersection, as displayed in **Fig. 1.** That shows the digitizes maps of the study area bounded by extension 33° 22' 30'' N to 33° 20' 50'' N and 44° 25' 0'' E to 44° 24' 10'' E. The selected segment consists of three links: link 1 (Mustansiriyah University to Al Nakhala Intersection), link 2 (Al Nakhala Intersection to Al Sakhara Intersection), and link 3 (Al

Sakhara Intersection to Bairut Intersection) for two directions of traffic movements (North-south and South-North). The collection of field data was aggregated in the field using the floating car technique and global positioning system (GPS) at different peak periods morning (8 a.m. to 12 p.m.) and evening (4 p.m. to 7 p.m.) on Monday, Tuesday 2023, 16 and 17 January, see **Tables 1 to 4.**

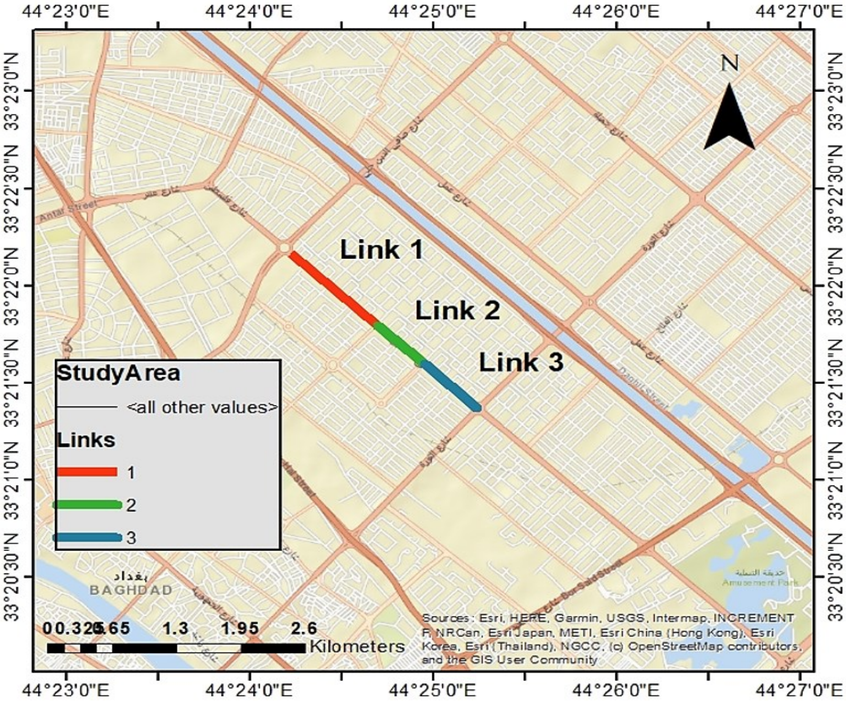


Figure 1. Study Area of Study Segment with Selected Links.

Table 1. Field Data Collection for Selected Links in the South-North Direction for Morning Peak Periods.

Field Data Collections		
8 a.m. -9 a.m.		
Segment	Travel Time (sec.)	Speed (km/hr)
Link 1	113	33
Link 2	107	35
Link 3	109	34
9 a.m. -10 a.m.		
Link 1	107	35
Link 2	99	37
Link 3	87	43
10 a.m. -11 a.m.		
Link 1	80	46
Link 2	60	62
Link 3	49	76
11 a.m. -12 p.m.		
Link 1	121	31
Link 2	86	43
Link 3	101	37

Table 2. Field Data Collection for Selected Links in the North-South Direction for Morning Peak Periods.

Field Data Collections		
8 a.m. -9 a.m.		
Segment	Travel Time (sec.)	Speed (km/hr)
Link 1	113	33
Link 2	107	35
Link 3	109	34
9 a.m. -10 a.m.		
Link 1	107	35
Link 2	99	37
Link 3	87	43
10 a.m. -11 a.m.		
Link 1	80	46
Link 2	60	62
Link 3	49	76
11 a.m. -12 p.m.		
Link 1	121	31
Link 2	86	43
Link 3	101	37

Table 3. Field Data Collection for Selected Links in the South-North Direction for Evening Peak Periods.

Field Data Collections		
4 p.m. -5 p.m.		
Segment	Travel Time (sec.)	Speed (km/hr)
Link 1	85	44
Link 2	55	34
Link 3	50	45
5 p.m. -6 p.m.		
Link 1	120	31
Link 2	57	33
Link 3	70	32
6 p.m. -7 p.m.		
Link 1	120	31
Link 2	101	37
Link 3	89	42

Table 4. Field Data Collection for Selected Links in the North-South Direction for Evening Peak Periods.

Field Data Collections		
4 p.m. -5 p.m.		
Segment	Travel Time (sec.)	Speed (km/hr)
Link 1	76	49
Link 2	45	42
Link 3	55	41
5 p.m. -6 p.m.		
Link 1	105	35
Link 2	60	31
Link 3	70	32
6 p.m. -7 p.m.		
Link 1	81	46
Link 2	56	33
Link 3	68	33

4. RESULTS AND DISCUSSIONS

4.1 Congestion Index

The congestion index of the urban street, as presented in Eq. (1), may provide a guide for measuring the traffic operation condition, and the induced traffic will exceed the sustained capacity during the working days. The congestion index is based on measuring the average traffic speed in the field and applied in Equation [1] to estimate the Congestion index. Congestion is the absence of freedom of movement for vehicles in the traffic stream and begins whenever there is friction or impedance to the free movements. **Figs. 2 to 5** depict the congestion index for the urban street during the working days for both (morning, 8-12 a.m., and evening, 4-7 p.m.) periods.

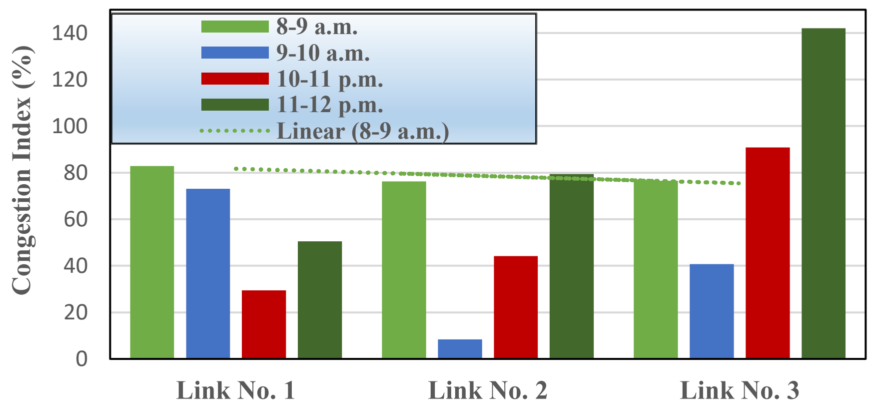


Figure 2. Congestion Index Results for North-South Direction during Morning Peak Periods.

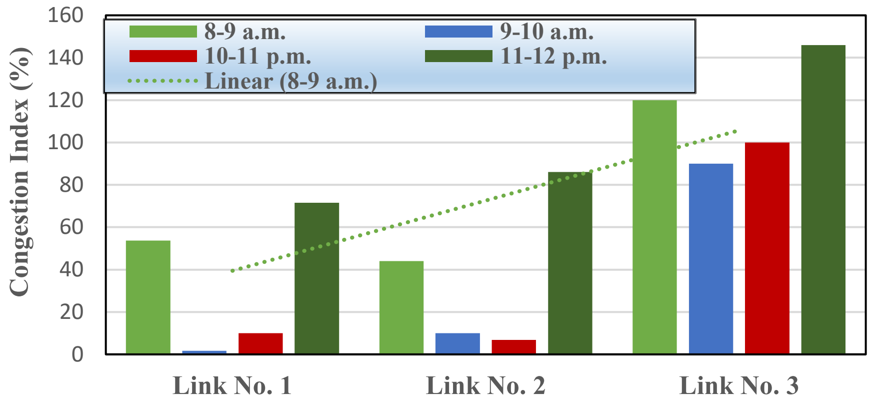


Figure 3. Congestion Index Results for South-North Direction during Morning Peak Periods.

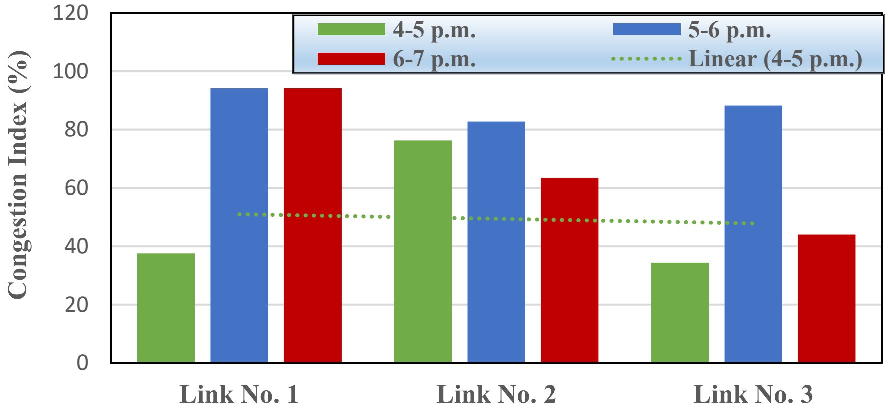


Figure 4. Congestion Index Results for North-South Direction during Evening Peak Periods.

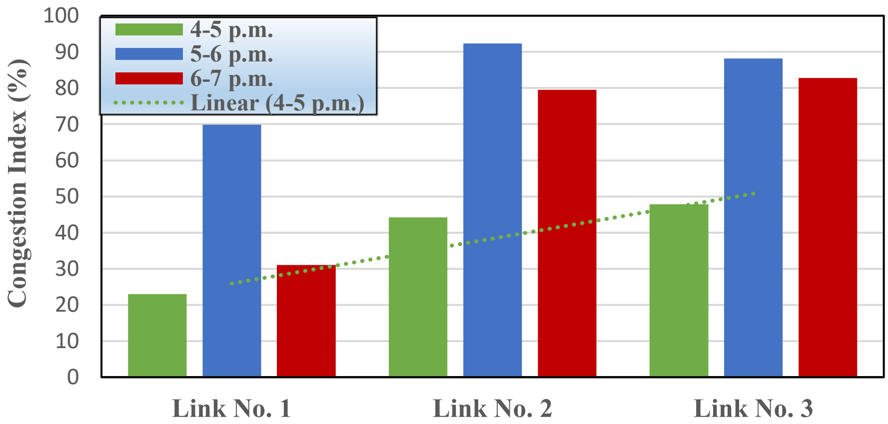


Figure 5. Congestion Index Results for South-North Direction during Evening Peak Periods.

Based on aggregated field data, the results of several links within the study area show that congestion conditions existed during the morning and afternoon rush hour in both directions. The time variation trend of the congestion index in each link is relatively consistent. The congestion index result of Link 3 shows severe congestion in the south-north direction at 11-12 p.m. due to the low running speed of traffic flow and higher saturated flow at peak periods.

$$\text{Congestion Index} = \frac{S_{non\ peak} - S_{peak}}{S_{Peak}} \times 100 \quad (1)$$

Where:
S_{Peak} : Average travel speed in peak periods.
$S_{non\ peak}$: Average travel speed in non-peak periods.

4.2 Travel and Delay Time

This research considers urban streets of more than three signalized intersections to aggregate total travel and delay time during peak periods (morning, 8-12 a.m. and, evening, 4-7 p.m.) within working days Monday and Tuesday for both directions of a traffic stream (North-South and South-North) as illustrated in **Figs. 6 to 13** respectively. Link 3 has the highest delay value of approximately (2 minutes) for the evening peak period in the north-south direction due to many vehicles, dense traffic and mixed land use of the study area that produce many attraction trips daily. A rapprochement between delay and travel time for peak periods on working days is obtained. The field results depicted that working days have the highest travel time and delay during the morning peak hours. Furthermore, the reasons behind high travel time and delay are established in Palestine Street with more signalized intersections along the corridor.

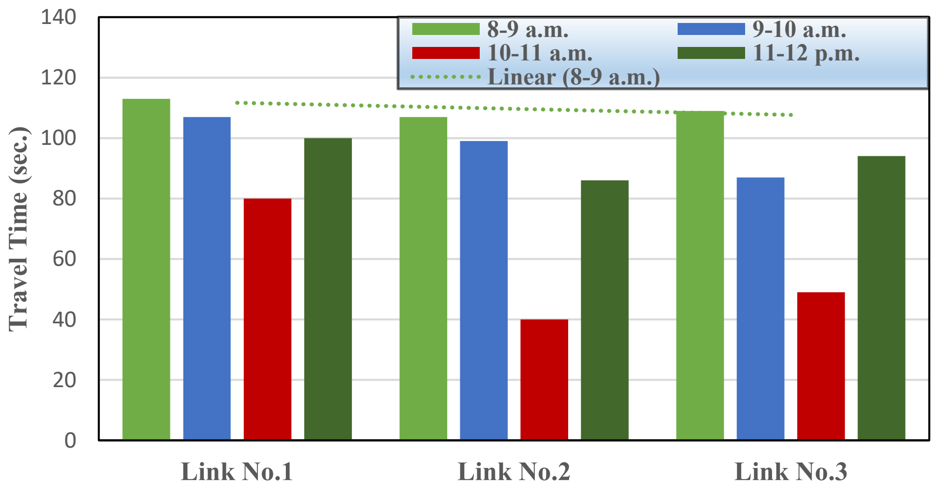


Figure 6. Travel Time Results for North-South Direction during Morning Peak Periods.

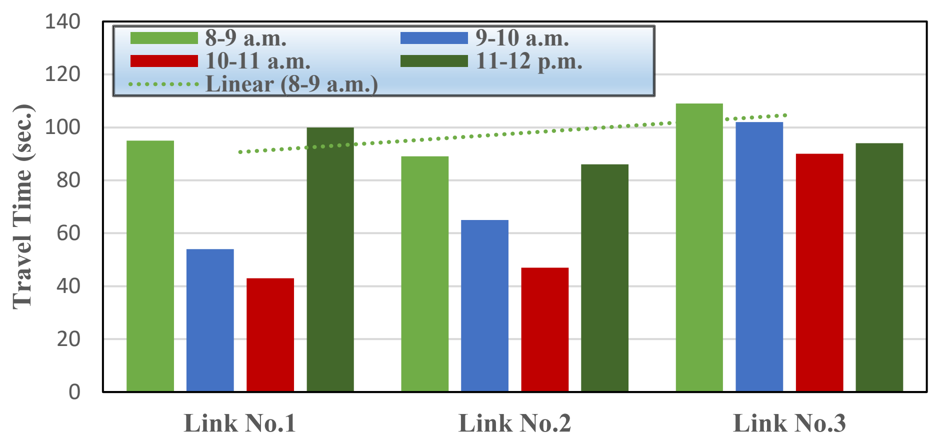


Figure 7. Travel Time Results for South-North Direction during Morning Peak Periods.

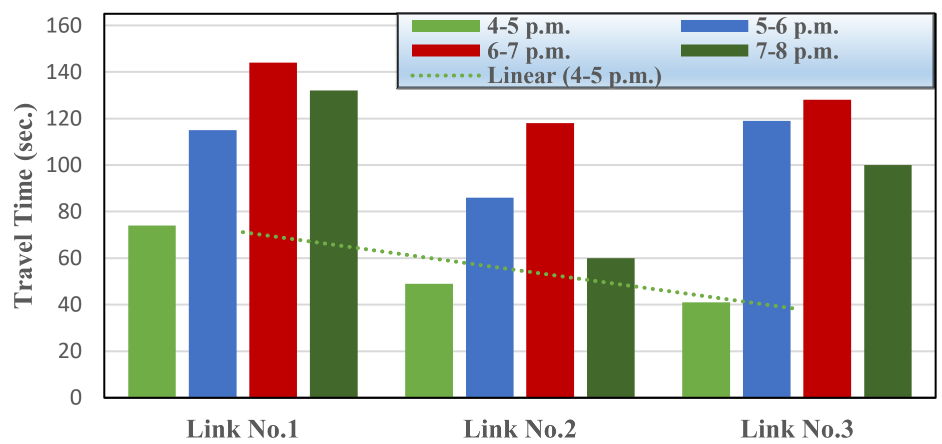


Figure 8. Travel Time Results for North-South Direction during Evening Peak Periods.

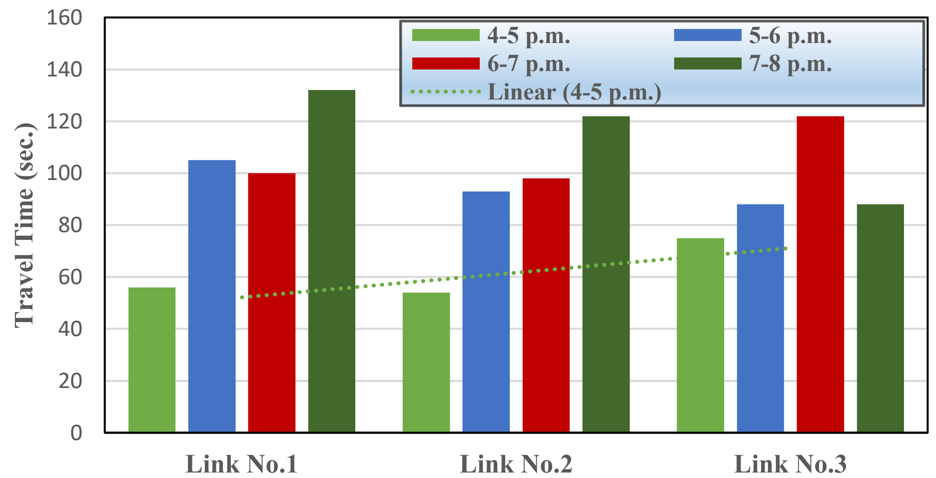


Figure 9. Travel Time Results for South-North Direction during Evening Peak Periods.

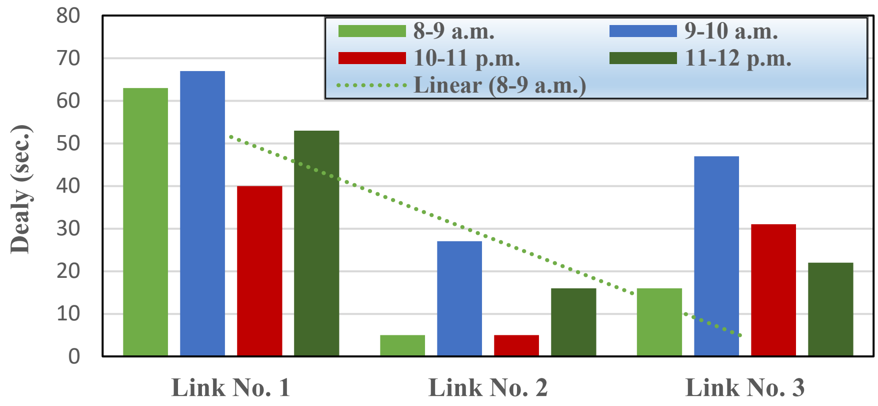


Figure 10. Delay Time Results for North-South Direction during Morning Peak Periods.

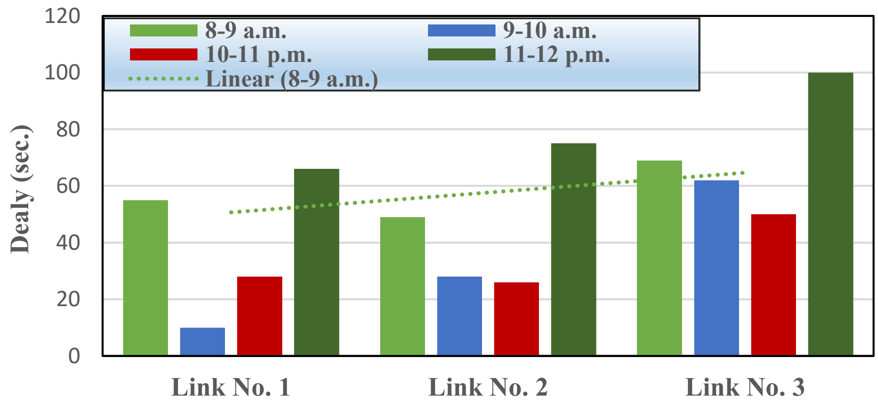


Figure 11. Delay Time Results for South-North Direction during Morning Peak Periods.

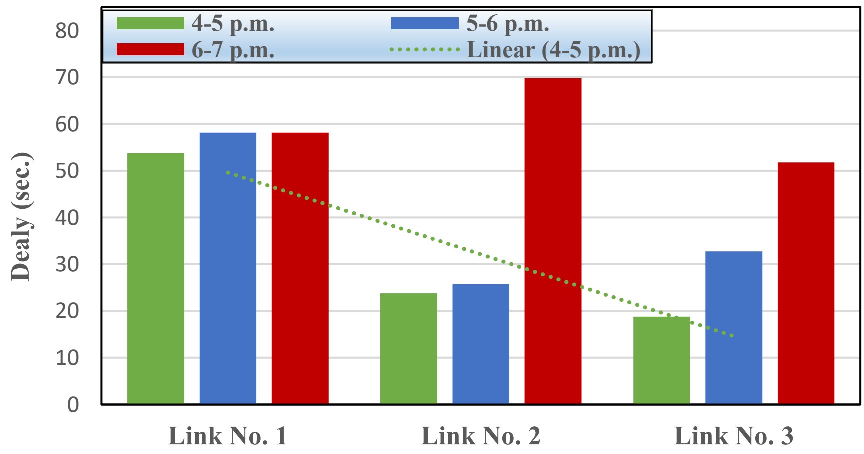


Figure 12. Delay Time Results for North-South Direction during Evening Peak Periods.

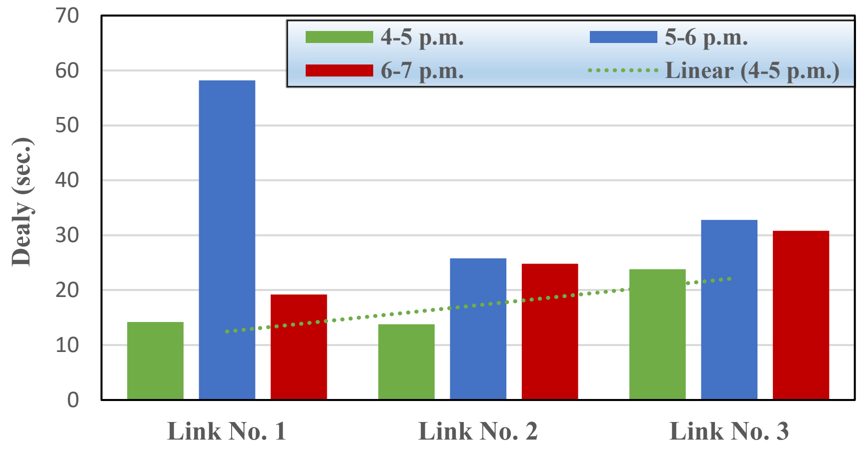


Figure 13. Delay Time Results for South-North Direction during Evening Peak Periods.

4.3 Cost and Pollution Emissions

The congestion significantly reduced speed based on the field data results. The vehicle cost in terms of vehicle operating cost for north-south and south-north directions are presented in **Figs. 14 and 15**, indicating morning peak periods (8 a.m. to 12 a.m.). The reduction in travel speed due to the congestion effect induced higher vehicle operating costs of an average unit of 2.9 per Km for links 1, 2.6, and 2.4 for links 2 and 3, respectively, at peak time from (8 a.m. to 12 a.m.).
One of the most dangerous is air pollution which threatens people's lives and health. The traffic flow, including passenger cars, trucks, and buses, is a major contributor to air pollution and in terms of fuel emissions (hydrocarbons HC, Carbone monoxide CO, Sulfur Dioxide SO_2, and Nitrogen Oxide NOx) in addition to the greenhouse gases emitted to air by traffic. **Figs. 16 and 17** depict the rate of fuel emissions in Liters per distance travelled by traffic vehicles in the peak period of the morning (8:00 a.m. to 12:00 p.m.) for the selected street links of the study area, link 1, link 2, and link 3, respectively, according to Eq. (2) **(Mathew, 2014)**. Air pollution increased due to higher delays and travel time accompanied by a significant reduction in speed due to traffic congestion.

$$F = k_1 + \frac{k_2}{v} \tag{2}$$

F: consumed fuel per vehicle per unit distance (liters/Km). k_1: parameter related with consumed fuel to overcoming the impedance of rolling, relative to weight of vehicle (liters/veh- km). k_2: Parameter related to consumption of fuel while idling (liters/hr). v: measured rate of average speed (Km/hr).

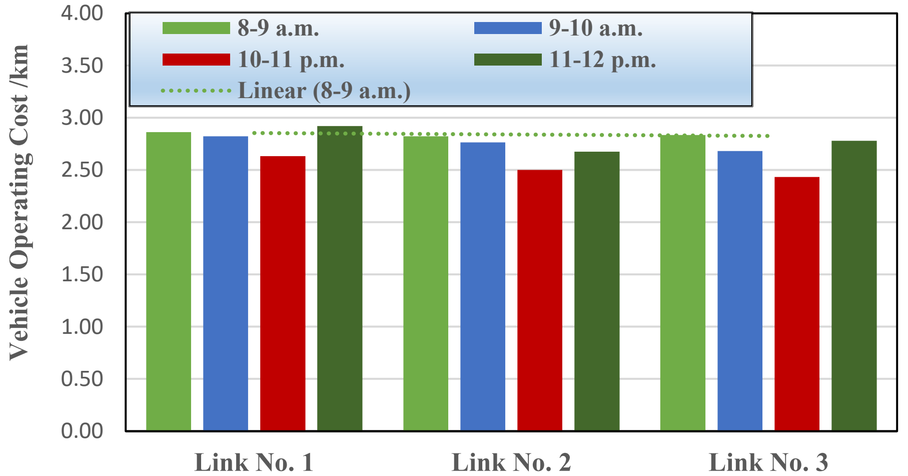


Figure 14. Vehicle Operating Costs Results for North-South Direction during Morning Peak Periods.

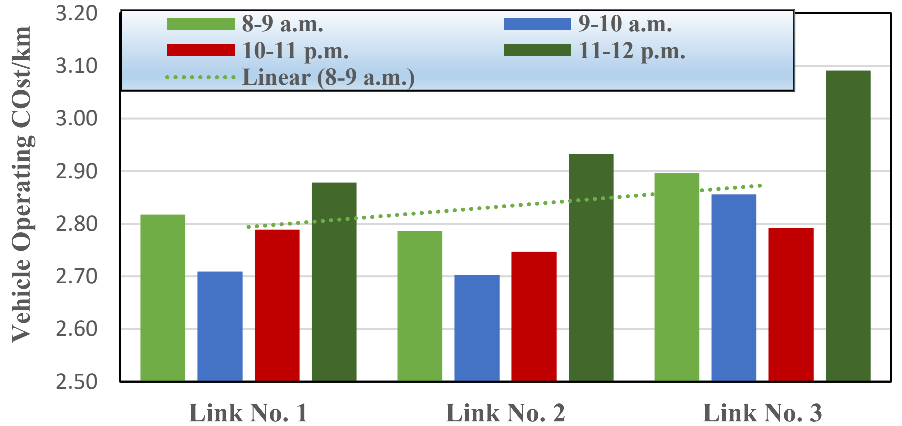


Figure 15. Vehicle Operating Costs Results for South-North Direction during Morning Peak Periods.

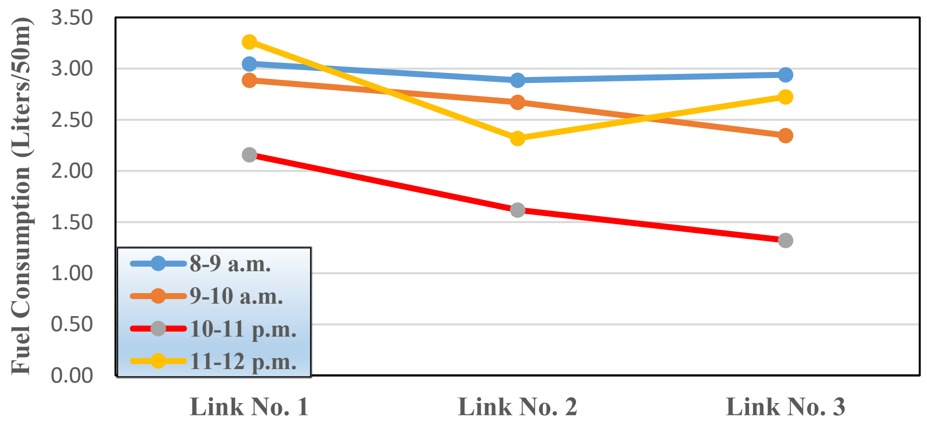


Figure 16. Emissions Rate for Selected Segments in the North-South Directions.

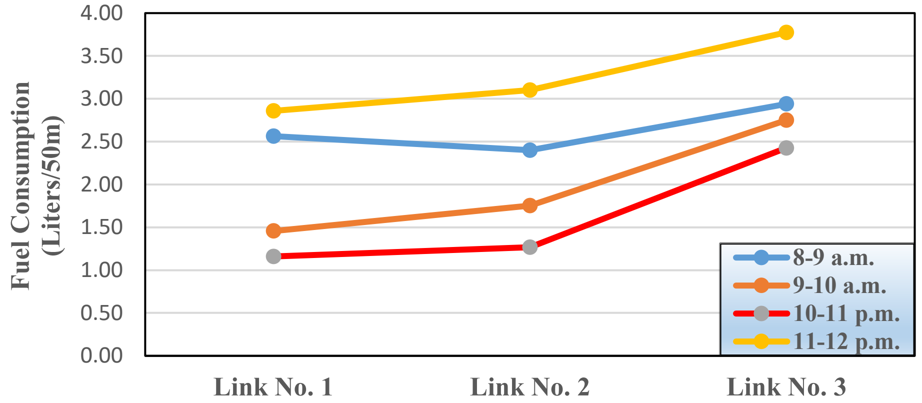
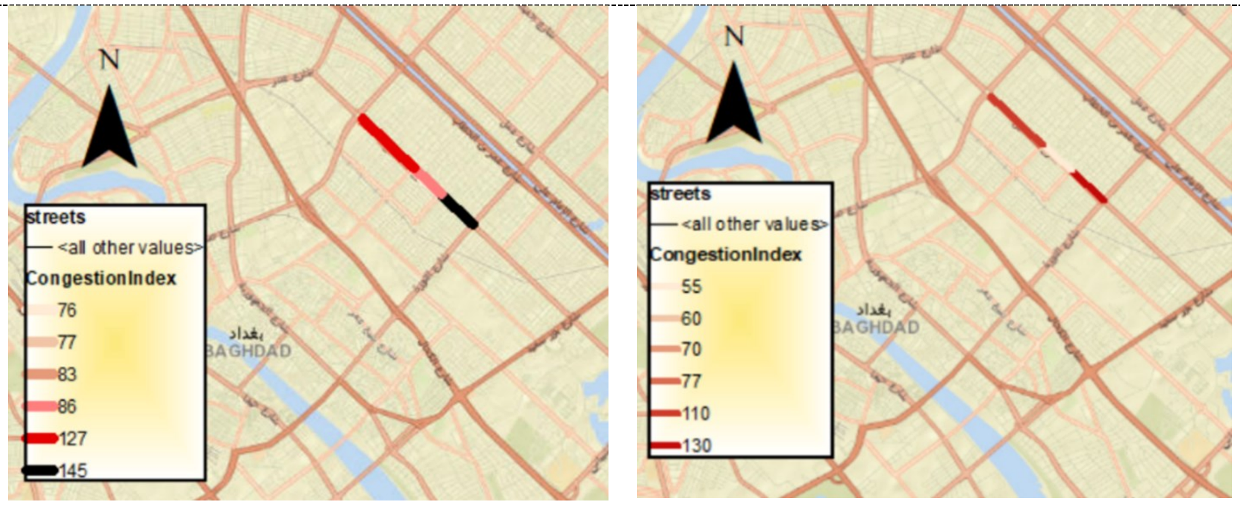


Figure 17. Emissions Rate for Selected Segments in the South-North Directions.

4.4 Segments Congestion Display

The ArcGIS Map version 10 was utilized to display the congestion of the studied segment, adopting the congestion index based on speed performance reduction. **Fig. 18** includes two graphs describing the street segment's congestion during two peak periods, peak morning (from 8 a.m. to 12 p.m.) and peak evening (from 4 p.m. to 7 p.m.). The congested part of street segments is shown with dark color. Also, congestion is distributed more spatially during the morning peak periods, while in the evening, it is relatively concentrated on a specific link. Generally, traffic congestion is mainly concentrated on Links 1 and 3 of Palestine's urban street segments.



a) Morning Peak b) Evening Peak

Figure 18. Congestion Index during Peak Periods.

4.5 Socioeconomic Analysis

The Socioeconomic life in the surrounding area of the urban street inclines the high activity rate on the street corridor. Furthermore, people migrating to live and work in the zone area in recent years indicate a high economic, social, and educational activity rate. The impact of mixed land use in the study area (residential, recreational, medical, commercial, and educational) and easy accessibility for daily trips imposed additional trip attractions.

Mobility in terms of congestion index, delay, and travel time is one of the categories stated indicators for sustainability measurement in this study. The user satisfaction index was predicted using a questionnaire sheet distributed to people living in the zone area and travellers on urban streets (30 samples) to capture individual opinions as a score for socioeconomic. The aim is to investigate the overall level of satisfaction with the performance of urban streets. A (12) parameters of categories were asked at different rates from (totally accepted, rating 5) to (acceptable rating 1), as shown in **Table 5**. The user satisfaction results, including their opinions and dissatisfaction about adopted sustainability indicators in this research, are displayed in **Table 5.** Furthermore, commuter satisfaction and opinions have been quantified based on category parameters mentioned in **Table 5**. The estimation of USI and weighted parameters are presented in **Table 6**. A higher rate level of 5 for sustainability requirements that need maximum satisfaction for the 12 adopted parameters in this study. Based on the above, the weight of each parameter is (0.083), and the overall user satisfaction index (USI) was 2.209 and about 44.18%, meaning user satisfaction is less than 50%. This illustrated that the selected segment of the study area is unsustainable regarding the social and commuter opinions aspect. The previous analysis of the user satisfaction results for sustainability indicators, congestion index, mobility, socioeconomic impact, and pollution emissions for links 1, 2, and 3 are illustrated and displayed in **Table 7**.

Table 5. Percentage Results Rating for Parameters of Commuter Satisfaction Questions.

Categories	Unacceptable (%)	Fairly Unacceptable (%)	Average (%)	Fairly Acceptable(%)	Acceptable (%)
Pollutions	50	33	17	0	0
Congestion	70	20	10	0	0
Parking	53	23	14	10	0
Public Transportatio	60	14	12	9	5
Pedestrian Facilities	58	20	10	7	5
Pavement conditions	74	14	12	0	0
Delay	80	12	8	0	0
Noise	55	22	12	5	6
Lane use proximity	5	10	20	35	30
Aesthetic	20	13	22	28	17
Accessibility	8	21	35	30	6
Land use attraction	7	4	28	35	26

Table 6. The Results of User Satisfaction Index (USI) and Weighted Parameters.

Categories	Average score	Weighting Factor	User Satisfaction Index (USI)
Pollutions	1.67	0.083	0.137
Congestion	1.40	0.083	0.116
Parking	1.81	0.083	0.150
Public Transportation	1.85	0.083	0.154
Pedestrian Facilities	1.81	0.083	0.150
Pavement conditions	1.38	0.083	0.115
Delay	1.28	0.083	0.106
Noise	1.85	0.083	0.154
Lane use proximity	3.75	0.083	0.311
Aesthetic	3.09	0.083	0.257
Accessibility	3.05	0.083	0.253
Land use attraction	3.69	0.083	0.306
Total	**2.209**		

Table 7. Summary Level of Selected Segments Based on Sustainable Indicators.

Segments	**Level of Sustainability Categories**			
	Mobility	Pollutions Emissions	Cost	Scio-economic Impact
Link 1				
Link 2				
Link 3				
	Totally Unacceptable			
	Unacceptable			
	Fairly acceptable			
	Average			
	Acceptable			

5. CONCLUSIONS

This research explained the congestion index and sustainability indicators for urban streets and their implementation to evaluate the performance measures proceeding toward sustainable roads. The following conclusions can be drawn:

1. The congestion index result of Link 3 shows severe congestion in the south-north direction at 11-12 p.m. due to the low running speed of traffic flow and higher saturated flow at peak periods.
2. Link 3 has the highest delay value of approximately (2 minutes) for the evening peak period in the north-south direction due to many vehicles, dense traffic and mixed land use of the study area that produce many attraction trips daily.
3. The reduction in travel speed due to the congestion effect induced higher vehicle operating costs of an average unit of 2.9 per km for links 1, 2.6, and 2.4 for links 2 and 3, respectively, at peak time from (8 a.m. to 12 a.m.).
4. Congestion is distributed more spatially during the morning peak periods, while in evening periods is relatively concentrated on a specific link. Generally, traffic congestion is mainly concentrated on Links 1 and 3 of Palestine's urban street segments.
5. The overall user satisfaction index (USI) was 2.209 and about 44.18%, meaning user satisfaction is less than 50%. This illustrated that the selected segment of the study area is unsustainable regarding the social and commuter opinions aspect.

NOMENCLATURE

Symbol	Description	Symbol	Description
F	Fuel consumed per vehicle per unit distance (L/km).	GMM	Gaussian mixture model.
k_1	The parameter associated with fuel consumed to overcome rolling resistance (L/veh-km)	GPS	Global positioning system.
k_2	Parameter proportioned to fuel consumption while idling (liters/hr).	HC	Hydrocarbons
S_{Peak}	Average travel speed in peak periods.	HCM	Highway Capacity Manual.
$S_{non\ peak}$	Average travel speed in non-peak periods.	NOx	Nitrogen Oxide
v	Average speed measured (Km/hr).	RCI	Roadway Congestion Index.
v/c	Volume to capacity ratio.	SO_2	Sulfur Dioxide
CO	Carbone monoxide	USI	User satisfaction index.

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Credit Authorship Contribution Statement

Zainab Alkaissi developed the objectives of the study. She reviewed all the field, analytical, discussion results, and writing. Ali Nasser, and Murtada Hassan collected the field data.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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