Assessment of Sustainable Indicators for Road Transportation: A Case Study of Palestine Arterial Street

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Abstract: ***The aim of this research is the evaluation and designation measurement of sustainable indicators for transportation roads with selected case study of Palestine arterial street. Collected field data for travel speed for three links is obtained to estimate the index for performance measures of sustainability including mobility, fuel emissions, vehicle operating cost and scio-economic impacts. The congestion index for RSR (%) is obtained which illustrated there was a maximum reduction about 78% ,83% and 82.8% for link(1),(2) and (3) respectively and the weighted relative speed reduction index for three links covering the whole study area is about (0.58). 85% percentile speed about 16.82 km/hr for link(1) during the peak period. Also the 85% percentiles speed were 15.9 km/hr and 18.7 km/hr for link(2) and (3) respectively which produced high emissions rate during the peak evening period for all links from 12:00 to 4:00 p.m. and then reduced to rise again at the evening peak period from 5:00 to 8:00p.m. The operating cost raised during peak period due to the reduction change in vehicle speed for all studied links in Palestine street. A 12.6 average unit cost per Km for Link(1) obtained at time period from (12-1) p.m while for links (2) and (3) were 13 , 12.32 average unit cost per Km at (2-3) p.m. respectively. User' satisfaction also is provided through questionnaire for individual' people opinion to incorporate the scio-economic impact interms of User Satisfaction Index (USI). The overall USI user satisfaction index was 2.109 which is about 42.18 % percent which demonstrated that the Palestine arterial street is unsustainable as far the social commuter opinion aspect is taken in consideration. The results obtained from analysis field data provide the application of ITS improve the traffic speed operation for Link (2) and (3) significantly by about 9% and 10% respectively but show insignificant negative impact traffic speed for Link (1). Another benefit of arterial ITS is the positive effect on environment, as depicted by the reduction in fuel consumption rate by about (8% ,9% and 6.8%) for Link (1), (2) and (3) respectively during the peak period. Furthermore positive impact on vehicle operating cost is by reduction factor of (9.09%, 6.47% and 6.06%) for Link (1), (2) and (3) respectively. The Design with sustainability requirements to reduce traffic congestion, air pollutions, economic should be harmonically coordinated with education peoples to change their attitude behaviour aspect as a whole community live within and understanding the transportation concept so they can provide actions to minimize recourses needs and then reduced negative impacts.***

Keywords: Sustainability; Arterial Street; Traffic speed; Congestion Index RSR%

1. Research Objectives

The aim of this research is the evaluation and designation measurement of sustainable indicators for transportation roads with selected case study of Palestine arterial street. A set of sustainability categories include mobility, pollutions emissions, costs and socio-economic impact had been implemented and investigated in this research to evaluate how performance measures progress toward sustainable arterial roads. Relative speed reduction index, fuel consumption and vehicle operating cost have been estimated during the peak and non peak period time for three sections of Palestine street as sustainable indicators. User' satisfaction also is provided through questionnaire for individual' people opinion to incorporate the scio-economic impact interms of User Satisfaction Index (USI). The second stage in this research is the investigation of intelligent transportation system application to arterial system as a sustainable solution for improvement of mobility and increase average speed and enhance the efficiency for traffic operation.

2. Motivations

The physical area surrounded Palestine street have been changed dramatically created a potential pressure of additional attraction and production daily trips. A congested commercial area with several shopping centers and malls like Pelastine mall, Maximall and Al-Kooch shopping centers in additions to the education institutional such as Al-Mustansiriyah and AlRafidain University that consider as a major attraction for trips. A residential area is also a part of the region surrounded Pelastine street. All these factors as well as increasing in motors vehicles produce problematic issues with traffic congestion during morning and evening peak period. The traffic congestion caused revolting reduction in average travel speed of the vehicles. On the other hand; another type of problems are given rise includes; lack of space, reduction in natural recourses and environmental pollutions. As we know and define the sustainable arterial streets as an street provide accessibility, safe social and economical activity with minimum environmental negative impacts of vehicle and balancing between the immediate street role and the urban system as a whole.

3. Introduction

Concept of transportation sustainability is basically arises from the lack of having an efficient transportation system that get the capture for rapidly increased demand. Many of transportation problems deduced from inadequate supply transport facilities; that results in delay ; congestion, dissatisfaction among user traveler and also produce negative impact for environmental through emissions.

How arterial street be active and sustainable and how sustainable arterial street contribute to sustainable cities and what are the design way methods to ensure a sustainable arterial street. All these question leads to a cross- disciplinary journey into expansive bibliographic territory. Just as streets connect, albeit sometimes divide or sever neighborhoods and districts of a city [1]. Figure (1) present arterial street from many disciplines [2]. Also the main observable categories influenced on active sustainable street are shown in Figure (2).

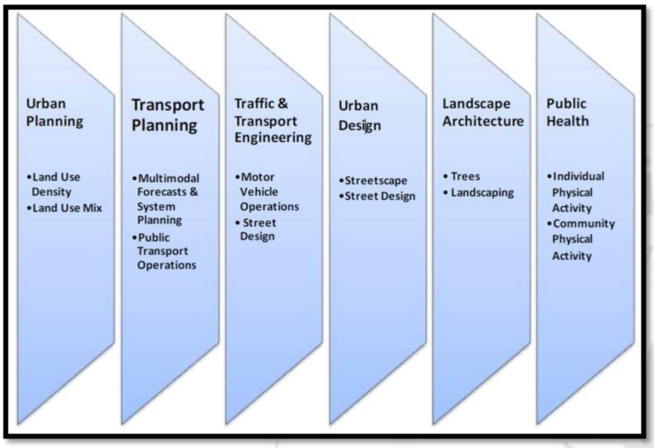


Figure 1: Disciplinary Domains Pertaining to Sustainable, Active Streets, [2]

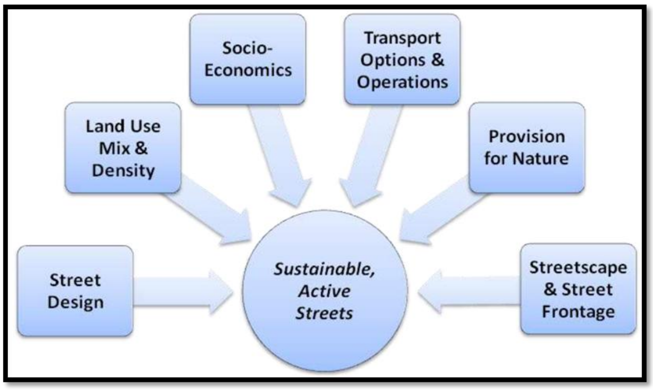


Figure 2: Visible, Measurable Influences on Active, Sustainable Streets, [2]

Model Of Sustainability And Integrated Corridors was done on three phase of project. Phase 1 define sustainability indicators and analyses the impacts of corridor improvements. While phase (2) focus on extending this corridor improvement options including HOV, and HOT lane, bus rapid transit /bus only lane. Phase (3) extends ability to analyse multiple improvement options [3]. The ways of minimum air pollutions used through non pollutant modes provide progressing towards sustainable streets [4].

The selection of indicators for comprehensive and sustainable transportation planning and its best to choose a balanced set of indicators which applied at several levels of planning process, options and incentives, travel behaviour, physical impacts, economic effects, effects of people on environment, and finally performance targets as shown in Table (1) [5] .

Table 1: Transportation Sustainable Indicators Ranked by Important and Type, [5]

	Economic	Social	Environmental
Most Important (Should usually be used)	Per capita mobility (daily or annual person-miles or trips). Mode split (*personal travel:* nonmotorized, automobile and public transport; *freight:* truck, rail, ship and air). Average commute travel time and reliability. Average freight transport speed and reliability. Per capita congestion costs. Total per capita transport expenditures (vehicles, parking, roads and transit services).	Per capita traffic crashes and fatalities. Quality of transport for disadvantaged people (disabled, low incomes, children, etc.). Affordability (portion of household budgets devoted to transport). Overall satisfaction rating of transport system (based on objective user surveys). Universal design (consideration of disabled people's needs in transport planning)	Per capita energy consumption, disaggregated by mode. Energy consumption per freight ton-mile. Per capita air pollution emissions (various types), disaggregated by mode. Per capita land devoted to transport facilities (roads, parking, ports and airports). Air and noise pollution exposure and health damages. Impervious surface coverage and stormwater management practices.
Helpful (Should be used if possible)	Relative quality (availability, speed, reliability, safety and prestige) of non-automobile modes (walking, cycling, ridesharing and public transit) relative to automobile travel. Number of public services within 10-minute walk and job opportunities within 30-minute commute of residents.	Portion of residents who walk or bicycle sufficiently for health (15 minutes or more daily). Portion of children walking or cycling to school. Community cohesion (quality of interactions among neighbors). Degree cultural resources are considered in transport planning.	Community livability ratings. Water pollution emissions. Habitat preservation. Use of renewable fuels. Transport facility resource efficiency (such as use of renewable materials and energy efficient lighting).
Specialized (Use to address particular needs or objectives)	Portion of households with internet access. Change in property values.	Transit affordability. Housing affordability in accessible locations.	Impacts on special habitats and environmental resources. Heat island effects.
Planning Process	Comprehensive (takes into account all significant impacts, using best current evaluation practices). Inclusive (substantial involvement of affected people, with special efforts to insure that disadvantaged and vulnerable groups are involved). Based on *accessibility* rather than *mobility*. Application of smart growth land use policies.		
Market Efficiency	Portion of total transportation costs that are efficiently priced. Neutrality (public policies do not arbitrarily favor a particular mode or group) in transport pricing, taxes, planning, investment, etc. Applies *least cost planning*.		

4. Site Selection

One of the most important urban arterial roads in Baghdad city is Palestine street which is located in the Eastern of Baghdad and it runs parallel to the west of Army Canal Bewteen Al-Mustansiriyah Sequare through Beirut square to the end of it at Maysalone sequar. As shown in Figure (3). As depicted in Figure (3) the three links that have been considered for this research namely as Link(1); From Al-Mwaal Intersection to Bab Al-Muatham Intersection, Link (2); From Bab Al-Muatham Intersection to AlSahkra Intersection, and Link (3); From AlSahkra Intersection to Beirut Intersection respectively.

Figure 3: Study Area Urban Arterial Palestine Street with Selected Three Links

5. Arterials and Street

The outstanding development in demand sustainability in general and particularly in transportation engineering resulted for the need of considering sustainable arterial streets in design and managements for all sustainable dimension include its economic; social and environmental should be considered for urban transportation planning. An arterial street is not closed system and its a part of a larger network transportation system providing function accessibility and circulation also its considered as major channel for traffic movement within different part of the urban city. sustainable arterial street provide a challenge for urban planning and based on the above statement ; a sustainable arterial street itself is considered as challenge case.

5.1 Indicators for Sustainability Measures

As a general definition of indicators " a variable selected and defined to measure progress toward objective [5] .Choosing a balanced set of indicators to illustrated the combination of economic, social and environmental objectives. A optimal decisions is made by considering all types of impact not focusing on one type and neglect others. Table (2) presents the sustainability indicators versus sustainability categories that had been considered in this research for Pelastine arterial street.

Table 2: Sustainability Indicators adopted for the Case Study

Sustainability Categories	Sustainability Indicators	Goal	Performance Measure Index
Mobility	Travel Speed (Km/hr)	Reduce Congestion	- Relative Speed Reduction Index(%) - Weighted relative speed reduction index (RSR%).
Pollutions Emissions	Fuel Consumption	Reduce air pollution	- Daily CO2 Emissions per 50m length of arterial street.
Costs	Travel Speed Variation (Km/hr)	Reduce cost	- Vehicle Operating Cost (Cost/ Km) length of street .
Socio-Economic Impact	User satisfaction (User Satisfaction Index USI)	Livability, Quality of life Land use access	-(USI) Index.

5.1.1 Mobility

The aim of any road and specially arterial street is to provide efficient traffic mobility for people within urban city. Traffic congestion on Palestine street for the three links stated below:

Link (1): from Al-Mwaal Intersection to Bab Al-Mutham Intersection.

Link (2): from Bab Al-Mutham Intersection to Al-Sakhara Intersection.

Link (3): from Al-Sakhara Intersection to Bairuit Intersection.

Speed data (using spot speed study method) are collected on the above three links (1), (2) and (3) of Palestine street in the south direction for period from (9:00 a.m.) to (8:00 p.m.) on Tuesday and Wednesday in May (2016) to capture the travel speed variation during peak and off peak periods. Figures (4) to (6) depict the variation of travel speed during the time interval. A general point of view from the results shown is the reduction of speed due to the traffic congestion that appeared during sharp peak congestion period from (12:00 to 3:00 p.m.) and also another less pounced congestion period illustrated from (4:00 to 8:00 p.m.) for all the observed links respectively.

For the more confidence in the obtained results ,a statistical analysis of vehicle average travel speed using (SPSS12) statistical software to describe their variation and statistical properties with the estimation of normal distribution , coefficient of variation , standard deviations and the squared skewness and the kurtosis for testing normality of travel speed at the study area. The Normal distribution, mean speed, percentile speed and standard deviation are estimated and the statistical analysis are shown in Figures (7),(8) and (9) and statistics summary in Tables (3) ,(4), and (5) below for all links. Link (1) show the higher speed reduction due to congestion effects from 12:00 to 4:00 p.m. which provide negative impact on mobility for traffic vehicle.

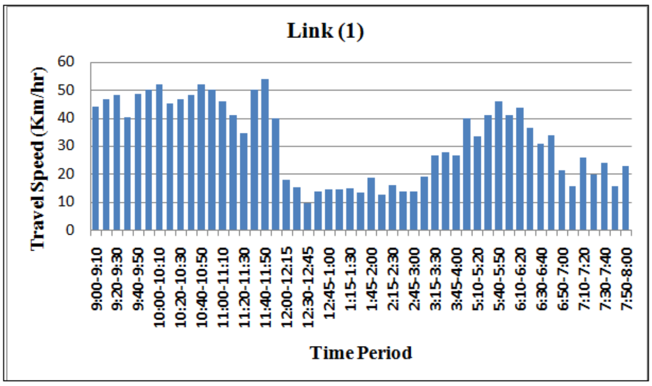


Figure 4: Travel Speed variation for Link (1)

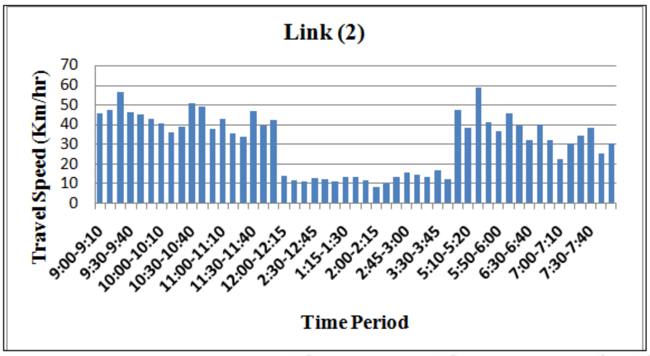


Figure 5: Travel Speed variation for Link (2)

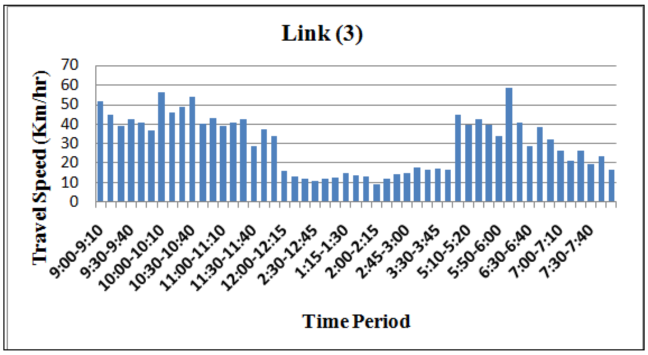


Figure 6: Travel Speed variation for Link (3)

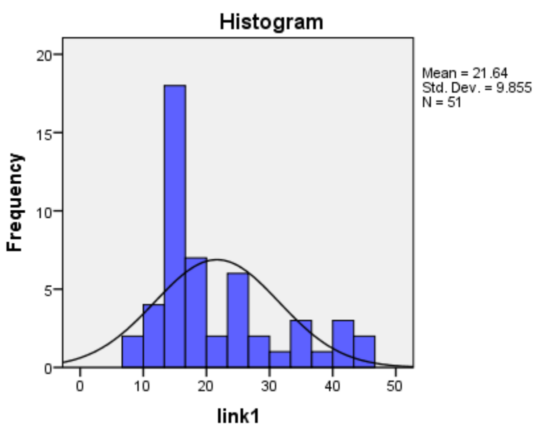


Figure 7: Travel Speed Normal Distribution for Link (1) at Peak Period 12-4 p.m

Table 3: Descriptive Statistics Results for Travel Speed of Link (1).

	N	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
link1	51	21.64	1.380	9.855	97.117	1.010	.333	-.089-	.656
Valid N (list wise)	51								

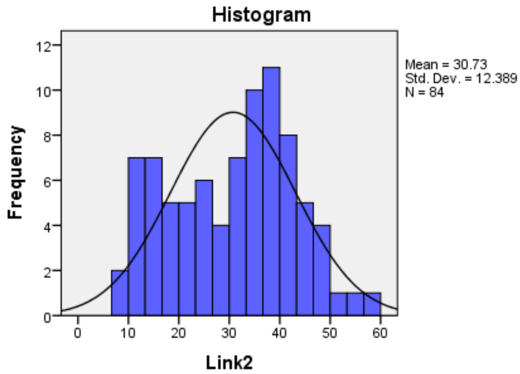


Figure 8: Travel Speed Normal Distribution for Link (2) at Peak Period 12-4 p.m

Table 4: Descriptive Statistics Results for Travel Speed of Link (2)

	N	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Link2	84	30.73	1.352	12.389	153.486	-.097-	.263	-.925-	.520
Valid N (list wise)	84								

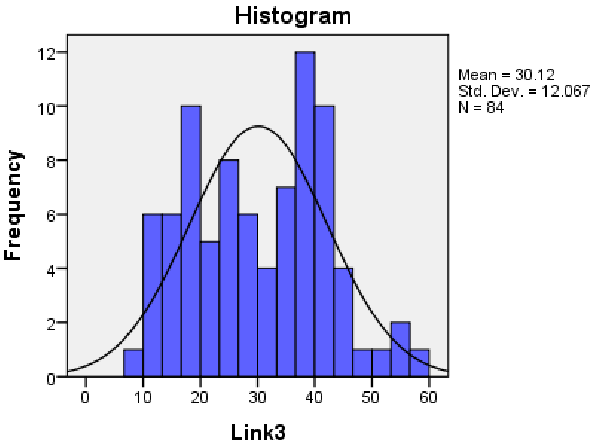


Figure 9: Travel Speed Normal Distribution for Link (3) at Peak Period 12-4 p.m

Table 5: Descriptive Statistics Results for Travel Speed of Link (3)

	N	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Link3	84	30.12	1.317	12.067	145.611	.138	.263	-.849-	.520
Valid N (list wise)	84								

5.1.1.1 Congestion Index

As general meaning of index is a group of indicators aggregated to single index [5]. To measure impact and evaluate traffic performance for arterial Palestine street interms of speed reduction due to traffic disruption from normal traffic flow. This achieved through estimating the average travel speed for three links during the peak and non peak hour within a day. A relative speed reduction is detected (RSR%) based on the collected field data. The relative speed reduction (RSR%) index is considered as congestion index for a link [6] :

$$RSR\ (\%) = \frac{S_i^{nonpeak} - S_i^{peak}}{S_i^{Peak}} \times [100] \qquad (1)$$

where:

$S_i^{nonpeak}$: Observed Travel speed at off -peak period .

S_i^{peak} : Observed Travel speed at on -peak period.

The weighted average relative speed reduction indicator is defined as:

$$weighted\ RSR\ (\%) = \frac{\sum_{i\in N}\sum_{K\in I} l_{ik} \frac{S_{i,k}^{nonpeak} - S_{i,k}^{peak}}{S_{i,k}^{Peak}}}{\sum_{i\in N}\sum_{K\in I} l_{ik}} \qquad (2)$$

where:

$S_{i,k}^{nonpeak}$: Observed Travel Speed at off peak-period for user k and link i.

$S_{i,k}^{peak}$: Observed Travel Speed at peak-period for user k and link i.

l_{ik}: the distance covered by user k on link i.

Figures (10), (11) and (12) illustrated the RSR(%) index for the three links respectively. The index results illustrated there was a maximum reduction about 78% ,83% and 82.8% for link(1),(2) and (3) respectively. The weighted relative speed reduction for three links covering the whole distance length from link1 to the end of link3 is about (0.58).

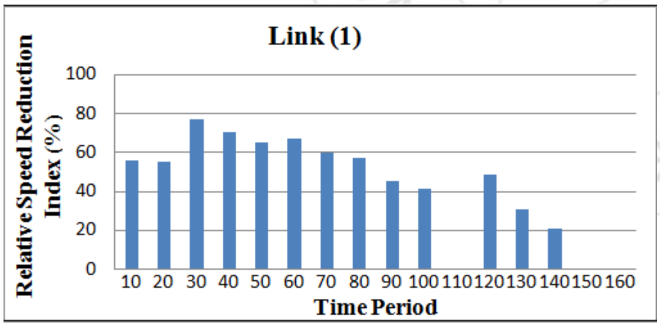


Figure 10: Relative Speed Reduction (%) Index for Link (1)

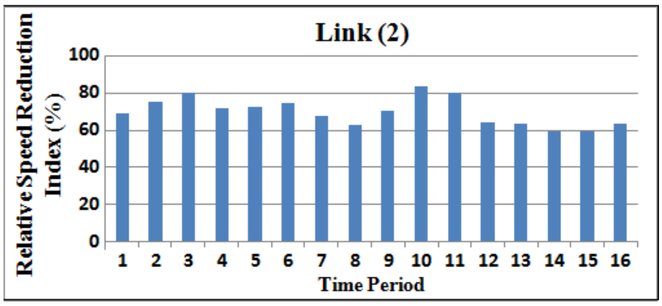


Figure 11: Relative Speed Reduction (%) Index for Link (2)

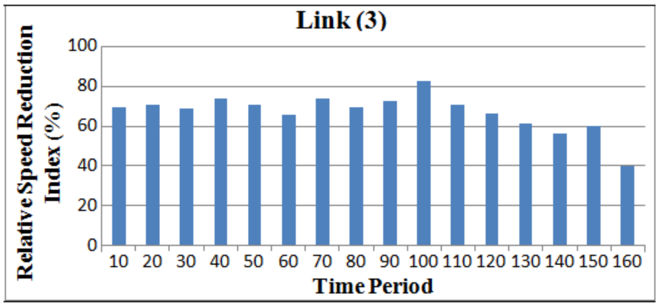


Figure 12: Relative Speed Reduction (%) Index for Link (3)

5.1.2 Pollutions Emissions

Air pollution become one of the most risks threaten people health. From environmental aspect point view cars including passenger car and trucks are major contribution for pollutions through vehicle operations. Hydrocarbons (HC), Nitrogen oxide (NOx), Carbone monoxide (CO), and Sulfur dioxide (SO2), particulate matter and Greenhouse gases are major pollution emitted to air by motor vehicle. As obtained from the collected field data for average travel speed for Palestine street, vehicles for all link studied in this research have low speed operation during the peak time period from 12:00 to 4:00 p.m. below (20 km/hr) and greater than (10 km /hr) as seen from Figures (1), (2) and (3). 85% percentile speed about 16.82 km/hr for link(1) which mean that 85% of all users traveled at 16.82 km/hr during the peak period. Also the 85% percentiles speed were 15.9 km/hr and 18.7 km/hr for link(2) and (3) respectively. Air Pollution increased due to traffic congestion and the low speed of vehicles.

5.1.2.1 Fuel Consumption

For describing congestion impacts considering fuel consumption models which are mathematical models relates different factors contributing to fuel consumption such as vehicle average speed, distance travelled by vehicle ,delay travel time including no. of stops. In this research average travel speed is considered as the major influencing factor for the adopted fuel consumption model [7] :

$$F = k_1 + \frac{k_2}{v} \qquad (3)$$

where:

F: fuel consumed per vehicle per unit distance (litres/km).

k_1: parameter associated with fuel consumed to overcome rolling resistance, approximately proportional to vehicle weight (litres/veh- km).

k_2 : Parameter approximately proportional to fuel consumption while idling (litres/hr)

v: average speed measured (Km/hr).

Figures (13) , (14) and (15) below depicts the emissions rate in Litres per distance travelled per vehicle during peak and non peak period for the three links studies in this research. The results presented high emissions rate during the peak evening period for all links from 12:00 to 4:00 p.m. and then reduced to rise again at the evening peak period from 5:00 to 8:00p.m.

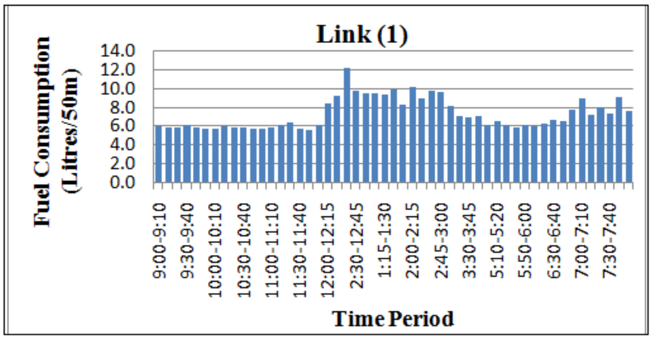


Figure 13: Emissions Rate versus Time Period for Link (1)

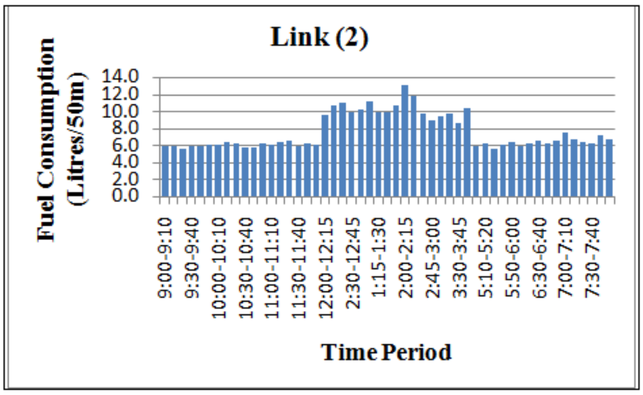


Figure 14: Emissions Rate versus Time Period for Link (2)

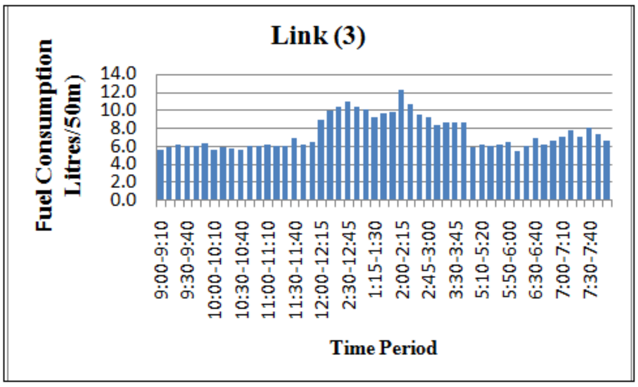


Figure 15: Emissions Rate versus Time Period for Link (3)

5.1.3 Cost

The third categories for sustainability measurement in this research is the vehicle cost with emphasis on the vehicle operating cost. Due to congestion effect that results in a significant reduction of vehicle speed as shown in the obtained results from survey data clarified the change in operating cost of vehicles. And based on this fact; average travel speed is considered as indicator for sustainability measurement.

5.1.3.1 Vehicle Operation Cost

Variation of vehicle cost using the arterial street is estimated using survey data for average travel speed. The average operating cost per kilometre for each link are calculated based on the following equation :

$$V.O.P = 2.05 + \frac{26.5}{V} + 0.000058\ V^2 \qquad (4)$$

Figure (16) shows how the change in travel vehicle speed affect the operating cost which raised during peak period due to the reduction change in vehicle speed for all studied links in Palestine street. A 12.6 average unit cost per Km for Link(1) obtained at time period from (12-1) p.m while for links (2) and (3) were 13 , 12.32 average unit cost per Km at (2-3) p.m. respectively.

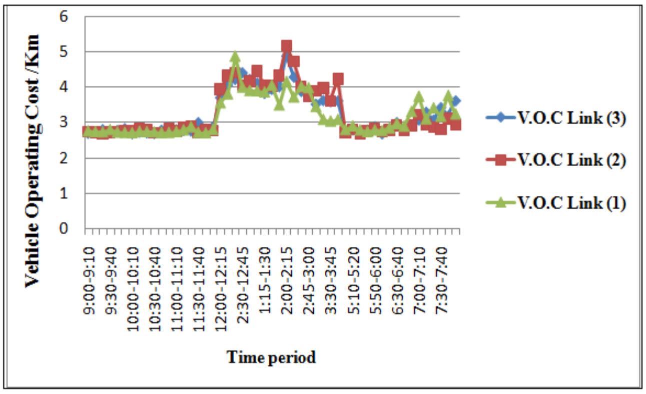


Figure 16: Vehicle Operating Cost per Kilometer

5.1.4 Scio-Economic Impact

The social economic life in the neighborhood area of street affect the potential of social activity on the street . Also the great peoples migration for living and working in Palestine street area in the last recent years is a clear indicator of high potential for social and economic activity. Also the type of mix land use (residential, educational, recreational, medical, commercial, shopping centers schools and malls) in the study area (Al-Mustansiriyah square and 14th Tammoz) residential area surrounded Palestine street) and easy accessibility for different necessary daily trip purposes provide attraction area for liveability and social communication better for peoples.

Liveability and land use and transportation accessibility considered as one of the categories indicators that stated for sustainability measurement in this research. A user satisfaction is important for this part of research so a questionnaire sheet presented in Table (6) is developed and distribute on people living in the study area and commuter user of arterial Palestine street to obtain individual' opinion as score for the scio-economic indicator. A 50 sample sheet was distributed to the commuter people to investigate the information about the overall satisfactions level for the performance of Palestine arterial street. Thirteen categories parameters were asked to rate the level f satisfaction from accepted (rating 5) to totally unacceptable (rating 1) rate as shown in Table (6); A sample sheet is given in Appendix A. The obtained results for percentage of rating for commuter questioner for Palestine street and parameters are displayed in Table (6). The results of survey illustrated the dissatisfaction of people opinion about congestion, road quality pollution, parking facilities, pedestrian facilities, public transportation and delay due to stopped vehicle. In order to quantity the commuter satisfaction opinion based on categories parameter mention above a **U**ser **S**atisfaction **I**ndex estimated (USI) as an indicator for sustainability requirements that should be achieved by the objective of this research. The USI calculation is shown in Table (7), the higher level for each parameter is 5 and for sustainability requirements that need maximum satisfaction for all 13 parameters considered in this research for commuter opinion; maximum level (5) is considered for each parameters and hence the weight of each parameter had been the same of (0.077). Also the weight of each parameter and USI is shown in Table (7). The overall USI user satisfaction index was 2.109 which is about 42.18 % percent and that mean a user satisfaction is less than 50 % percent , and demonstrated that the Palestine arterial street is unsustainable as far the social commuter opinion aspect is taken in consideration.

Table 6: The Results of Percentage Rating for Parameters of Commuter Satisfaction Questioner

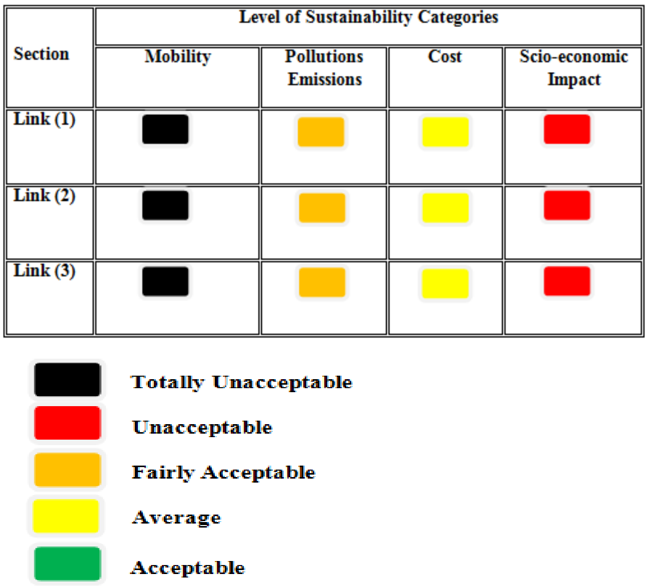
	Totally Unacceptable (%)	Fairly unacceptable (%)	Average (%)	Fairly acceptable (%)	Acceptable (%)
Pollution	56	32	12	0.0	0.0
Congestion	62	34	4	0.0	0.0
Parking	50	8	36	0.0	6
Public Transportation	38	28	20	0.0	14
Pedestrian Facilities	56	28	11	5	0.0
Road Quality	84	0.0	14	2	0.0
Delay due to speed of vehicle	64	24	12	0.0	0.0
Noise	46	22	24	4	4
Aesthetics	24	40	30	6	0.0
Location of different Land use close to others	16	42	22	10	10
Historical road , site protection	66	24	8	2	0.0
Land Use attraction	0.0	2	10	0.0	88
Accessibility to transportation	12	10	62	8	8

Table 7: The Results of Weighted Parameters and User Satisfaction Index (USI)

Parameters Categories	Average score	Weighting Factor	User Satisfaction Index
Pollution	1.56	0.077	0.120
Congestion	1.38	0.077	0.106
Parking	2.04	0.077	0.157
Public Transportation	2.24	0.077	0.172
Pedestrian Facilities	1.65	0.077	0.127
Road Quality	1.34	0.077	0.103
Delay due to speed of vehicle	1.48	0.077	0.114
Noise	1.98	0.077	0.153
Aesthetics	2.18	0.077	0.168
Location of different Land use close to others	2.46	0.077	0.189
Historical road , site protection	1.46	0.077	0.112
Land Use attraction	4.74	0.077	0.365
Accessibility to transportation	2.9	0.077	0.223
Total			2.109

Also Table (8) below presents summary output for sustainability indicators estimation.

Table 8: Summary Level of Palestine Arterial Street



6. Application of Intelligent Transportation System on Arterial Performance

Based on the previous analysis results for sustainability indicators of mobility , congestion index, emissions rate and vehicle operating cost, for Palestine arterial street and to provide a sustainable solution for the congestion issue observed in the case study instead of classic improvement method of widening lane or at grade intersection which had been applied to solve many traffic congestion problems of road network in Baghdad city and most of these solution dose not solve the intrinsic traffic congestion problems that Baghdad city face it in the last 15 years.

Application of intelligent transportation system to arterial system to enhance significantly traffic operation efficiency and to improve mobility and increase the average speed.

The ITS strategies would be most useful to improve arterial management. Arterial management elements is used to manage traffic and reduce congestion index and improve traffic operation through technologies within the arterial network, such as dynamic messages signs or highway advisory radio. ITS operators may also send information to in-vehicle devices capable of displaying traveler information. Coordination with regional or multimodal traveler information efforts, as well as freeway and incident management programs, can increase the availability of information on arterial travel conditions which provide improvement by increasing the average travel speed by (16-33)% ,[8].

In this research a value within the range (16-33)% is selected to simulate the application of ITS of advanced signal system. Figure (17) to (19) illustrated the effect of ITS on increasing travel speed and consequently result in the reduction of congestion index in Figure (20) to (21) for Link (1), (2) and (3) respectively. The results obtained from analysis field data provide the application of ITS improve the traffic speed operation for Link (2) and (3) significantly by about 9% and

10% respectively but show insignificant negative impact traffic speed for Link (1), due to the fact that link(1) provide shifting for traffic flow diversity before entering link(2) and link(3). As mention earlier Palestine arterial street have accessibility opportunity for diverging flow to lateral minor street connectors on the contrary of other major arterial street in Baghdad city which provide block conditions if accidents or suddenly check point occurred due to security conditions in Baghdad city. That demonstrated the useful application for ITS to reduce congestion and improve traffic operation efficiency.

Another benefit of arterial ITS is the positive effect on environment, as shown in Figure (22) and (23) which depicted by the reduction in fuel consumption rate by about (8% ,9% and 6.8%) for Link (1), (2) and (3) respectively during the peak period. Furthermore positive impact on vehicle operating cost is shown in Figure (24) and (25) by reduction factor of (9.09%, 6.47% and 6.06%) for Link (1), (2) and (3) respectively.

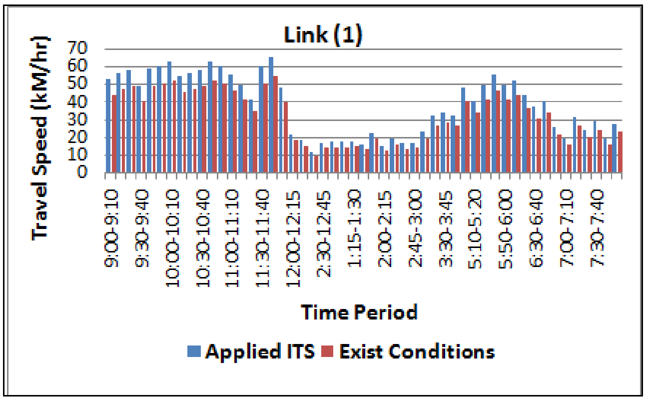


Figure 17: Effect of ITS Application on Average Travel Speed for Link (1)

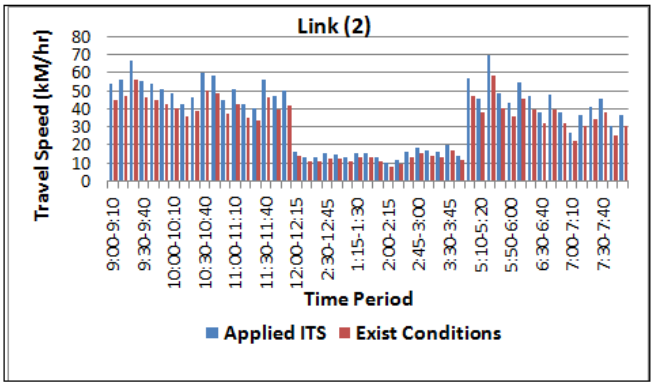


Figure 18: Effect of ITS Application on Average Travel Speed for Link (2)

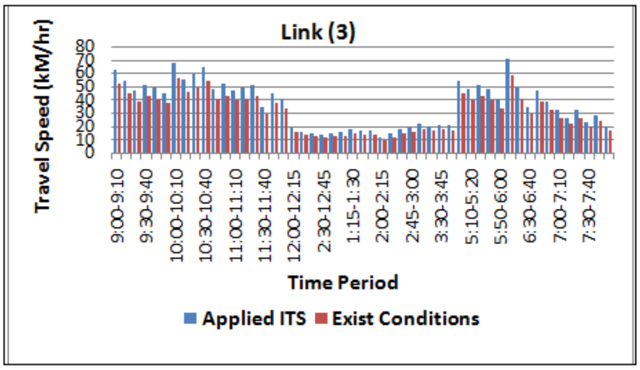


Figure 19: Effect of ITS Application on Average Travel Speed for Link (3)

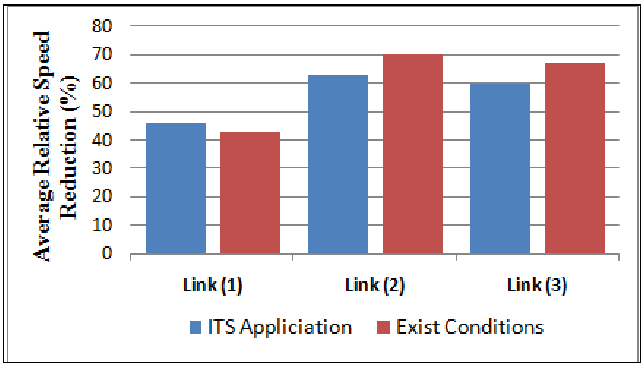


Figure 20: Effect of ITS Application on Relative Speed Reduction (%)

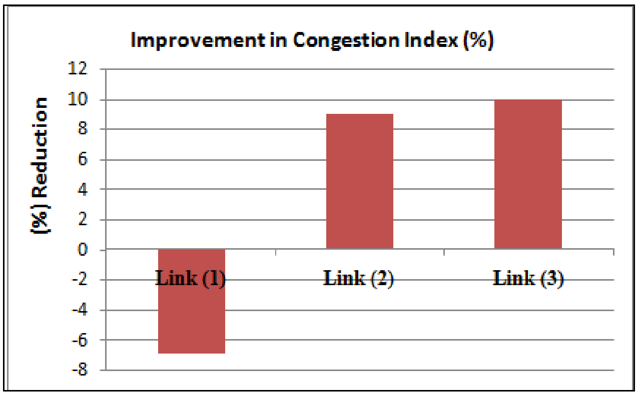


Figure 21: Effect of ITS Application on (%) Reduction of Congestion Index for Link (1), (2) and (3).

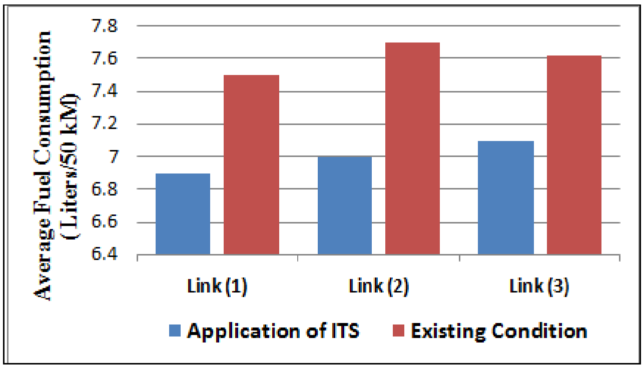


Figure 22: Effect of ITS Application on Fuel Consumption for Link (1), (2) and (3)

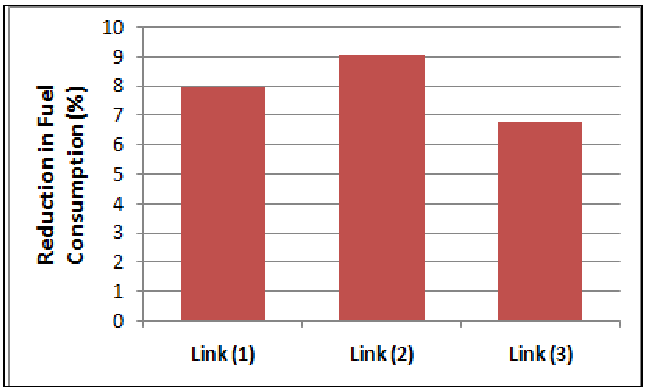


Figure 23: Effect of ITS Application on Reduction of Fuel Consumption for Link (1), (2) and (3)

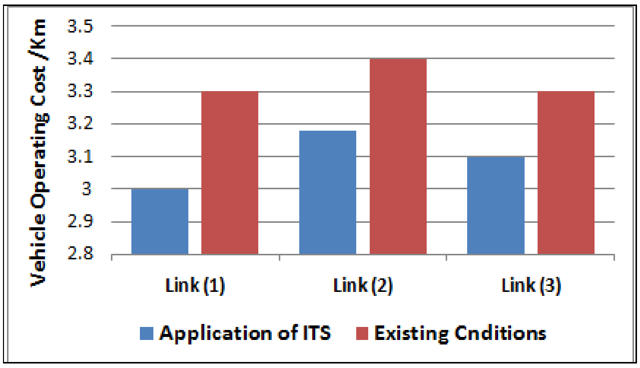


Figure 24: Effect of ITS Application on Reduction of Vehicle Operating Cost / Km for Link (1), (2) and (3)

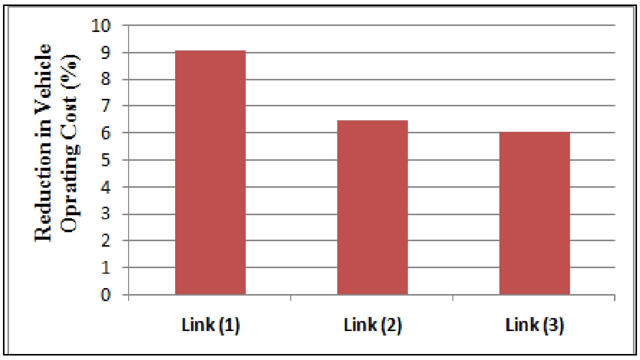


Figure 25: Effect of ITS Application on Reduction of Vehicle Operating (%) for Link (1), (2) and (3)

General Point Observed in the Study Area by the Researcher Survey

It's obvious the analysis results for the study area, traffic congestion and delay due to reduction an travel speed make people unsatisfied due wasting valuable time for daily trips also higher fuel consumption result in poor air quality. At evening period from 4:00 to 8:00 traffic jam again rise and reduction in travel speed, excess delay negatively affect mobility and social activity of people. Also parking vehicles on street side near shopping center due to lack of parking availability produced excess congestion on arterial street. The survey of the study area showed that most of the shopping centers and Malls along Palestine street and specially for link(1), are constructed the buildings without standard consideration for parking construction. This wrong strategy produce negative effect for mobility and traffic conditions in the study area; since parking is one major critical problem in Baghdad city generally and the study area particularly. These forced people to park on road side which produce conflict with pedestrian and the other traffic vehicle on street. This one of big critical problems in the study area especially in the evening peak period from 4to 8p.m.

Also the shopping building malls and centers used the curbs which specialized for pedestrian to park people illegally; which intern affect adverse on path for pedestrian and make walking in efficient to use by people. Another important factor seen from surveying is pedestrian facilities, as mention previously for walking path for pedestrian is negatively affected but for crosswalk Palestine street for all link provided with curbs 4 for link(1) and 3 for Link(2) and (3) respectively although we can considered as crosswalk but people waiting long time to cross the street since its depend on the corporation of vehicle driver to permit people to cross. Although there are three bridges for pedestrian crossing but its unsafe to use by people due to poor maintenance and for security reasons. Indeed great attention must give to maintenance for these bridges to be safe for pedestrian use to reduce accidents for pedestrian crossing street.

Another point observed the absence of public transportation bus in the study area. Since there was bus line (79) available from Bab -AL-Mutham station to New Baghdad Station in the last years ago.

The attitude behaviour of people and community is traveling faster in their own car than public transportation and even walking; and based on the survey of study area most people traveled by car to bring the simple daily needs which result in negative effect of traffic conditions and inconvenient to all people within urban city and convert the area to car dependent and poorly for walking, cycling even the study area is land use mix as explained earlier.

Finally, it can be said that for sustainability of road transportation to reduce congestion, air pollutions, economic cost is not achieved by design with sustainability requirements only but also by educated peoples to change their attitude behaviour aspect as a whole community live within and understanding the transportation concept so they can provide actions to minimize recourses needs and then reduced negative impacts.

7. Conclusions

The research presents the sustainability indicators for transportation road and their implementation in arterial street for investigation and evaluation of performance measures progress toward sustainable arterial roads. The following points can be drawn:

1. The reduction of speed due to the traffic congestion that appeared during sharp peak congestion period from (12:00 to 3:00 p.m.) and also another less pounced congestion period illustrated from (4:00 to 8:00 p.m.) for all the observed links respectively. A higher speed reduction due to congestion

effects from 12:00 to 4:00 p.m. which provide negative impact on mobility for traffic vehicle.

2. The congestion index for RSR (%) results illustrated there was a maximum reduction about 78% ,83% and 82.8% for link(1),(2) and (3) respectively. The weighted relative speed reduction for three links covering the whole distance length from link1 to the end of link3 is about (0.58).

3. 85% percentile speed about 16.82 km/hr for link(1) during the peak period. Also the 85% percentiles speed were 15.9 km/hr and 18.7 km/hr for link(2) and (3) respectively. Air Pollution increased due to traffic congestion and the low speed of vehicles and produce high emissions rate during the peak evening period for all links from 12:00 to 4:00 p.m. and then reduced to rise again at the evening peak period from 5:00 to 8:00p.m.

4. The operating cost raised during peak period due to the reduction change in vehicle speed for all studied links in Palestine street. A 12.6 average unit cost per Km for Link(1) obtained at time period from (12-1) p.m while for links (2) and (3) were 13 , 12.32 average unit cost per Km at (2-3) p.m. respectively.

5. The overall USI user satisfaction index was 2.109 which is about 42.18 % percent which demonstrated that the Palestine arterial street is unsustainable as far the social commuter opinion aspect is taken in consideration.

6. The results obtained from analysis field data provide the application of ITS improve the traffic speed operation for Link (2) and (3) significantly by about 9% and 10% respectively but show insignificant negative impact traffic speed for Link (1), due to the fact that link(1) provide shifting for traffic flow diversity before entering link(2) and link(3). Another benefit of arterial ITS is the positive effect on environment, as depicted by the reduction in fuel consumption rate by about (8% ,9% and 6.8%) for Link (1), (2) and (3) respectively during the peak period. Furthermore positive impact on vehicle operating cost is by reduction factor of (9.09%, 6.47% and 6.06%) for Link (1), (2) and (3) respectively.

7. Design with sustainability requirements to reduce congestion, ail pollutions, economic should be harmonically coordinated with education peoples to change their attitude behavior aspect as a whole community live within and understanding the transportation concept so they can provide actions to minimize recourses needs and then reduced negative impacts.

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