International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-5, March 2020

Traffic Demands Policies Effect on Congestion, Delay and Fuel Consumption

Amani Al Tamseh, Eslam Al Karabsheh, Salam AL Kasassbeh

Abstract **:** ***Traffic demands on Jordanian streets have been affected by the increasing human population and the number of vehicles. This study aims to apply transportation demand management (TDM) techniques to improve the level of service (LOS). The study employs both TDM and transportation system management (TSM). In order to investigate what type of strategies to be considered a questionnaire is used. The acceptance degrees of the TDM and TSM groups were measured via the questionnaires using SPSS version 20. The selected policies then are used on a certain location as a study case in Amman city; an intersection is connecting two urban main streets. The used policies have a reduction percentage in traffic demands which is expected throughout an expert panel. The results show that delay and fuel consumption are indeed reduced; however, this does not lead to any considerable improvement in the LOS. The LOS was enhanced when the reduction in traffic demand reached 20% with an increase in capacity achieved by adding 3 new lanes. The fuel consumption and delays were measured to be about 35% less with growth rate of 8% for the coming five years. This study is expected to help popularize TDM policies in place of other solutions so that inexpensive measures can be adopted by the government.***

Keywords: Transportation demand management; traffic demand, fuel consumption; delay.

I. INTRODUCTION

Amman city is the capital of Jordan and the largest metropolis; therefore, there is a higher concentration of jobs in Amman. According to the Jordanian statistics department, the population was 5.1 million in 2004, and it increase to more than ten million at the end of 2018, with more than half of them being concentrated in Amman city (Department of Statistics in Jordan, 2019). Ordinary fuel prices are a real problem because the prices increase with time. The economic ramifications of increasing fuel consumption are a challenge such that when the era of fuel usage diminishes, new challenges are faced by the government, and there is a need for an established economic ascent (Raad and Burke, 2018). The people in Amman have been disappointed with the congestion situations in peak hours that result in long lines of motors queuing and moving slowly on the streets. Traffic congestion is increasing at a fast scale, thereby increasing pollution and delays in trips. The efficiency and safety of traffic can be improved using several demand control strategies (Bauza and Gozálvez, 2013). Delay and increased fuel consumption are daily challenges faced by drivers in Amman city. Most arterial streets in the city require immediate solutions. The main challenge here is that the number of vehicles continuously increases where all facilities are designed to achieve certain demands (Won, Cho, and Kim, 2015). Nowadays, highway and traffic experts have focused on controlling and managing traffic demands rather than the supply. The travel demand management (TDM) is a methodology that reduces the number of vehicular trips or traffic volume to solve the problem of congestion; this enables controlling system demands with existing traffic facilities. In addition, this is the main objective of demand management (Rahman and Al-Ahmadi, 2010; Raad and Burke, 2018).

Revised Manuscript Received on March 30, 2020.
* Correspondence Author
Amani Al Tamseh*, Civil Engineering Department, Al Balqa Applied University/ Faculty of Engineering Technology, Amman, Jordan.
Eslam Al Karabsheh, Civil Engineering Department, Al Balqa Applied University/ Faculty of Engineering Technology, Amman, Jordan.
Salam Al Kasassbeh, , Civil Engineering Department, Al Balqa Applied University/ Faculty of Engineering Technology, Amman, Jordan. Email: amani.tamseh@bau.edu.jo

II. LITERATURE REVIEW

Transportation supply management (TSM) includes many measures such as the improvement of traffic signals, pedestrian facilities, and geometry design, all of which represent effective TSM measures where they can decrease the vehicular delay and increase road capacity, decrease vehicle delay, and improve system performance.(Eikenberry et al. 2015) examined the advantages and disadvantages that enable and support sustainable transportation modes. In addition, the highest benefit of transportation sustainability options is cost-effectiveness. It is very important to optimize TDM and transportation planning (Eikenberry et al., 2015) as all policies cannot be used simultaneously. This can be achieved using policies that incorporate traffic operations and control activities. The variation in commuter trips have emphasized the need for immediate demand management strategies (Bricka et al., 2015). Recently, many countries have applied different strategies. The good cases are considered in Canada, Japan, and America using TDM polices for decreasing the traffic demands (Hai and Hiep, 2013). A study by Sharif, Khan, and Yousaf (2012) found two main approaches for solving transportation system congestion in Pakistan. Decreasing vehicular pollution and congestion are the effects of developing TDM strategies. Another study mentioned the causes behind the low number of public transit users in Malaysia, which were high income, subsidies on fuel, and increasing population.

They showed that people in Malaysia have high dependency on private transportation modes, which results in high traffic demands such a passenger cars, motorcycles, heavy trucks, para-transit taxies, and public transit buses. In addition, developed countries have experienced all effects of not employing a suitable TDM strategy such as pollution, congestion, commuter trip delays, public transit delay, and fuel consumption (Pojani and Stead, 2015). Mahmood, Basher, and Akhter (2009) focused on the strategies of large cities such as Dhaka, which include the regulation of public transit, wherein an immediate solution is to replace old fleets with unused bus systems such as electronic buses, gas-powered buses, and double-Decker buses, the usage of automated enforcement programs, and the application of heavy penalty systems (Pojani and Stead, 2015) and (Jerw et al, 2019).

In Jordan, there are more than two million driver licenses only in Amman city (Driver and vehicle licensing directorate belonging to Public security directorate, 2015). This is a relatively large number for a city such as Amman. Hasnine, Weiss, and Nurul Habib (2016) adopted the method of an evaluation TDM strategy as its effective implementation concept depends on a high-population target city. On the other hand, Alwrikat (2015) expected that the population of Amman city will reach 9 million by 2025, which is now 5 million (Department of Statistics in Jordan, 2019). This means that the number of trips will increase from 6 million trips/day to reach to 12 million trips/day, based on the meeting of urban transportation that was held in Jordanian ministry of transportation national on October 2015 (Alwrikat, 2015). As a result, vehicle numbers will increase causing a 3.8–11% reduction in traffic fuel. Alwrikat (2015) provided a good guidance for the application of TDM and the evaluation of its impact on the traffic system. Further, he used a TDM strategy based on the flexibility of office hours with compressed work hours depending on 34% private cars (Alwrikat, 2015). Rahman and Al-Ahmadi (2010) showed the effects of TDM usage on congestion and vehicle emission in Saudi Arabia using TDM policies. They provided many TDM strategies such as electronic governmental services and shopping, road pricing, and effective public transit system, and the light rail transit (LRT) that can be used (Rahman and Al-Ahmadi, 2010).

III. CASESTUDY

Six elements of roadway networks have been described by the Highway Capacity Manual (HCM)-2010. These elements include systems, areas, facilities, corridors, segments, and point. An urban intersection controlled by a traffic signal in Amman city (31 54 23 °N ,35 53 07 °E) is selected as the case study due to the availability of data. Al-Ersal traffic signal (Al Quds intersection) is the selected location (Google Earth, 2013); Figure 1 shows the case study traffic demands vehicle classification (GAM, 2017). Majority of the traffic at this location comprises private passenger cars and the lowest percentage is that of trucks and small vans.

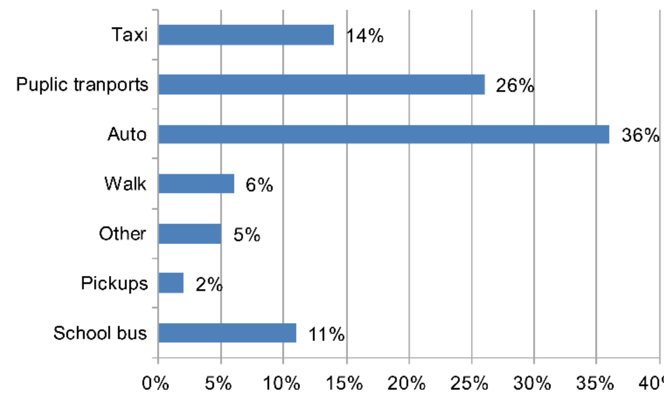

Figure 1: Al-Ersal Traffic Signal vehicle classification (Source: The Traffic Control Centre)

The Al Ersal traffic light located at Al Quds Intersection is shown in Figure 3. The data was obtained by visiting the intersection and from the Traffic Center of Great Amman Municipality (GAM). The PHF was determined using an hourly traffic count every 15 min for each approach. The selected intersection is defined as a high demand intersection, where 90% of southern Amman drivers pass through it to eastern Amman. The number of crashes on this intersection is relatively high; there were 91 crashes between 2014 and 2017 of which 10 crashes resulted in fatalities (JTI, 2017; Jadaan et al., 2013). The selected intersection includes two main roads with high-speed limits (60–70 km/h); further, the crash frequency was significantly increased by 35% at one red light running (RLR) camera location between 2014 and 2017. This can be explained by the high speed of the two intersecting roads (Naghawi et al, 2018).

IV. METHODOLOGY

A. Data Collection

A questionnaire was used for data collection. SPSS version 20 (IBM, NY, USA) was used to conduct the statistical analysis. The questionnaire analysis was validated by a transportation specialist’s group. The sources of collected data were the questionnaire comparison data obtained from GAM Traffic Control Center. The third part was the transportation engineering experts in Jordan who are professionals in traffic area. The role of these experts was to draft the questionnaire and validate it. The questionnaire is in Arabic so that it can be easily understood by the respondents. In addition, both TDM and TSM strategies were part of the questionnaire. Traffic and highway engineers from the Jordan engineer's association (JEA) participated in the questionnaire survey. The Likert scale was used to construct the questionnaire where the sample size was 800 engineers. To select the sample size, 50% of the questionnaire population was selected randomly; where the sample size is determined before data collection. 25% of the population were respondents, and 384 questionnaires were distributed.

The questionnaire was distributed to many governmental institutions and companies as well as to the private sector. Questionnaires were distributed using two methods: electronic method using a link (online survey) and a face-to-face 15-min interview. Of the 384 questionnaires, 194 were recovered. The questionnaire distribution details are listed in Table 1.

Table 1. Questionnaire distribution

Municipality	Questionnaires sent	Questionnaires received	Net Rate %	Distribution method
Via e-mail	200	35	17.5	Internet
GAM	50	42	84	Interview
MPWH	61	55	90	Interview
Private companies	25	20	80	Interview
Academics at universities	28	24	86	Interview
The Jordanian association for the prevention of traffic accidents	20	18	90	Interview
Total	384	194	Average 51%> 50 % so it is accepted	

B. Data Analysis

Two parts of the statistical analysis were performed for the questionnaire, which includes the TDM strategies. For the questionnaire that includes TDM and TSM strategies, Lee Cronbach's Alpha—developed in 1951—was used to validate the accuracy of the information and to evaluate the questionnaires. The Lee Cronbach's Alpha approach is a reliability index that correlates the results with themselves. Further, Lee Cronbach's Alpha value ranges from 0 to 1; values up to 0.95 are acceptable. The TDM questionnaire did not have any strategy that related to road pricing, where this strategy did not have approval from the public. Jadaan et al. (2013) showed that 45% of the respondents rejected the pricing of road strategy. Table 2 lists all strategies used in the questionnaire divided into two groups: TDM and a combination between TDM and TSM.

Table 2. Strategies that are included in the questionnaire

First part of the questionnaire Demand reduction strategies						Second part of the questionnaire Traffic volume reduction and increasing capacity					
Strategy number	N	Mean	Std. Deviation	Scores	Rank	Strategy number	N	Mean	Std. Deviation	Scores	Rank
1	194	3.81	0.930	High	4	1	194	3.92	0.830	High	4
2	194	3.97	0.986	High	6	2	194	2.66	0.886	Moderate	1
3	194	3.80	1.114	High	3	3	194	3.90	1.14	High	3
4	194	4.36	0.839	Very High	11	4	194	4.34	0.939	High	13
5	194	4.22	0.845	Very High	10	5	194	4.63	0.945	Very High	16
6	194	4.50	0.756	Very High	15	6	194	4.63	0.856	Very High	16
7	194	4.43	0.703	Very High	13	7	194	4.44	0.803	Very High	14
8	194	3.50	1.078	High	2	8	194	3.51	1.11	High	2
9	194	4.15	0.884	Very High	9	9	194	4.16	0.784	Very High	8
10	194	4.42	0.708	Very High	12	10	194	4.44	0.808	Very High	15
11	194	3.91	1.043	High	5	11	194	3.93	1.113	High	6
12	194	4.62	0.697	Very High	16	12	194	4.60	0.797	Very High	15
13	194	4.62	0.690	Very High	16	13	194	4.60	0.906	Very High	15
14	194	3.80	1.035	High	3	14	194	3.81	1.115	High	4
15	194	2.66	1.421	Moderate	1	15	194	3.08	1.214	High	2
Valid N	194										

Table 3. Ranking for strategies that can reduce traffic demand on urban roads

First part of the questionnaire	Second part of the questionnaire
Demand reduction strategies	**Traffic volume reduction and increasing capacity**
1. Legislation planning before construction.	1.Add special lanes for HOVs
2.Carpooling strategy and vehicles with two-to-three occupants	2.Use solid painting lines instead of medians or casted barriers for more safe conditions
3.Van-pooling and high-occupancy vehicles (HOV)	3.Decrease lane width to increase number of lanes

4.Public transit with bust vehicles that have less than 20 passengers.	4.Disallow truck trips during peaks hours and replace day delivery services with night shifts
5.Public transit with bus vehicles that have less than 40 passengers and more than 20 passengers.	5.Non-peak hour maintenance. Or evening time maintenance.
6.public transit with bus vehicles that have less than 20 passengers	6.Redesign phasing at the intersection with future traffic demands based on growth rate
7.In addition to the previous strategy, usage of HOV lanes	7.All traffic facilities with level of service D or less should be improved
8.Allow street parking on streets that feed into the main streets	8.Bridge and tunnels should be used for intersections with level of service E or F where the previous strategy was applied, and the intersection did not improve
9.Provide off-street parking lots that have service availability with less than half km and with acceptable price to drivers	9.In addition to the previous strategy, the at-grade approaches should be controlled by a signalized system
10.Electronic services in the government and private sectors	10.Install intelligent system as guidance to inform drivers about different traffic conditions
11.Off-street parking for high demand government and private centers	11.Encourage forced usage of crosswalk and pedestrian bridge at intersection
12.Internet SMS services and via internet interview.	12.Use one-way traffic flow systems at main roads
13.Park-and-ride with parking lots at the transfers stops of public transits	13.Establish a legislation for automated enforcement programs
14.The odd even strategy for all vehicles.	14.Apply heavy penalties for exceeding the speed limit at main streets or for running the red light at intersections
15.The odd even strategy for the private vehicles only	15.Application of technology with suitable updated information in the processes of planning, controlling, and management of any traffic system
The Cranach's Alpha value of these 15 strategies was 0.784, and it is acceptable as it is greater than 0.7.	The Cronbach's Alpha value of these 15 strategies was 0.858. This value is acceptable because it is above 0.7.

Table 3 lists the degree of acceptance according to the results of the questionnaire. For the first part of the questionnaire that includes TDM strategies, strategy numbers 12 (Internet SMS services and via internet interview) and 13 (.Park-and-ride with parking lots at the transfers stops of public transits) have the highest degree of acceptance. The lowest degree of acceptance was for strategy number 15 (odd–even policy). For the second part of questionnaire, it was found that strategy numbers 5 (continuous maintenance at nonpeak hours) and 6 (traffic signal cycle length redesign using updated software with annual future traffic growth rates) have the most acceptance. In addition, strategy number 2 (replacing the median by iron barriers or yellow solid lines) has the lowest degree of acceptance. All strategies that have the highest degree of acceptance were considered to reduce the traffic demand percentage from the point of view of the experts panel. We can say that there are 14 TDM strategies considered acceptable by the Jordanian people based on the questionnaire results.

V. RESULTS AND DISCUSSION

An expected rate of reduction was selected by the majority of experts. All experts are considered specialists in highway, transportation, and traffic engineering; they consist of three groups (academics working at universities, consultants for government administrations, and experts' engineers working in private sectors). Four significant reduction rates—5%, 10%, 15%, and 20% —were used for the intersection analysis. The geometric and traffic conditions of the selected case study, which is Al Quds intersection, were analyzed by Synchro 8. Figure 2 shows the different stages of the intersection analysis; the stages consist of the existing condition evaluation and the decrease in the traffic demand applied with four significant rates (5%, 10%, 15% and 20%). In the third stage, a short-term period growth rate was applied, where the growth rate is 8% for the coming five years (GAM, 2017). In the fourth stage, a combination between the capacity increases and demand reduction is applied to increase capacity by changing the geometric design. Table 4 lists the Synchro software outputs for the first stage of analysis, which is the evaluation of the existing condition of the intersection.

Retrieval Number: E2487039520/2020©BEIESP
DOI: 10.35940/ijitee.E2487.039520
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

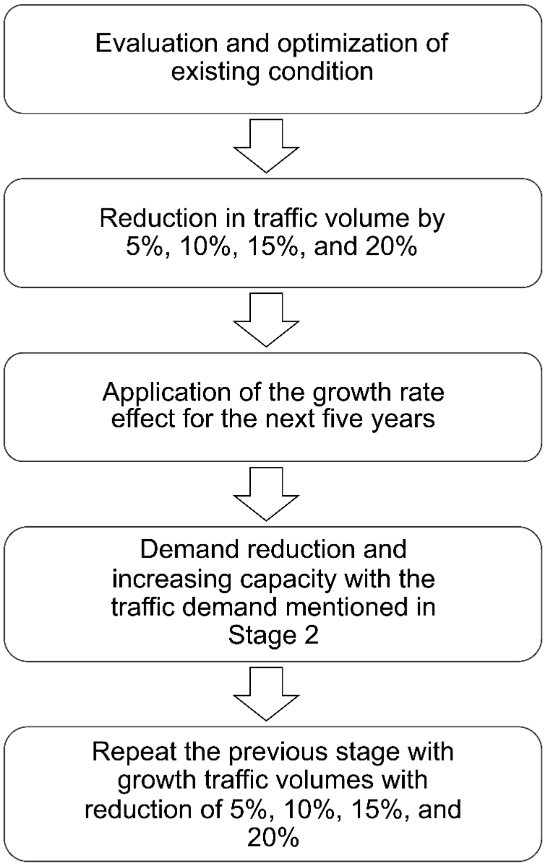

Figure2: Stages of analysis

To determine the optimum reduction rate, many reduction runs were performed in the four trials (5%, 10%, 15%, and 20%). The four streets considered in this analysis and intersected at the selected intersection are AL-Hurriah street, Al-Quds street, from Dear Agbar Street, from Airport street. The most congested approaches at the selected intersection are the approaches between Al-Quds street from the Airport street.

Whereas, the traffic from Dear Agbar street had the lowest congestion. According to Tables 4 and 5, the existing condition evaluation results are; the LOS is F with a total delay of 234 s/veh and the consumption of fuel is 1115 L/h; this provides the worst existing conditions. From Table 4, the reduction rate of 20% in traffic demands were chosen for analysis with the Synchro software and the results are listed in Table 6 with a growth rate of 8% for a short-term period of 5 years (GAM, 2017). The analysis was carried out with two considerations: reduction in traffic demand by 20% and increase in geometric capacity (one or two additional lanes in every approach). All results in Table 6 proved no improvement in the LOS of the intersection; however, there is an enhancement in the delay and fuel consumption, where the total delay is 1028.3 s/veh and the fuel consumption is 5905.25 L/h.

Table 4. Analysis process conducted using Synchro 8

Approach	Street name	Existing Conditions			5% Reduction			10% Reduction			15% Reduction			20% Reduction		
		L	**TH**	**U**	**L**	**TH**	**U**	**L**	**TH**	**U**	**L**	**TH**	**U**	**L**	**TH**	**U**
1 (NB)	From Dear Agbar street	2730	921	770	2593	874	731	2457	828	693	2320	782	654	2180	736	616
2 (EB)	From Airport street	586	5442	165	556	5169	156	527	4897	148	498	4625	140	468	4353	132
3 (SB)	Al-Hurriah street	713	676	200	677	642	190	641	608	180	606	574	170	570	540	160
4 (WB)	**Al-Quds street**	**1186**	**3341**	**334**	**1126**	**3173**	**317**	**1067**	**3006**	**300**	**1008**	**2839**	**288**	**948**	**2672**	**267**

Table 5. Results of the existing conditions for the Al- Quds intersection

Approach	From Airport street	From Dear Agbar	Al-Quds street	Al Hurriah-Al street
	EB	**NB**	**WB**	**SB**
Approach delay (s/veh)	1608.8	406.4	1024.8	2670.5
LOS	F	F	F	F
Highest V/C ratio	1.89	2.18	3.63	1.37
Intersection LOS	F			
Intersection cycle length (s)	450			
Intersection delay (s/veh)	1606.7			
Intersection fuel used (L/h)	9085			

Table 6. Results of the traffic conditions with 20% traffic volume reduction, growth rate of 8%, and capacity up to six lanes for each approach

Approach	From Airport street	From Dear Agbar	Al-Quds street	Al Hurriah-Al street
	EB	**NB**	**WB**	**SB**
Approach delay (s/veh)	1029.6	260.1	655.9	1709.1
LOS	F	F	F	F
Highest V/C ratio	2.89	2.18	2.63	1.37
Intersection LOS	F			
Intersection cycle length (s)	450			
Intersection delay (s/veh)	1028.3			
Intersection fuel used (L/h)	5905.25			

Retrieval Number: E2487039520/2020©BEIESP
DOI: 10.35940/ijitee.E2487.039520
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

VI. CONCLUSION

The TDM strategies play a significant role in the improvement of roads performance measures such as delay, fuel consumption, V/C volume to capacity ratio, and LOS. Analysis results from the Synchro software show that the LOS did not really improve although there was an enhancement in fuel consumption and delay. The selected intersection is defined as one of the intersections with the worst existing condition. Further, the volume traffic condition would be more congested in the coming 5 years where the growth rate is 8%. More extensive studies are required to convince people of the congestion pricing strategy; further, as mentioned before, it is not an acceptable strategy. This study can provide a direct indicator for the stake holders to select the most suitable TDM strategies. The strategies accepted among the Jordanian society can be employed at any traffic facility to enhance the transportation network around the country. The intelligent transportation system (ITS) can be used to implement some TDM strategies with TSM. An issue that must be considered when developing traffic programs is the future population growth. The main limitation of this study was the availability of data as only one intersection was used in the synchro analysis. The future scope must focus on acceptance to consider the TDM as a solution for road congestion, by people who are both the decision makers and road users.

REFERENCES

1. Alwrikat, A.R. 2015. A study by Greater Amman Municipality, at National Days of Urban Transport which held in Ministry of Transport.
2. Bauza, R., Gozálvez, J. 2013. Traffic congestion detection in large-scale scenarios using vehicle-to-vehicle communications. J. Netw. Comput. Appl. 36, 1295–307.
3. Bricka, S., Moran, M., Miller, K., Hudson, J. 2015. The future of TDM: Technology and demographic shifts and their implications for transportation demand management.
4. Department of Statistics in Jordan website. 2019. Retrieved from http://census.dos.gov.jo/. [Accessed at 10 July 2019] DOI: https://doi.org/10.1016/j.jnca.2012.02.007.
5. Driver and vehicle licensing department. 2015.
6. Eikenberry, A., Maher, C., Grant, F., Kim, J. 2015. Enhancing transportation demand management options at the University of Nebraska at Omaha: The costs, benefits and challenges of implementation.
7. Google Earth Application. 2013.
8. Greater Amman Municipality (GAM). 2017. Traffic control Center.
9. Hai, T.H., Hiep, D.V. 2013. Transportation demand management: A solution to reduce congestion and towards a sustainable transportation in Hanoi. Proc. Eastern Asia Soc. Transport. Studies 9, 2013.
10. Hasnine, M.S., Weiss, A., Nurul Habib, K., 2016. Development of an employer-based transportation demand management strategy evaluation tool with an advanced discrete choice model in its core. Transport. Res. Rec. 2542(1), 65–74. DOI: 10.3141/2542-08.
11. Jadaan, K., Al-Hyari, I., Naghawi, H, Ammourah R, Al Nabulsi Z. 2013. Traffic Safety in Jordan: Magnitude, Cost and Potential Countermeasures. J. Traffic Logist. Eng.; 1, 54–7.
12. Jrewa, B., Msallamb, M., & Momanic, M. (2019). Strategic Development of Transportation Demand Management in Jordan. Civil Engineering Journal, 5(1), 48-60.
13. Jordan Traffic Institute (JTI), Traffic Accident statistics reports for years 2004-2016. Ministry of Interior, Jordan. [Online]. Available from: http:// www.psd.gov.jo/images/jti/images/411.pdf [Accessed: 6th January 2017].
14. Mahmood, M., Bashar, M. A., & Akhter, S. (2009). Traffic management system and travel demand management (tdm) strategies: suggestions for urban cities in Bangladesh. Asian J. Manage. Humanity Sci. 4, 161–78.
15. Naghawi, H., Al Qatawneh, B., Al Louzi, R. 2018. Evaluation of automated enforcement program in Amman. Periodica Polytechnica Transp. Eng. 46, 201–6.
16. Pojani, D., Stead, D. 2015. Sustainable urban transport in the developing world: beyond megacities. Sustainability 7, 7784–805.
17. Raad, N., Burke, M. I. 2018. What are the most important factors for pedestrian level-of-service estimation? A systematic review of the literature. Transp. Res. Rec. 2672, 101–17.
18. Rahman, S.M., Al-Ahmadi, H.M. 2010. Evaluation of transportation demand management (TDM) strategies and its prospect in Saudi Arabia. Jordan J. Civil Eng. 4, 1.
19. Sharif, M.B., Khan, A.H., Yousaf, M. 2012. Transportation demand management models for transportation system of Pakistan. Pak. J. Sci. 64.
20. Won, S., Cho, S.E., Kim, S. 2015. The neighborhood effects of new road infrastructure: Transformation of urban settlements and resident’s socioeconomic characteristics in Danang, Vietnam. Habitat Int. 50, 169–79. DOI: 10.1016/j.habitatint.2015.08.037.

AUTHORS PROFILE

Amani Al Tamseh, Ms.C in transportation engineering from Jordan university, full time lecturer, civil engineering department, faculty of engineering technology/ al Balqa applied university.

Eslam Al Karabsheh,, Ms.C in pavement design from Jordan university, full time lecturer, civil engineering department, faculty of engineering technology/ al Balqa applied university.

Salam Al Kasassbeh, Ms.C in structure engineering from Jordan university, full time lecturer, civil engineering department, faculty of engineering technology/ al Balqa applied university.