Advances in Research
7(3): 1-16, 2016, Article no.AIR.26153
ISSN: 2348-0394, NLM ID: 101666096

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The Impact of Intersection Geometry and Control Type on Fuel Consumption Cost at Various Types at the Level of Service

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AMA and MAB proposed the research plan, and reviewed the manuscript. Author AK analyzed the results of the study, processed the calculations and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2016/26153
Editor(s):
(1) Enedir Ghisi, Federal University of Santa Catarina, Department of Civil Engineering, Florianópolis-SC, Brazil.
Reviewers:
(1) Marco Guerrieri, University of Enna “Kore”, Italy.
(2) Dipak Kumar Sahoo, Iowa State University, USA.
(3) Yordanka Tsankova Tasheva, University "Prof. Assen Zlatarov", Bulgaria.
Complete Peer review History: http://sciencedomain.org/review-history/14874

Original Research Article

Received 3rd April 2016
Accepted 25th May 2016
Published 2nd June 2016

ABSTRACT

Aims: As motor vehicle volumes increase around the globe, further pressure is placed on limited financial budgets to fund projects that address traffic congestion on the road networks. This research aims at studying the traffic impact and financial resulted from the traffic congestion on the urban road networks.
Study Design: Through the study of the intersection geometry and control type impact on fuel consumption cost at different levels of service for roads.
Place and Duration of Study: Benha Faculty of engineering, Benha university, Egypt. Between November 2013 and Feb 2016.
Methodology: The Sidra Intersection program was used to calculate the fuel consumption rate, cost of fuel and total cost of the different intersection geometry.

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Results: Conclusion some relationships which illustrate the effect of the intersection geometry and control type impact on fuel consumption cost at different levels of service for roads.
Conclusion: We can decrease the fuel consumption rate, cost of fuel and total cost at different number of lanes due to various of intersection control type by improving levels of service for roads from F to A.

Keywords: Intersection geometry; control type; fuel consumption; level of service.

1. INTRODUCTION

In order to achieve best funds allocation, accurate predictions of the various alternative projects are required. The analysis of congestion has traditionally been confined to either the simplistic concept of increased flows resulting in decreased speeds and increased travel times or the highly complex use of traffic assignment and micro-simulation models. The simplest models are often disregarded as being too unsophisticated to warrant use in heavily congested conditions, while the full-scale simulations require so much data to calibrate, that they are unwarranted for many day-to-day projects.

Fuel consumption is a significant component of vehicle operating cost (VOC), typically accounting for between 20 and 40 per cent of the total VOC. It is influenced by traffic congestion, road condition and alignment, vehicle characteristics and driving style, so it is sensitive to virtually any investment decisions on the road network.

Sidra intersection model to establish the additional fuel consumption due to traffic congestion. The vehicles were simulated travelling along an idealized section of road at different levels of congestion. As the congestion increased, so did the acceleration noise and thus the fuel consumption.

Congestion is one of the major pre-occupation of urban decision-makers. A quick scan of policy statements from across urban cities highlights the importance of congestion to the public, elected officials road and transport administrations in many urban areas.

Congestion prevents us from moving freely and it slows and otherwise disrupts the conduct of business within urban areas. These benefits can be delivered either through speed or through greater proximity. Congestion may affect travel speed, but in some circumstances, such as dense urban cores, congestion may both be expected and, to some degree, accepted. In these cases, cities have come to accept a degree of congestion and continue to get along relatively well as long as overall accessibility is high [1].

This is not to say that cities should not proactively and vigorously address growing congestion – they should, especially in cases where congestion can be linked to specific traffic bottlenecks and cost-effective measures are available. However, in the long run, what matters most for policy is how congestion can be managed such that the beneficial outcomes of agglomeration are not eroded unacceptably by the negative impacts of congestion [2].

Measuring congestion is a necessary step in order to deliver better congestion outcomes. However, congestion should not be described using a single metric for policy purposes.

These two aspects cannot be disassociated and progress in managing congestion should be based on sets of indicators that capture both these aspects [3].

Good indicators can be based on a wide network of roadway sensors, but simple indicators based on less elaborate monitoring can sometimes adequately guide policy. What is important is to select metrics that are relevant to both road managers (e.g. Speed and flow, queue length and duration, etc.) and road users (e.g. Predictability of travel times, system reliability, etc.).

These may capture the variance in travel times or, alternatively, communicate the amount of time buffers road users have to include in their travel plans to make their trips “on time”. Insofar as these reliability indicators give an understanding of the quality of travel conditions, they are important to policymakers seeking to address the qualitative aspects of congestion [4].

Effective congestion management policies should seek to understand the nature of travel demand in congested conditions. While commuting trips may be a key factor, it is important not to overlook other types of peak-hour trips, including school runs, leisure, travel and freight travel that often make a substantial contribution to traffic in peak periods [5].

This study presents a methodology for the evaluation of traffic congestion within the highway evaluation context, wherein the trade-off between accuracy of prediction and simplicity of application of methods needs to be made.

Approximately 47 billion LE, or 8 billion USD, are wasted every year in the GCMA due to congestion; this is expected to increase to 105 billion LE by 2030. With Egyptian's GDP estimated at USD 229.5 billion in 2011, the economic costs of congestion in GCMA are estimated at about 3.6 percent of Egypt's total GDP. Assuming that the burden of this cost is primarily distributed across a population of 19.6 million people living in GCMA, this results in a per capita cost of about LE 2,400 (USD 400). And represents about 15 percent of their GDP per capita, estimated at USD 2,700 in 2010 by the World Bank. The relative share of congestion cost is also expected to continue to rise through 2030 unless proper actions are taken.

The single largest driver of costs is delayed costs, which represents 31 percent of the total costs. If we add the costs associated with the lack of reliability, the extra time travelers need to build into their trip, to the costs of delay, the value of wasted time constitutes 50 percent of the costs of congestion in the GCMA.

Emissions of carbon monoxide (CO), volatile organic compounds, nitrous oxide (NOx), and particulate matter (PM10), are the second largest contributor to congestion costs, largely due to their impacts on public health and the environment. Though smallest in terms of actual volume of pollutant, PM10 comprises 82 percent of emissions costs due to its high impacts on human health. CO2 contributes a relatively small amount to total costs (about 1 percent).

Wasted fuel is another contributor to costs, both in terms of its cost to the government due to the subsidy and the direct cost to users. Agglomeration and business productivity losses that can be linked to congestion constitute 11 percent of costs. Suppressed demand and the impacts on demand for housing together constitute about 3 percent of total costs. Finally, congestion helps to improve the safety situation in the GCMA due to lower speeds and hence lower fatalities, reducing the cost of road safety by 0.5 billion LE (see Fig. 1).

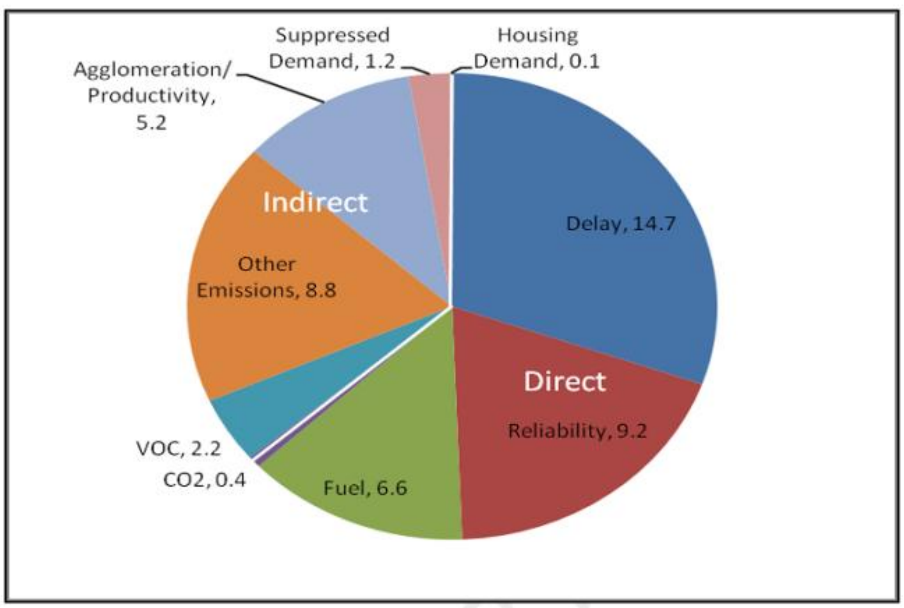


Fig. 1. Direct and indirect costs in 2010 (Billion LE)

2. STUDY MOTIVATION

Traffic congestion is a serious problem in the Cairo metropolitan area with substantial adverse effects on personal travel time, vehicle operating costs, air quality, public health, business environment and business operations.

3. RESEARCH OBJECTIVES

The main objective of this research is to develop fuel consumption model for use in highway evaluation projects, which can estimate the impacts of traffic congestion and the marginal benefits of operational changes.

The secondary objective is to have a new modeling framework that significantly improves the predictive capability in comparison with traditional steady speed models, yet does not require the significant and detailed modeling associated with micro-simulation models.

4. SCOPE OF WORK

Delays in road networks mainly center on intersections, areas where the capacity of the links equal to six times the capacity of the intersection of the same axis capacity. Therefore, this study focused on the intersections because they are the most effective and focused on urban mobility because it represents the biggest problem in Greater Cairo.

Two investigated types of intersection at different levels of service for roads using the Sidra Intersection program to calculate the (fuel consumption - cost of fuel-total cost which include total vehicle operating and time cost) as shown in Fig. 2.

Increasing the number of lanes in the intersection approach reduce the queue length and delay time, which leads to smaller Shockwave time.

5. STUDY ASSUMPTIONS

To use the Sidra Intersection program, some parameters should be stated as inputs. Table 1, shows the assumed parameters based on the Egyptian data by expert system.

The six common levels of service from A to F are referred in the equations of this study by the numbers from 1 to 6 respectively. The equations derived in this study on the basis of the Egyptian data by expert system. It is possible to neglect results in the case of service levels (A & F), this is because they have no boundary limits. In this study, there is no specified number of vehicles incoming or outgoing from any intersection or any specified description of the intersection and the layout because in this study assumed data were used to reach a certain level of service and logic simulation in Fig. 3 some examples of intersection geometry.

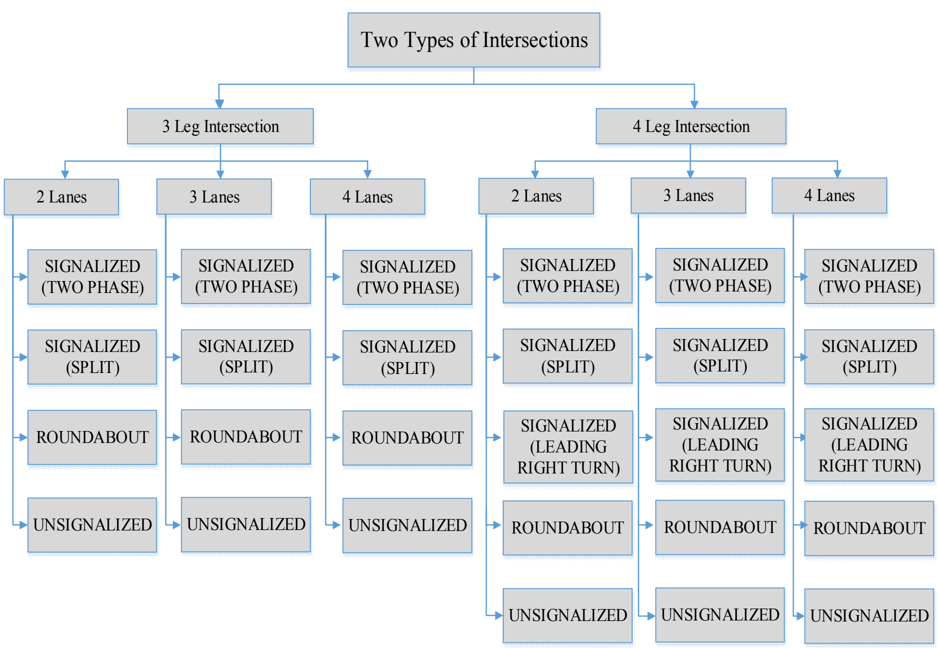
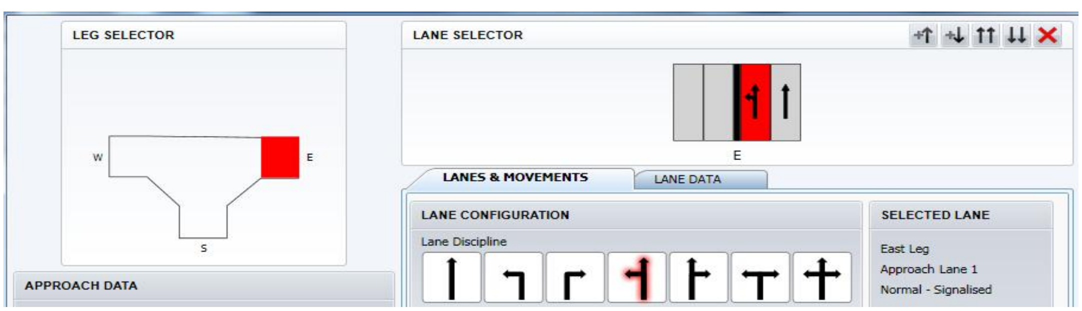
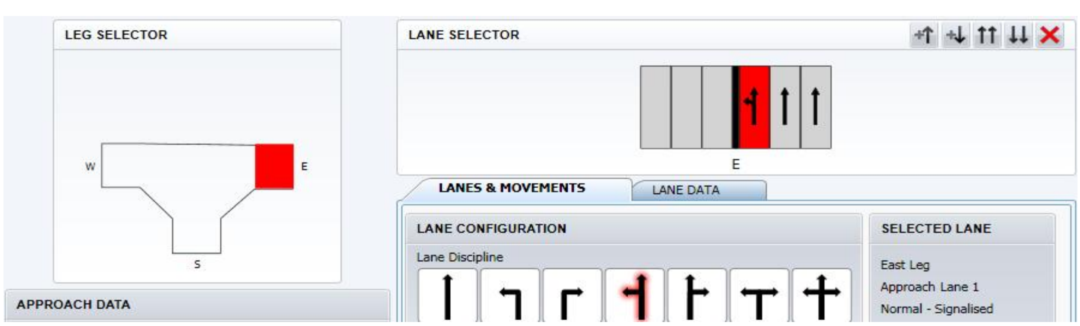


Fig. 2. Types of intersection

Table 1. Assumed input parameters for the sidra intersection program

Item		Assumed value
Intersection data	**Signal analysis method**	**Fixed-time/Permitted**
Volume data setting	Unit time for volume	60 minutes
	Peak flow period	15 minutes
Lane data	Lane type	Normal
	Lane length	500 meters
	Lane width	3.6 meters
	Grade	0.0%
Volume data	Heavy vehicle	0.0%
	Peak flow factor	90%
	Vehicle occupancy	1.2 per/veh
	Growth rate	2.0% / year
Movement path data	Approach cruise speed	60 km/hr
	Exit cruise speed	60 km/hr
	Approach travel distance	500 m
Movement data	Queue space (LV)	7.6 m
	Queue space (HV)	14 m
	Vehicle length (LV)	5.1 m
	Vehicle length (HV)	11 m
Vehicle operating cost	Pump price of fuel	2.24 cost unit / liter (Egyptian unit)
	Fuel resource cost factor	0.625 (Egyptian unit)
	Ratio of running cost to fuel cost	3 (Egyptian unit)
Time cost	Average income	13 cost unit / hour (Egyptian unit)
	Time value factor	0.85 (Egyptian unit)
Cycle time options	Signals	Fixed time
	Cycle time (fixed time)	40 seconds (user given phase time)
	Yellow time	3 seconds
	All-red time	1 seconds





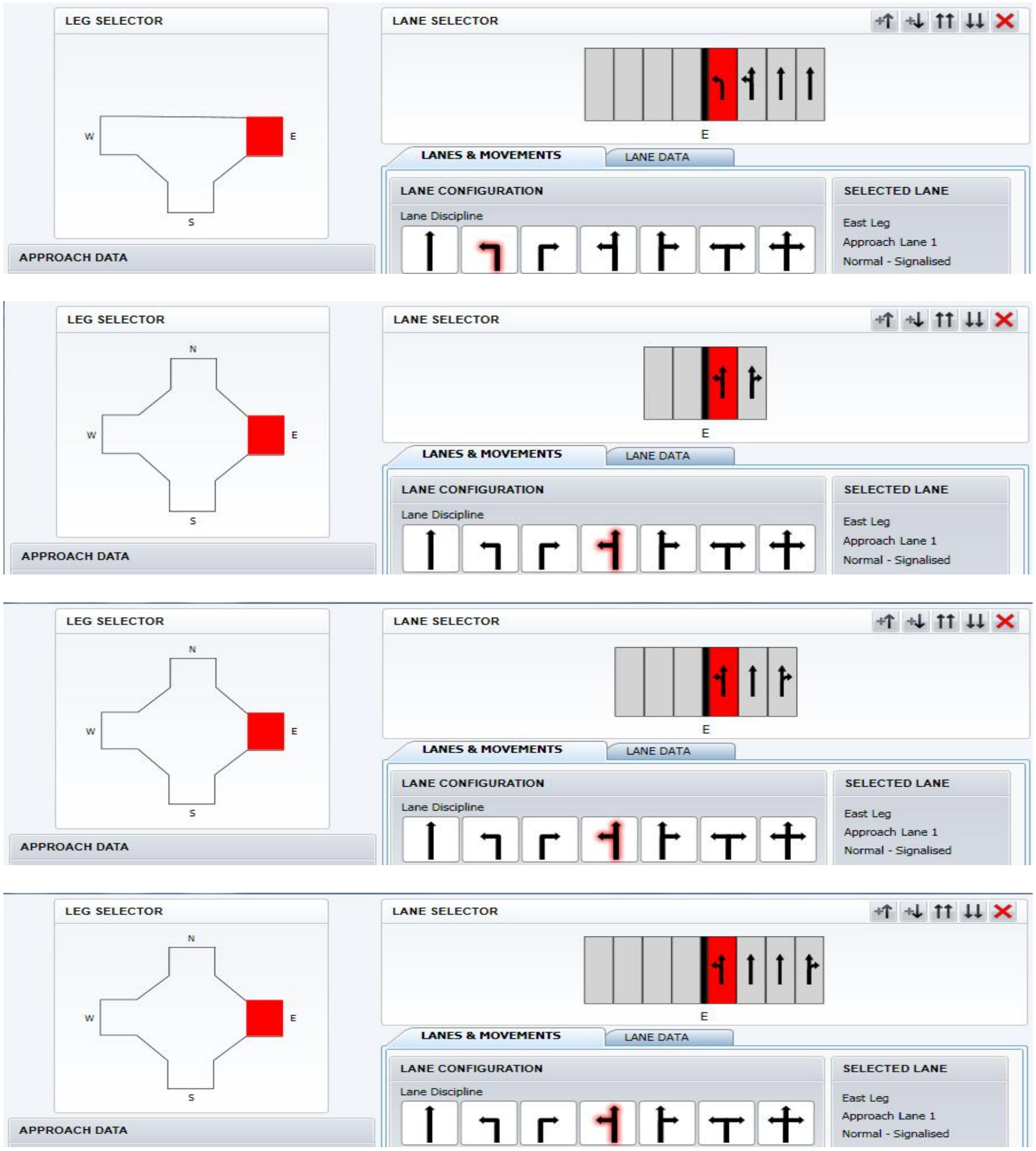


Fig. 3. Examples of intersection geometry

6. SIDRA INTERSECTION SOFTWARE

The Sidra intersection software is for use as an aid in the design and evaluation of signalized intersections (fixed-time /pretimed and actuated), signalized pedestrian crossings, single point interchanges (signalized), roundabouts, roundabout metering, two-way stop sign control, all-way stop sign control, and give-way / yield sign-control [6].

Sidra intersection is an advanced micro-analytical traffic evaluation tool that employs lane-by-lane and vehicle drive-cycle models coupled with an iterative approximation method to provide estimates of capacity and performance statistics (delay, queue length, stop rate, etc.).

Sidra intersection traffic models can be calibrated for local conditions. Sidra intersection provides various facilities for this purpose. The US HCM version of Sidra intersection is based on the calibration of model parameters against the US Highway Capacity Manual [7,8].

Analyze a large number of intersection types including signalized intersections (fixed-time / pretimed and actuated), signalized pedestrian crossings, single point interchanges (signalized), roundabouts, roundabout metering, two-way stop sign control, all-way stop sign control, and give-way / yield sign-control [9,10,11,12].

Obtain estimates of capacity and performance characteristics such as delay, queue length, stop rate as well as operating cost, fuel consumption and pollutant emissions for all intersection types [13,14].

Analyze many design alternatives to optimize the intersection geometry, signal phasing and timings specifying different strategies for optimization.

Determine signal timings (fixed-time / pretimed and actuated) for any intersection geometry, allowing for simple as well as complex phasing arrangements.

Analyze oversaturated conditions, making use of the time-dependent delay, queue length and stop rate models used in Sidra intersection.

Carry out sensitivity analyses to evaluate the impact of changes on parameters representing intersection geometry and driver behavior [15].

Calibrate the parameters of the operating cost model for your local conditions allowing for factors such as the value of time and resource cost of fuel.

The total operating cost for vehicles, Ct in "Cost Unit" per hour, e.g. $/h, can be calculated from:

$$Ct = ko\ Ft / 1000 + kt\ Tt \qquad (1)$$

Where Ft = total fuel consumption (mL/h), Tt = total vehicle travel time (veh-h/h), and ko and it are determined from special Equations by Sidra software.

Delays obtained using the path-trace method agrees with the queue sampling method of measurement for low to medium degrees of saturation (v/c ratios), but the difference between the two methods is significant for oversaturated conditions (degree of saturation > 1). For more detailed information, refer to Akçelik (1981, 1988b, 1990a,b, 1996a,b); Akçelik and Chung (1994b); Akçelik and Rouphail (1993, 1994); Brilon and Wu (1990); Rouphail and Akçelik (1992).

The Sidra intersection output includes Level of Service (LOS) results based on the basic concept described in the US Highway Capacity Manual (HCM) and various other publications. As specified by HCM, Sidra intersection uses the average control delay as the LOS measure for vehicles at signalized and un signalized intersections (TRB 2000, 2010). The default method used when a new Site is created differs according to the model used: Delay & v/c (HCM 2010) for US HCM Customary and Metric models.

7. RESULTS AND DISCUSSION

Three and four leg intersections are considered in this study. Figures from (4 to 23) present the output data by Sidra software based on the input values stated in the research. Since the levels of service A and F have no specified boundary limits we consider the remaining levels in discussion.

7.1 Four Leg Intersections

There are five cases of control type they are from case 1 to case 5 respectively: signalized(two phase), signalized(split), signalized(leading right turn), roundabout; and unsignalized.

The relation between fuel consumption (liters/hr) & number of lanes at different cases of control type and different levels of service. Figs. (4 through 8) are constructed. From the figures it is clear that the fuel consumption due to various types of intersection control and levels of service for different number of lanes indicates that the saving in fuel consumption due to improving level of service is computed by the formula:

$$\text{Saving in fuel consumption} = [1 - (0.65 : 0.85)^{\text{Los computed} - \text{Los targeted}}] * \text{fuel consumption computed} \qquad (2)$$

The relation between total cost which include total vehicle operating and time cost (egp/hr) & number of lanes at different cases of control type and different levels of service. Figs. (9 through 13) are constructed. From the figures it is clear that the total cost which include total vehicle operating and time cost due to various types of intersection control and levels of service for different number of lanes indicates that the saving in total cost due to improving level of service is computed by the formula:

$$\text{Saving in total cost} = [1 - (0.65 : 0.85)^{\text{Los computed} - \text{Los targeted}}] * \text{total cost computed} \qquad (3)$$

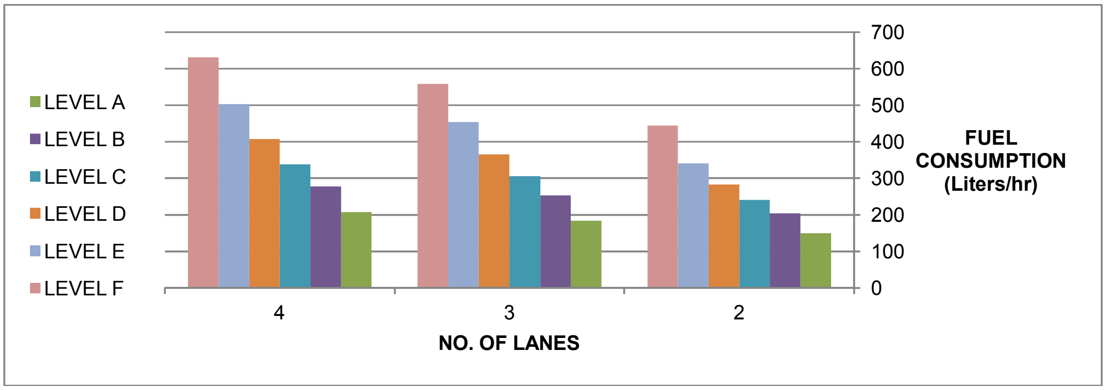


Fig. 4. The relation between fuel consumption (liters/hr) and the number of lanes at case 1 of control type (signalized-two phase) at different levels of service

It can be noted that the improving level of service from E to D resulted in fuel reduction by about 18%. On the other hand to enhance the level E to levels C and B resulted in fuel reduction by about 32% and 43% respectively

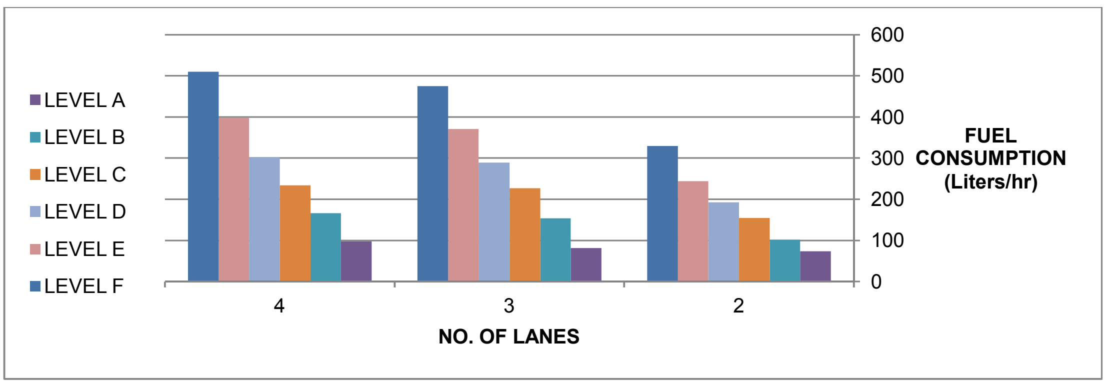


Fig. 5. The relation between fuel consumption (Liters/hr) and the number of lanes at case 2 of control type (signalized-split) at different levels of service

It can be noted that the improving level of service from E to D resulted in fuel reduction by about 22%. On the other hand to enhance the level E to levels C and B resulted in fuel reduction by about 39% and 58% respectively

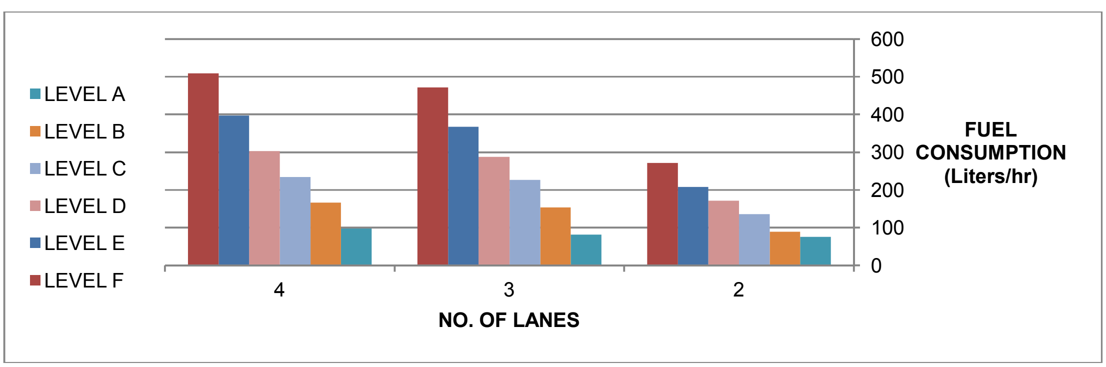


Fig. 6. The relation between fuel consumption (liters/hr) and the number of lanes at case 3 of control type (signalized- leading right turn) at different levels of service

It can be noted that the improving level of service from E to D resulted in fuel reduction by about 21%. On the other hand to enhance the level E to levels C and B resulted in fuel reduction by about 38% and 58% respectively

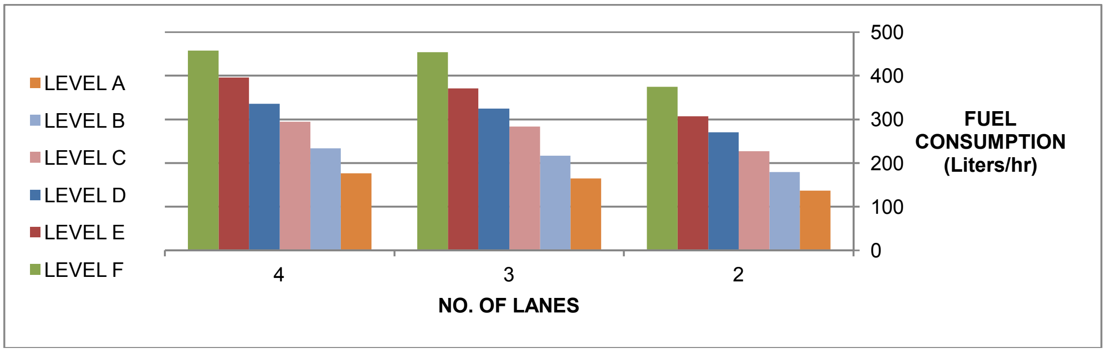


Fig. 7. The relation between fuel consumption (liters/hr) and the number of lanes at case 4 of control type (roundabout) at different levels of service

It can be noted that the improving level of service from E to D resulted in fuel reduction by about 17%. On the other hand to enhance the level E to levels C and B resulted in fuel reduction by about 25% and 41% respectively

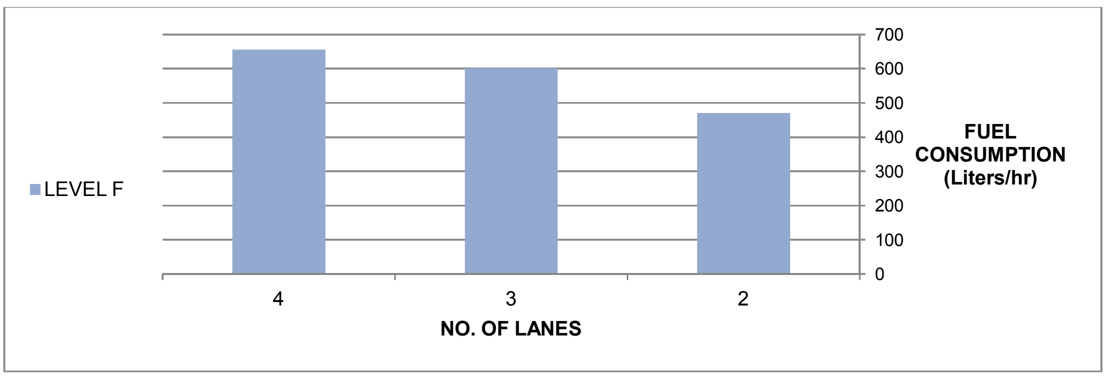


Fig. 8. The relation between fuel consumption (liters/hr) and the number of lanes at case 5 of control type (unsignalized) at different levels of service

This means whenever the level of service is improved to better lead to a significant reduction in the fuel consumption and that this reduction is more than worth the higher level of service improvement

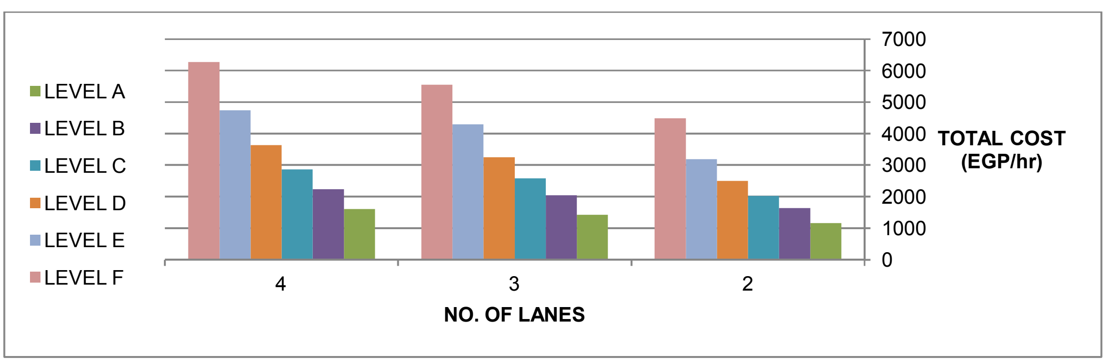


Fig. 9. The relation between total cost (egp/hr) and the number of lanes at case 1 of control type (signalized-two phase) at different levels of service

It can be noted that the improving level of service from E to D resulted in total cost reduction by about 23%. On the other hand to enhance the level E to levels C and B resulted in fuel reduction by about 39% and 51% respectively

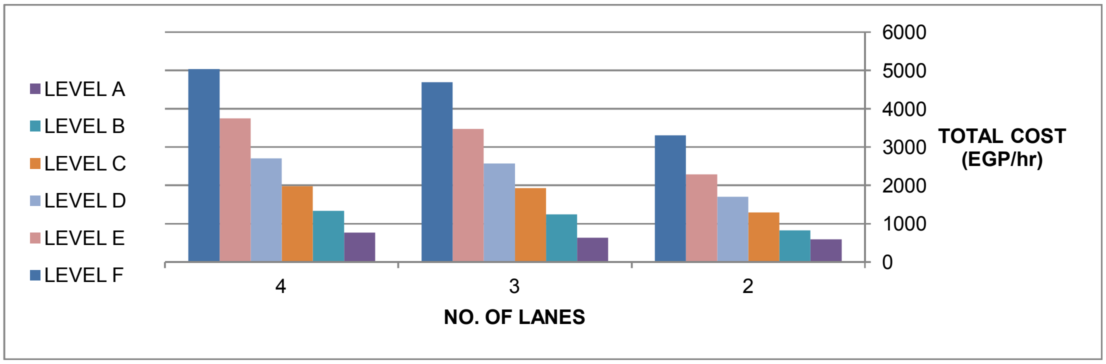


Fig. 10. The relation between total cost (egp/hr) and the number of lanes at case 2 of control type (signalized-split) at different levels of service

It can be noted that the improving level of service from E to D resulted in total cost reduction by about 26%. On the other hand to enhance the level E to levels C and B resulted in fuel reduction by about 45% and 64% respectively

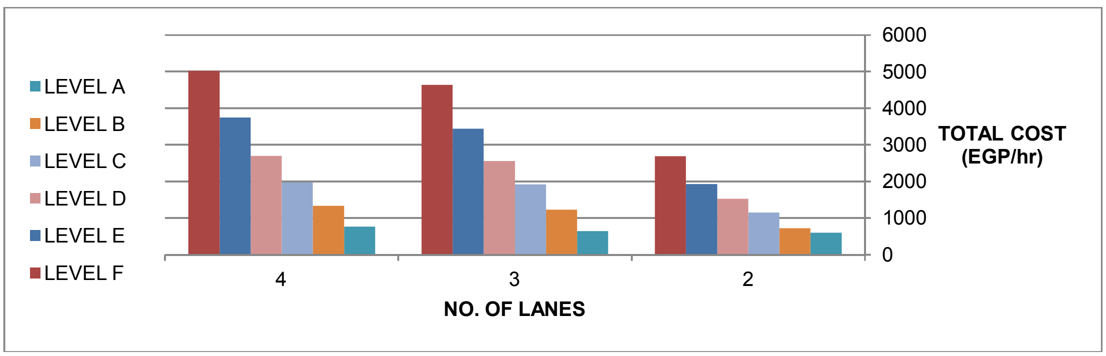


Fig. 11. The relation between total cost (egp/hr) and the number of lanes at case 3 of control type (signalized- leading right turn) at different levels of service

It can be noted that the improving level of service from E to D resulted in total cost reduction by about 25%. On the other hand to enhance the level E to levels C and B resulted in fuel reduction by about 44% and 64% respectively

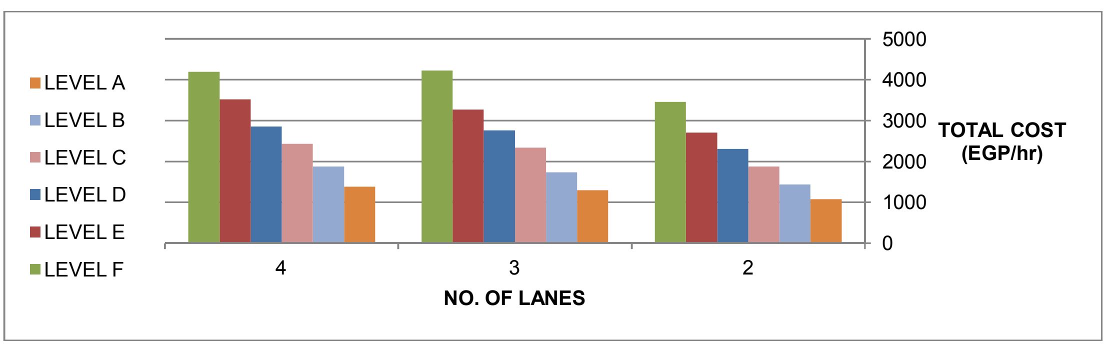


Fig. 12. The relation between total cost (egp/hr) and the number of lanes at case 4 of control type (roundabout) at different levels of service

It can be noted that the improving level of service from E to D resulted in total cost reduction by about 16%. On the other hand to enhance the level E to levels C and B resulted in fuel reduction by about 30% and 47% respectively

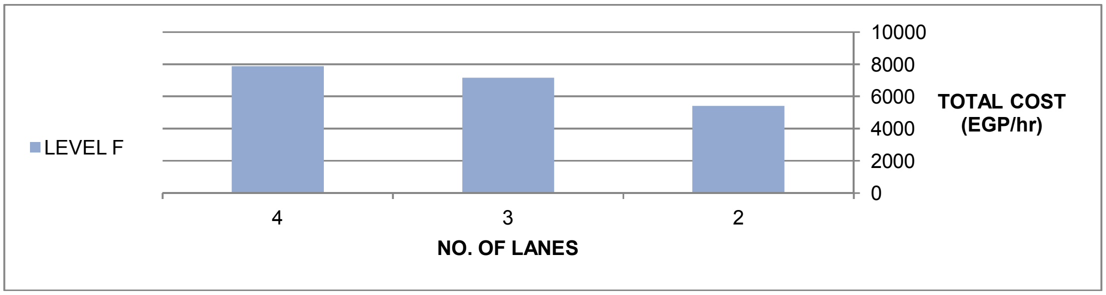


Fig. 13. The relation between total cost (egp/hr) and the number of lanes at case 5 of control type (unsignalized) at different levels of service

This means whenever the level of service is improved to better lead to a significant reduction in the total cost and that this reduction is more than worth the higher level of service improvement

The relation between the fuel cost (egp/hr) & number of lanes at different cases of control type and different levels of service. Figs. (14 through 18) are constructed. From the figures it is clear that the fuel cost due to various types of intersection control and levels of service for different number of lanes indicates that the saving in fuel cost due to improving level of service is computed by the formula:

$$\text{Saving in fuel cost} = [1 - (0.65 : 0.85)^{\text{Los computed} - \text{Los targeted}}] * \text{fuel cost computed} \quad (4)$$

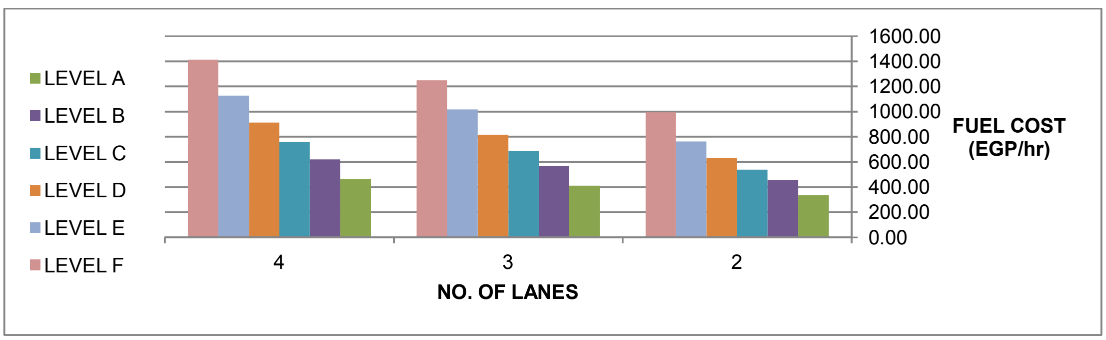


Fig. 14. The relation between fuel cost (egp/hr) and the number of lanes at case 1 of control type (signalized-two phase) at different levels of service

It can be noted that the improving level of service from E to D resulted in fuel cost reduction by about 18%. On the other hand to enhance the level E to levels C and B resulted in fuel reduction by about 32% and 44% respectively

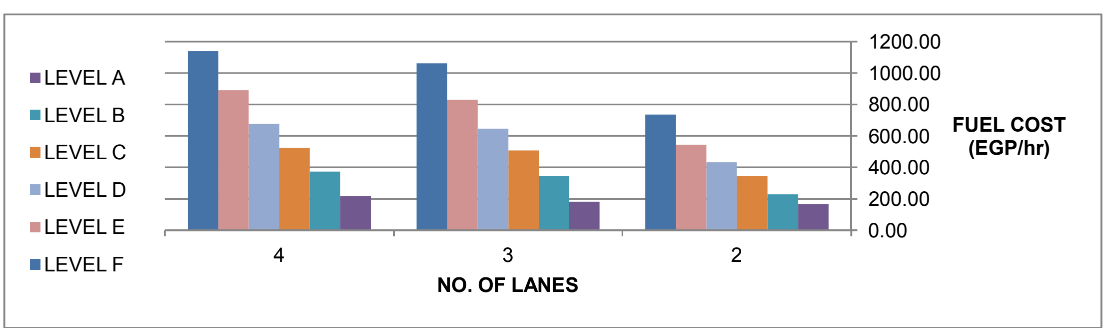


Fig. 15. The relation between fuel cost (egp/hr) and the number of lanes at case 2 of control type (signalized-split) at different levels of service

It can be noted that the improving level of service from E to D resulted in fuel cost reduction by about 22%. On the other hand to enhance the level E to levels C and B resulted in fuel reduction by about 39% and 58% respectively

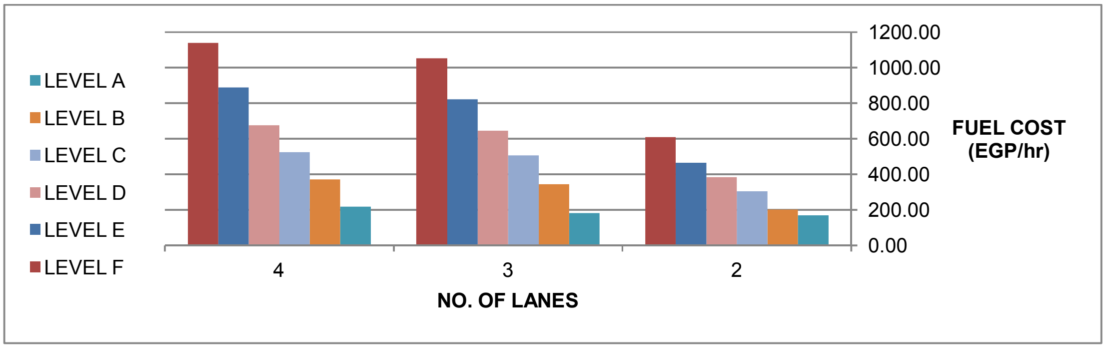


Fig. 16. The relation between fuel cost (egp/hr) and the number of lanes at case 3 of control type (signalized- leading right turn) at different levels of service

It can be noted that the improving level of service from E to D resulted in fuel cost reduction by about 21%. On the other hand to enhance the level E to levels C and B resulted in fuel reduction by about 38% and 58% respectively

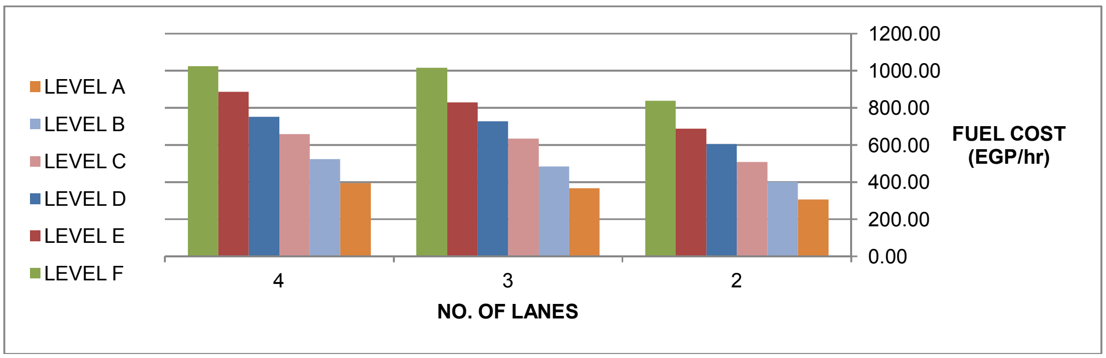


Fig. 17. The relation between fuel cost (egp/hr) and the number of lanes at case 4 of control type (roundabout) at different levels of service

It can be noted that the improving level of service from E to D resulted in fuel cost reduction by about 13%. On the other hand to enhance the level E to levels C and B resulted in fuel reduction by about 25% and 41% respectively

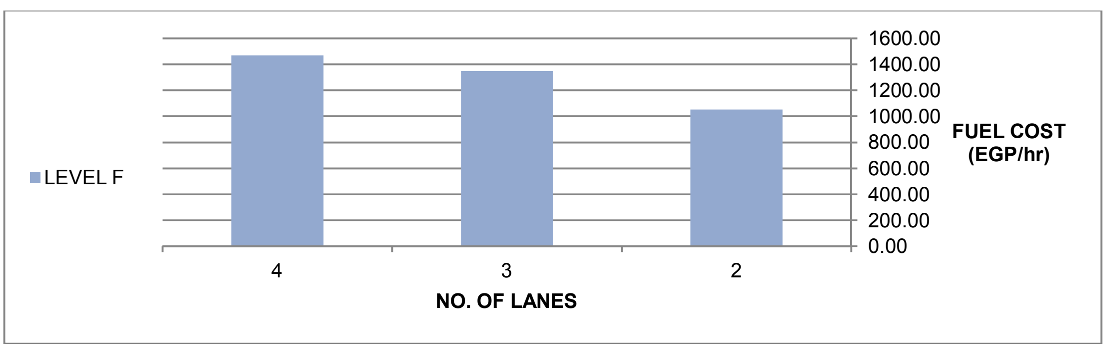


Fig. 18. The relation between fuel cost (egp/hr) and the number of lanes at case 5 of control type (unsignalized) at different levels of service

This means whenever the level of service is improved to better lead to a significant reduction in the fuel cost and that this reduction is more than worth the higher level of service improvement

The relation between the fuel cost / total cost & number of lanes at different cases of control type and different levels of service. Figs. (19 through 23) are constructed. From the figures it is clear that the ratio between the fuel cost / total cost due to various types of intersection control and levels of service for different number of lanes indicates that the rate of increasing of fuel cost / total cost due to improving level of service is computed by the formula:

$$\text{Fuel cost / total cost targeted} = (1.02 : 1.06)^{\text{Los computed} - \text{Los targeted}} * \text{fuel cost / total cost computed} \quad (5)$$

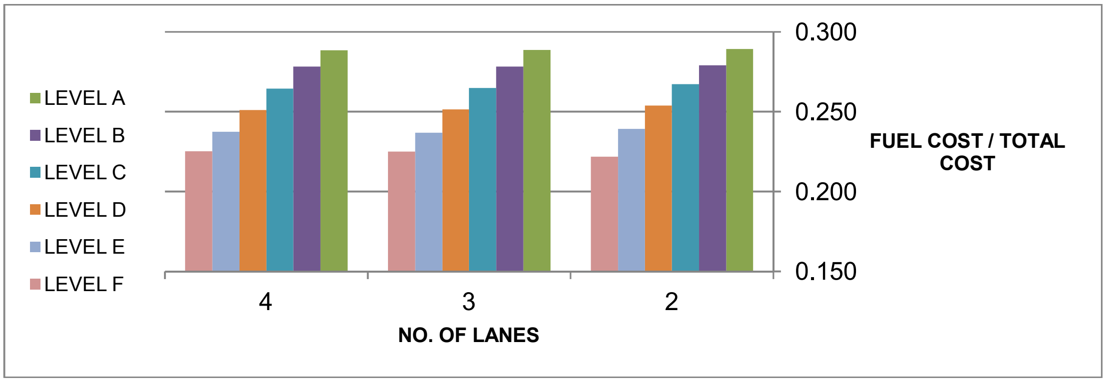


Fig. 19. The relation between fuel cost / total cost and the number of lanes at case 1 of control type (signalized-two phase) at different levels of service

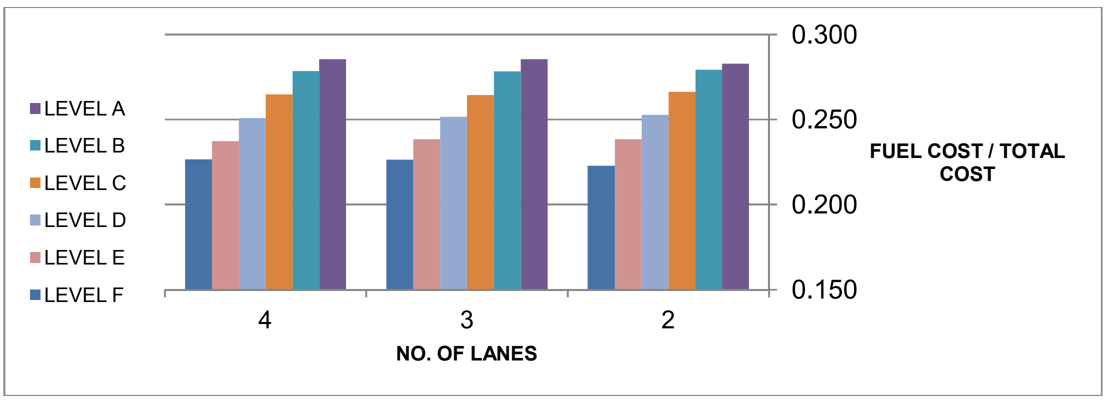


Fig. 20. The relation between fuel cost / total cost and the number of lanes at case 2 of control type (signalized-split) at different levels of service

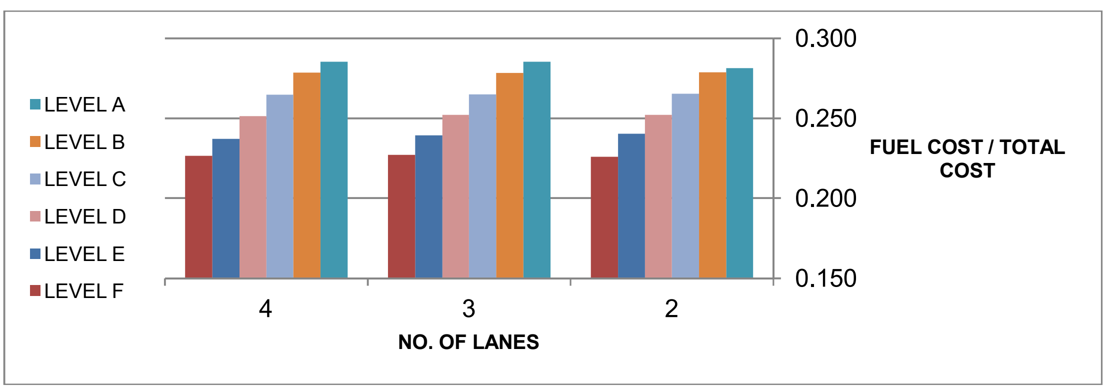


Fig. 21. The relation between fuel cost / total cost and the number of lanes at case 3 of control type (signalized- leading right turn) at different levels of service

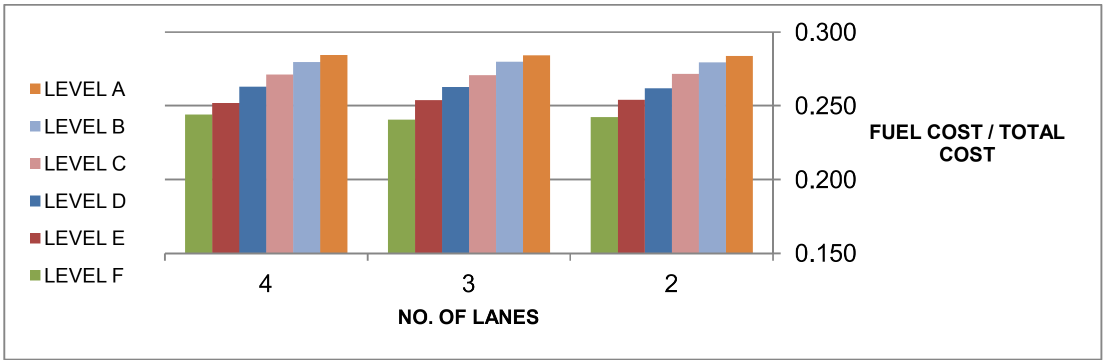


Fig. 22. The relation between fuel cost / total cost and the number of lanes at case 4 of control type (roundabout) at different levels of service

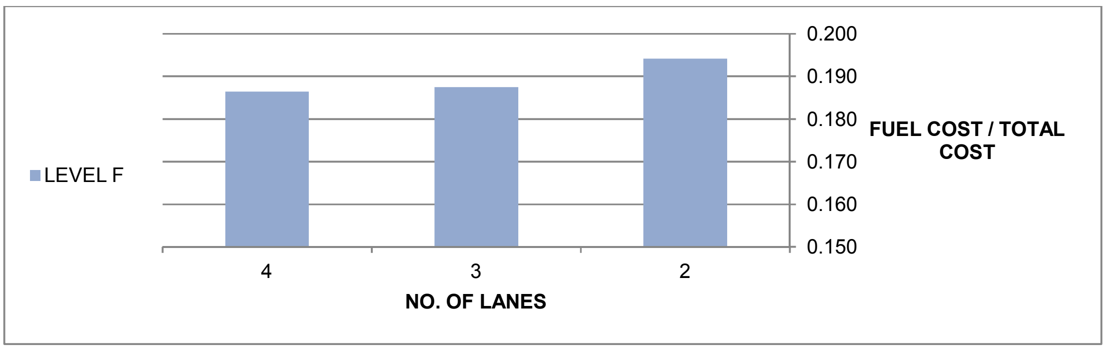


Fig. 23. The relation between fuel cost / total cost and the number of lanes in case 5 of control type (unsignalized) at different levels of service

7.2 Three Leg Intersections

There are four cases of control type they are from case 1 to case 4 respectively: signalized (two phase), signalized (split), roundabout; and unsignalized.

The relation between fuel consumption (liters/hr) & number of lanes at different cases of control type and different levels of service. Which the result of three leg intersection similar to the result of the four leg intersection the fuel consumption due to various types of intersection control and levels of service for different number of lanes indicates that the saving in fuel consumption due to improving level of service is computed by the formula:

$$\text{Saving in fuel consumption} =[1- (0.7 : 0.85)^{\text{Los computed -Los targeted}}]\text{* fuel consumption computed} \quad (6)$$

The relation between total cost which include total vehicle operating and time cost (egp/hr) & number of lanes at different cases of control type and different levels of service. Which the result of three leg intersection similar to the result of the four leg intersection the total cost which include total vehicle operating and time cost due to various types of intersection control and levels of service for different number of lanes indicates that the saving in total cost due to improving level of service is computed by the formula:

$$\text{Saving in total cost} =[1- (0.7 : 0.85)^{\text{Los computed -Los targeted}}]\text{* total cost computed} \quad (7)$$

The relation between the fuel cost (egp/hr) & number of lanes at different cases of control type and different levels of service. Which the result of three leg intersection similar to the result of the four leg intersection the fuel cost due to various types of intersection control and levels of service for different number of lanes indicates that the saving in fuel cost due to improving level of service is computed by the formula:

$$\text{Saving in fuel cost} =[1- (0.7 : 0.85)^{\text{Los computed - Los targeted}}]\text{* fuel cost computed} \quad (8)$$

The relation between the fuel cost / total cost & number of lanes at different cases of control type and different levels of service. Which the result of three leg intersection similar to the result of the four leg intersection the ratio between the fuel cost / total cost due to various types of intersection control and levels of service for different number of lanes indicates that the rate of increasing of fuel cost / total cost due to improving level of service is computed by the formula:

Fuel cost / total cost targeted = $(1.02 : 1.06)^{\text{Los computed -Los targeted}}$ * fuel cost /total cost computed (9)

8. CONCLUSIONS

In view of the results obtained in this study. The saving in fuel consumption, cost of fuel and total cost (which include total vehicle operating and time cost) due to improving level of service was computed at different number of lanes. The number of lanes in the intersection approach affects the queue length and delay time, which leads to different Shockwave time. The six common levels of service from A to F are referred in the equations of this study by the numbers from 1 to 6 respectively. Based on the analysis of research results the following conclusions can be stated:

1- Enhancing the level of service at any intersection type increase the saving in fuel consumption, cost of fuel and total cost.
2- The fuel consumption due to various types of intersections control and levels of service for different number of lanes indicates that the saving in fuel consumption due to improving level of service is computed for 3 and 4 leg intersection respectively by the formulas:

   Saving in fuel consumption =[1- $(0.7:0.85)^{\text{Los computed -Los targeted}}$]* fuel consumption computed.

   Saving in fuel consumption =[1- $(0.65:0.85)^{\text{Los computed -Los targeted}}$]* fuel consumption computed.

3- The total cost due to various types of intersections control and levels of service for different number of lanes indicates that the saving in total cost due to improving level of service is computed for 3 and 4 leg intersection respectively by the formulas:

   Saving in total cost =[1- $(0.7 : 0.85)^{\text{Los computed -Los targeted}}$]* total cost computed

   Saving in total cost =[1- $(0.65 : 0.85)^{\text{Los computed -Los targeted}}$]* total cost computed

4- The fuel cost due to various types of intersections control and levels of service for different number of lanes indicates that the saving in fuel cost due to improving level of service is computed for 3 and 4 leg intersection respectively by the formulas:

   Saving in fuel cost =[1- $(0.7:0.85)^{\text{Los computed -Los targeted}}$]* fuel cost computed

   Saving in fuel cost =[1- $(0.65:0.85)^{\text{Los computed -Los targeted}}$]* fuel cost computed

5- The ratio between the fuel cost / total cost due to various types of intersections control and levels of service for different number of lanes indicates that the rate of increasing of fuel cost / total cost due to improving level of service is computed for 3 and 4 leg intersection respectively by the formulas:

   Fuel cost / total cost targeted = $(1.02:1.06)^{\text{Los computed -Los targeted}}$ * fuel cost / total cost computed.

   Fuel cost / total cost targeted = $(1.02:1.06)^{\text{Los computed -Los targeted}}$ * fuel cost / total cost computed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Golob T, Regan A. Impacts of highway congestion on freight operations: Perceptions of trucking industry managers. Transportation Research Policy and Practice. 2001;35a:577-599.
2. Golob T, Regan A. Traffic Conditions and Truck Accidents on Urban Freeways, Working Paper UCI-ITS-WP-04-3, Institute of Transportation Studies, University of California-Irvine, Irvine, California; 2004.
3. Golob T, Recker W, Alvarez V. Freeway safety as a function of traffic flow. Accident

Analysis and Prevention. 2004;36(6):933-946.
4. Goodwin P, Noland R. Building new roads really does create extra traffic: A response to prakash et al. Applied Economics. 2003;35(13):1451-1457.
5. Goodwin P. The economic costs of road traffic congestion, discussion paper published by the Rail Freight Group, ESRC Transport Studies Unit, University College London, London; 2004.
6. Akçelik R. Speed-flow and bunching models for uninterrupted flows. Transportation Research Board 5th International Symposium on Highway Capacity and Quality of Service, Yokohama, Japan; 2006a.
7. Akçelik R. A review of gap-acceptance capacity models. Paper presented at the 29th Conference of Australian Institutes of Transport Research (CAITR), University of South Australia, Adelaide, Australia; 2007.
8. Akçelik R. An investigation of the performance of roundabouts with metering signals. Paper presented at the National Roundabout Conference, Transportation Research Board, Kansas City, MO, USA, 18-21 May; 2008.
9. Tollazzi T, Mauro R, Guerrieri M, Renčelj M. Comparative analysis of four new alternative types of roundabouts: "Turbo", "flower", "target" and "four-flyover" roundabout; 2016.
10. Guerrieri M, Corriere F, Lo Casto B, Rizzo G. A model for evaluating the environmental and functional benefits of "innovative" roundabouts; 2015.
11. Tollazzi T, Tesoriere G, Guerrieri M, Campisi T. Environmental, functional and economic criteria for comparing "target roundabouts" with one- or two-level roundabout intersections; 2015.
12. Mauro R. Calculation of roundabouts: Capacity, waiting phenomena and reliability; 2010.
13. Akçelik R. Evaluating roundabout capacity, level of service and performance. Paper presented at the ITE Annual Meeting, San Antonio, Texas, USA; 2009a.
14. Akçelik R. An assessment of the highway capacity manual 2010 roundabout capacity model. Paper presented at the TRB International Roundabout Conference, Carmel, Indiana, USA; 2011a.
15. Akçelik R. Some common and differing aspects of alternative models for roundabout capacity and performance estimation. Paper presented at the TRB International Roundabout Conference, Carmel, Indian; 2011b.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/14874