The Effect of One-Way Urban Street on Traffic Operation Performance

Zainab Ahmed Alkaissi

Highway and Transportation Department, Mustansiriyah University, Baghdad, Iraq

dr.zainabalkaissi77@uomustansiriyah.edu.iq

Corresponding Author

Abstract. Traffic congestion has become a serious problem affecting citizens' daily life. Many adopted strategies are studied and applied to alleviate this problem and reduce traffic pressure on street networks. Some are costly, and others are unsuccessful in solving the problem due to higher demand. The one-way traffic movement with circulation modification is adopted in this work which promotes the capacity of streets to sustain higher demand. The study area is identified with the most congested signalized intersection (Al-Nakhala, Al-Sakhara, and Beirut) along the urban corridor. The obtained results suggest using one-way traffic movement with a circulation network that significantly improves traffic operation and reduces congestion to a great extent. Control delays of selected signalized intersections are reduced from about 95%, and v/c is reduced to 0.69 (Al-Nakhala), 0.59 (Al-Sakhara), and 0.99 (Beirut) intersections. The results of modified traffic movement show excessive delays are not experienced, and the traffic movement modification ensures the sufficiency of the signalized corridor to accommodate the traffic demand. The traffic one-way movement can solve the problem of traffic congestion in the study area and improve the level of service from (F) to (A) and (B).

Keywords: Traffic operation; one-way movement; congestion; urban streets; modified traffic movement; vehicular movement.

1. INTRODUCTION

The urban development and high growth rate of cars in big cities induce serious congestion problems that affect the daily life of citizens. Many strategies are studied and applied to alleviate traffic jams and relieve the traffic pressure due to high demand. Some of these strategies are costly to reduce traffic congestion; others are not practical to apply. The strategy of changing the two-way street to a one-way street is efficient to reduce traffic congestion and provide smooth traffic movement. Zhuo and Wang [1] used a microsimulation model to evaluate one-way traffic movement. They stated that traffic management can reduce traffic jams and facilitate the implementation plan. However, interchanges such as bypasses may alleviate traffic efficiency in a wide range. Miandoabchi [2] studied the optimal combination of two-way and one-way links, the optimal allocation of lanes on two-way links, and the optimal selection of capacity for network expansion projects to optimize the reverse capacity and performance measures such as travel time. Salman and Alaswad [3] applied a mathematical model based on the Markov chain traffic assignment to optimize traffic patterns within the street network using vehicle density through two-way to one-way conversions. Peng [4] applied a bi-level optimization programming model. The variable of decision–making for the upper-level model (equilibrium traffic assignment model) is the one-way scheme to minimize the travel time.

Kim [5] developed a model to optimize the direction of the street to increase the flow and find the optimal solution for the model using a simulated annealing algorithm. Xiao [6] applied a multimodal logit model to simulate the actual situation of residence and flow space of the traffic flow in a one-way street scheme and suggested some reasonable strategies to adjust the commercial entrance space of the west road. Wang and Zhu [7] studied the operation status for different forms of one-way traffic scheme organization in a main urban area and concluded that the density of traffic and network are considered fundamental reasons for determining the impact of one-way organization. Bavarez and Newell [8] investigated the effect of implementing one-way streets on signal timing, including the total number of stops and delays. Khooban [9] studied the redesigning of current street link directions, determined signal settings as intersections, and expanded the network capacity to optimize the reverse capacity of the whole system. Riggs and Gilderbloom [10] analyzed and tested the relationship between configuration, one-way streets, collision, community, and crime. Mao [11] investigated open and closed communities to promote urban traffic microsimulation, increase accessibility and density of regional traffic networks, and thus distribute the traffic pressure of major streets and strengthen communications.

Miandoabchi [12] studied total CO emissions and total travel time as objective function measures and determined the optimal combination of two-way and one-way links. Bianca and Coscia [13] analyzed a new mathematical model with their derivation, modeled for vehicular traffic with a stochastic model obtained through an adaptive and uniform discretization coupling. Zhang [14] applied the Braess paradox and road traffic ability to assess the effect of the opening of the microcirculation scheme on the surrounding streets in residential areas. Lykov [15] suggests an N particles one-way road deterministic traffic model by a locally controlled one-way road flow chart. The genetic algorithm (GA) was widely utilized in the transportation field. Song [16] used a model of micro-traffic flow combined with the vehicle emission model to explore the problem of minimizing traffic emissions

on main streets. And suggest an optimal signal control model by utilizing the simulated annealing GA for model solving. Yuan [17] applied GA to analyze and solve the dynamic control model with consideration of the merge lane signal. Zhao [18] suggested a design model for site selection of station and vehicle deployment utilizing the GA for model solving. Mao [19] analyzed the optimization of road sign numbers and route length by implementing GA to solve linear programming problems.

The literature review of studies in the previous paragraphs indicated that research on one-way streets is not limited to theoretical models; many papers consider the simulation of real network systems. Most work objectives are based on reducing the number of stops and costs due to travel length and fuel emissions. The advantage of one-way modification is minimizing the traffic pressure on the street network. Since the urban street network is complicated due to the large size of the system, exploring the optimal one-way traffic with circulation and accessibility movement makes change of the overall traffic state of the street network to solve the congestion problem. This work contributes to finding a suitable one-way traffic movement for a real urban network with mixed land uses surrounding that induce significant congestion problems during rush hour. Apply the traffic modification to a real street network and verify the effect of the proposed system on improvement and alleviating congestion through the analysis of field data and suggest the obtained strategies to increase the efficiency of traffic operation performance.

2. METHODOLOGY AND STUDY AREA

The proposed one-way traffic movement adopted in this paper is developed to solve the congestion problem in the most oversaturated urban corridor (Palestine Street) in Bagdad City. The methodology of this work is divided into three parts as follows:

- Select the most congested urban corridor to apply the developed modification of one-way traffic movement and circulation and evaluate their efficiency.
- The study area includes a road network of major and minor urban streets that can find the optimal traffic movements to provide the accessibility and circulation of a one-way scheme.
- Investigate the developed strategy using Synchro (ver.9) SimTraffic software.
- Estimate the traffic operation performance for signalized intersections in terms of control delay, degree of saturation, and level of service.
- Compare the results of the developed strategy to the actual condition to investigate its benefit in reducing congestion problems.

The digitized map of the study area is presented in Figure 1. It displays a street network of the urban area in Baghdad city, focusing on the urban corridor of Palestine Street. The street network is bounded by an extension of 33° 21' 0" N and 44° 24' 30" E to 44° 25' 30" E and 33° 22' 30" N to 33° 21' 0" N. The study area is identified with the most congested signalized intersection (Al-Nakhala, Al-Sakhara, and Beirut) along the urban corridor based on literature studies that investigated and studied the area extensively with detailed field data using Global Positioning System (GPS) and simulation analysis using VISSIM that have been adopted in this work to explore the one-way traffic scheme [20-24].

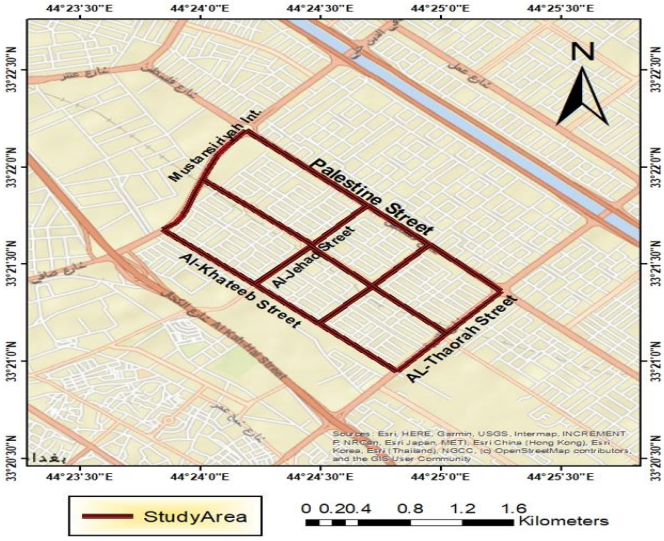


Figure 1: Study area for the proposed modification.

3. TRAFFIC MOVEMENT MODIFICATION

It is necessary to find applicable solutions, such as one-way traffic movements, to ease the daily congestion problem, assess the developed modification, and formulate recommendations for the study area. One-way street modification can be defined as the drive in one direction and improving the street capacity to sustain high demand and promote traffic circulation to provide smooth traffic operation. The increased traffic demand on urban streets (Major Palestine Street) induced oversaturated traffic conditions, excess control delay, and travel time. Therefore, the implementation of traffic circulation in the network with one-way movement on the main street serves the through traffic and provides two-way movement for traffic circulation and accessibility, as shown in Figure 2. It is modifying two-way segments of the main street (Palestine St.) from Beirut intersections to Mustansiriyah Intersection into a one-way traffic movement. Also, modify traffic movement from two-way for Al-Khateeb Street into one-way, and keep the other minor streets within the network operating in two-way movement. This modification of traffic movements would improve the traffic operation performance of the study area. To get the advantages of modified traffic movements, it is necessary to display the layout of the one-way streets from the perspective of the overall street network within the study area and give accurate guidance to some extent for implementing the efficient street network in the direction of Palestine Street.

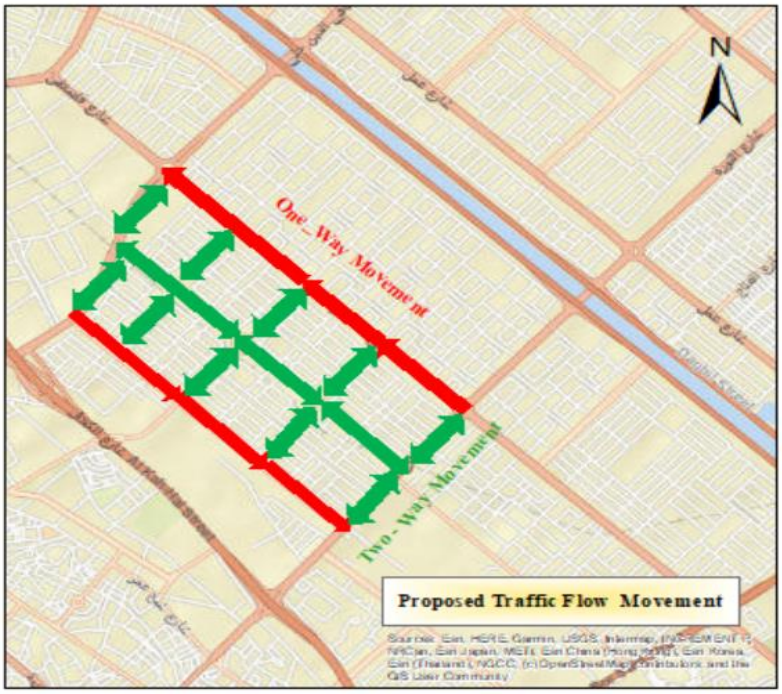


Figure 2: Proposed traffic movement of the study area.

4. RESULTS AND DISCUSSIONS

The application of one-way traffic movement on the selected street network is explored and analyzed by Synchro (ver.9) traffic software. The traffic jam during the rush hours of selected signalized intersections is severe. The signalized intersections within the study area operated with oversaturated conditions (LOS F) and induced delays of about (197.2, 166.8, and 262.3) sec/veh for Al-Nakhala, Al-Sakhara, and Beirut intersections, respectively (Alkaissi, 2023). The results of the proposed traffic movement of the network area improved the traffic operation and reduced the control delay of selected signalized intersections, as depicted in Figure 3. The control delay was reduced from (197.2 to 8) sec/veh, (166.8 to 11.1) sec/veh, (262.3 to 19.5). The proposed traffic movement obtains a total reduction of about 95% in vehicle delay.

To detect the street operation of the actual condition and modified one-way traffic movement after analyzing by Synchro more clearly, the obtained results of degree of saturation (v/c) for actual conditions compare to the proposed solution (Figure 4). In general, the actual conditions for the results of the degree of saturation were 1.71, 1.5, and 1.86; Al-Nakhala, Al-Sakhara, and Beirut intersections (Alkaissi, 2023). The v/c ratio exceeds 1.00 for

signalized intersections that experience unstable conditions, excessive delays, and a long queue. Under these traffic conditions, traffic vehicles required more than one cycle time to pass through intersections along Palestine Street, which induced cycle failure with a worse level of service F. For these results, improvement will be necessary to avoid excessive delay and operation failure. The results of modified traffic movement show that v/c is reduced to 0.69 (Al-Nakhala), 0.59 (Al-Sakhara), and 0.99 (Beirut) intersections that indicate adequate capacity is promoted and operating under capacity. Excessive delays and vehicle queues are not experienced, and the traffic movement modification ensures the sufficiency of the signalized corridor to accommodate the traffic demand.

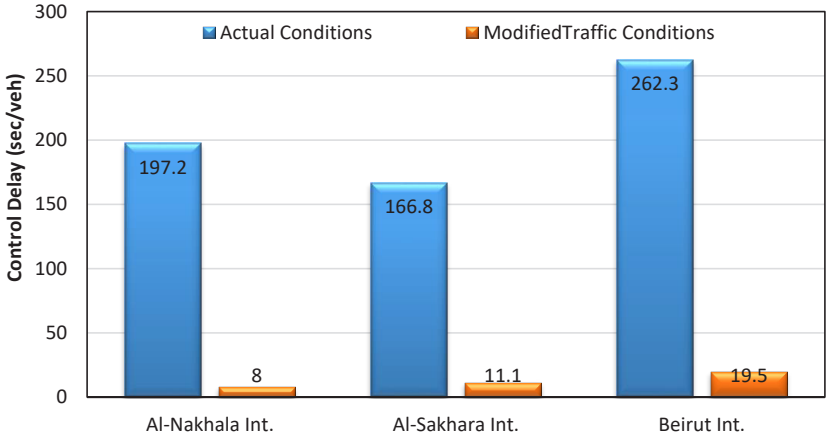


Figure 3: Effect of modified traffic movement on control delay.

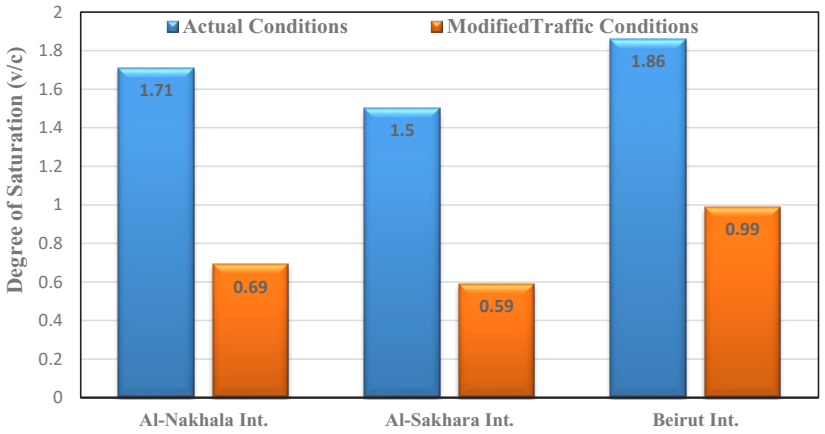
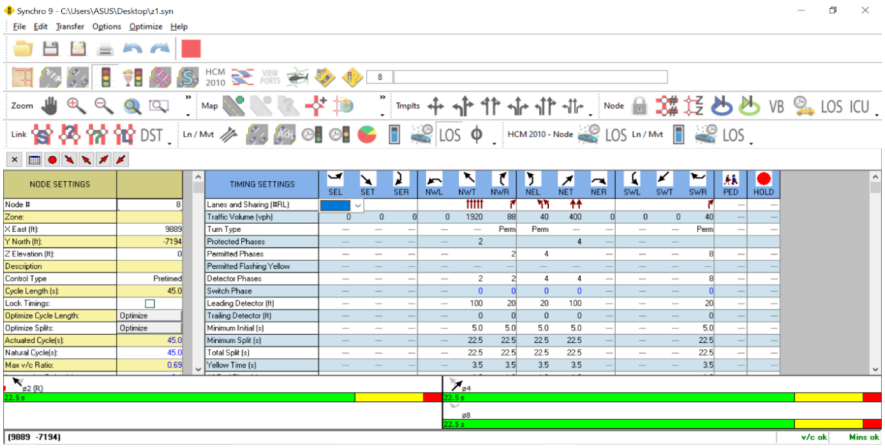
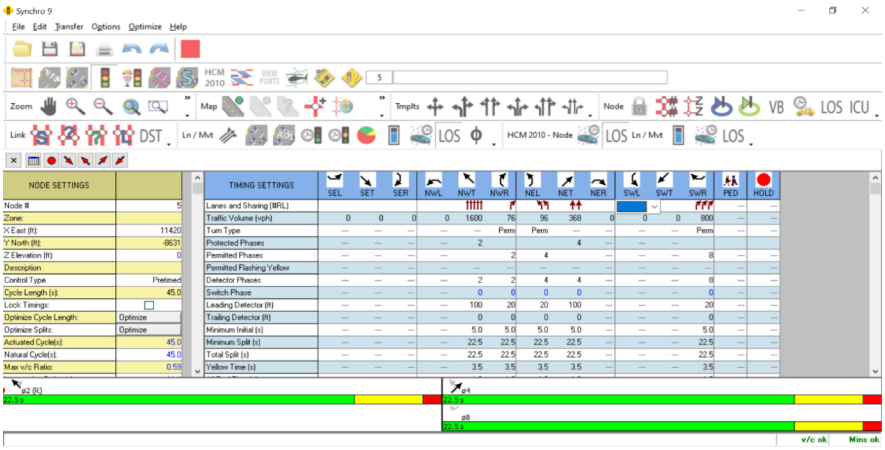


Figure 4: Effect of modified traffic movement on the degree of saturation.

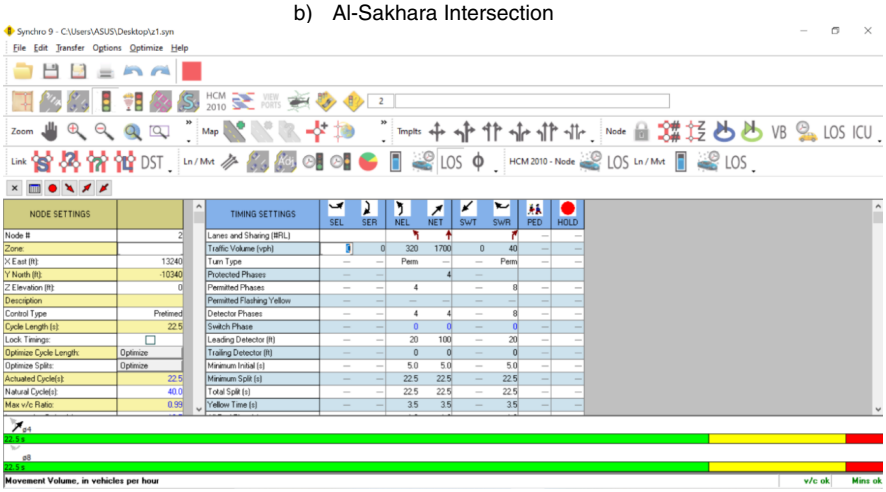
The signal timing of signalized intersections is considered an important role in their operational performance; Figure 5 shows the signal timing results by Synchro. Therefore, the serving of traffic movement is explored by depicting the cycle time required during the peak hour for vehicle movement through selected signalized intersections. The longer cycle time induced higher delays and queues for all vehicles flow. Observing Figure 6, it can be stated that the cycle time for actual conditions is significantly longer than the proposed traffic movement, which means that modification of on-way movement reduced excessive delay and improved traffic performance operation. The traffic one-way movement can solve the problem of traffic congestion in the study area and enhance the level of service from (F) to (A) and (B); see Figure 7 for simulation results.



a) Al-Nakhala Intersection



b) Al-Sakhara Intersection



C) Bairut Intersection

Figure 5: Analysis results of Palestine street corridor by Synchro for selected signalized intersections.

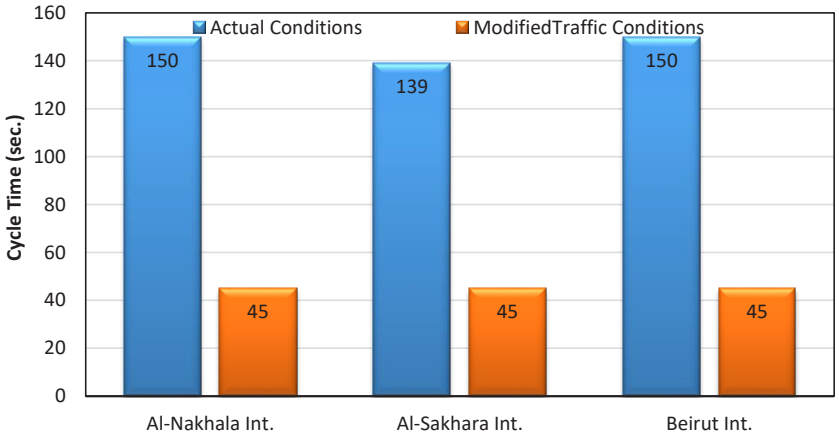


Figure 6: Effect of modified traffic movement on cycle time.

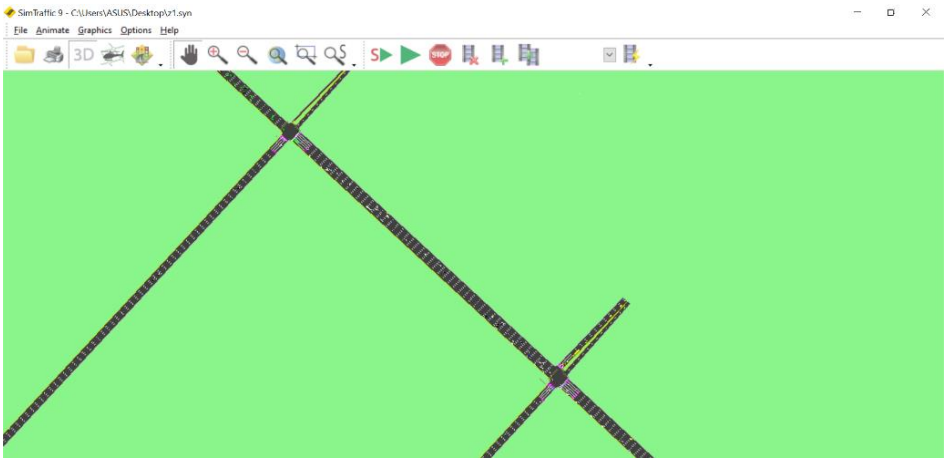


Figure 7: Simulated Palestine Street corridor by Synchro for selected intersections.

6. CONCLUSIONS

Based on the implementation of traffic modification of vehicular movement, this research demonstrates a one-way street and developed this traffic movement to alleviate traffic congestion and find the best solution for recommendation to policy decisions. The following points can be drawn:

- One-way traffic movement with a circulation network can significantly improve traffic operation and reduce congestion to a great extent. The results of the proposed traffic movement of the network area improved the traffic operation and reduced the control delay of selected signalized intersections, a reduction from (197.2 to 8) sec/veh, (166.8 to 11.1) sec/veh, (262.3 to 19.5). The proposed traffic movement obtains a total reduction of about 95% in vehicle delay.
- The results of modified traffic movement show that v/c is reduced to 0.69 (Al-Nakhala), 0.59 (Al-Sakhara), and 0.99 (Beirut) intersections that indicate adequate capacity is promoted and operating under capacity. Excessive delays are not experienced, and the traffic movement modification ensures the sufficiency of the signalized corridor to accommodate the traffic demand.
- It can be stated that the cycle time for actual conditions is significantly longer than the proposed traffic movement, which means that modification of on-way movement reduced excessive delay and improved traffic performance operation.
- The traffic one-way movement can solve the problem of traffic congestion in the study area and improve the level of service from (F) to (A) and (B).

REFERENCES

[1] Zhuo Y and Wang Y. Application of VISSIM simulation on evaluation of one-way traffic plans. Urban Transp China. 2016; 14(1): 72–79.
[2] Miandoabchi E, Daneshzand F, Szeto WY, et al. Multiobjective discrete urban road network design. Comput Oper Res. 2013; 40(10): 2429–2449.
[3] Salman S and Alaswad S. Alleviating road network congestion: traffic pattern optimization using Markov chain traffic assignment. Comput Oper Res. 2018; 99(1): 191–205.
[4] Peng Z, Guan F, Wang K, et al. Simulation-optimization model for one-way traffic reconfiguration. Simul-T Soc Mod Sim. 2016; 92(7): 627–635.
[5] Kim D, Andriamonje S, Bak SI, et al. Identifying the optimal configuration of one-way and two-way streets for contraflow operation during an emergency evacuation. Nat Hazard. 2013; 69(3): 1315–1334.
[6] Xiao Y, Zhu L, Li Z, et al. The effect of one-way traffic on commercial entrance space based on the low carbon concept: the case of Changsha liberate west road. Archit J. 2012; 2012(8): 24–27.
[7] Wang J and Zhu J. The adaptability study on one-way traffic organization in big cities. Urban Public Transp. 2016; 2016(6): 30–33.
[8] Bavarez E and Newell GF. Traffic signal synchronization on a one-way street. Transp Sci. 1967; 1(2): 37–46.
[9] Khooban Z, Farahani RZ, Miandoabchi E, et al. Mixed network design using hybrid scatter search. Eur J Oper Res. 2015; 247(3): 699–710.
[10] Riggs W and Gilderbloom JI. How multi-lane, one-way street design shapes neighbourhood life: collisions, crime and community. Local Environ. 2017; 22(1): 1–17.
[11] Mao X. Opening up gated communities to public road system and urban traffic microcirculation: a case study of Donghu district in Nanchang. J Landscape Res. 2017; 9(4): 1–3.
[12] Miandoabchi E, Daneshzand F, Zanjirani FR, et al. Time-dependent discrete road network design with both tactical and strategic decisions. J Oper Res Soc. 2015; 66(6): 894–913.
[13] Bianca C and Coscia V. On the coupling of steady and adaptive velocity grids in vehicular traffic modelin. Appl Math Lett. 2011; 24(2): 149–155.
[14] Zhang ZH. The impact of traffic microcirculation system in residential district on road traffic. J Lanzhou Univ Arts Sci 2017; 31(2): 36–41.
[15] Lykov AA, Malyshev VA and Melikian MV. Phase diagram for one-way traffic flow with local control. Phys A. 2017; 486(1): 849–866.
[16] Song ZR, Zang LL and Zhu WX. Study on minimum emission control strategy on arterial road based on improved simulated annealing genetic algorithm. Phys A. 2020; 537: 122691.
[17] Yuan Y, Liu Y and Liu W. Dynamic lane-based signal merge control for freeway work zone operations. J Transp Eng A: Syst. 2019; 145(12): 04019053.
[18] Zhao D, Li X, and Cui J. A simulation-based optimization model for infrastructure planning for electric autonomous vehicle sharing. Comput Aid Civ Inf. Epub ahead of print 13. 2019. DOI: 10.1111/mice.12506.
[19] Mao F, Huang M, Zheng J, et al. Optimization model and solution method of multi-sources guide paths. IET Intell Transp Sy. 2019; 13(11): 1668–1676.
[20] Alkaissi, Z.A. Travel Time Prediction Models and Reliability Indices for Palestine Urban Road in Baghdad City. Al-Khwarizmi Engineering Journal (Alkej), 13(3), 120–130, 2017.
[21] Alkaissi ZA. Traffic simulation of continuous flow intersection with displaced left-turn: a case study. Journal of Engineering and Applied Science. 2022; 69(1):39.
[22] Alkaissi ZA. Effect of Signal Coordination on the Traffic Operation of Urban Corridor. Tikrit Journal of Engineering Sciences. 2023; 30(1): 12-24.
[23] Sabaa MR, Salman AD, Dakhil AJ, Jawad SI, Karkush MO, Athab A. Production Thematic Maps of Bearing Capacity of Shallow Foundation for Al-Basrah Soil Using Standard Penetration Data and GIS. Journal of Rehabilitation in Civil Engineering. 2023 Nov 1;11(4):77-90.
[24] Karkush MO, Ziboon AR, Hussien HM. Studying the effects of contamination on soil properties using remote sensing. Journal of Engineering. 2014 Jun;20(6).