

Strathmore

UNIVERSITY

**ESTIMATING THE COST OF TRAFFIC CONGESTION IN
NAIROBI (LANGATA) TO THE KENYAN ECONOMY**

NAVJOT ATTRI

078515

**Submitted in partial fulfillment of the requirements for the Degree of Bachelors of
Business Science in Actuarial Science at Strathmore University**

School of Finance and Applied Economics

Strathmore University

Nairobi, Kenya

25th November, 2016

Acknowledgements

I would like to thank God for the favor, strength and ability to do this research study. I would also like to express special gratitude to my supervisor, who gave me the golden opportunity to do this wonderful project, and for guiding me through it and making sure I completed the project within the limited time frame.

I extend my sincere gratitude to the family and friends I have, who have encouraged me to do this study and made sure I never gave up.

I would also like to thank the respondents of the questionnaire, who took out time and filled the questionnaire with sincerity.

Finally, to the School of Finance and Applied Economics, for providing me with adequate knowledge and skills and having me as a student.

DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the Research Proposal contains no material previously published or written by another person except where due reference is made in the Research Proposal itself.

© No part of this Research Proposal may be reproduced without the permission of the author and Strathmore University

Navjot Attri

..... [*Signature*]

..... [*Date*]

This Research Proposal has been submitted for examination with my approval as the Supervisor.

John Ocheche

..... [*Signature*]

..... [*Date*]

School of Finance and Applied Economics
Strathmore University

Table of Contents

Abstract	1
List of tables and figures	2
List of tables	2
List of figures	2
1. INTRODUCTION	3
1.1. Background Information	3
1.1.1. Impacts of traffic congestion	4
1.1.2. Variability in traffic congestion	5
1.2. Problem Statement	6
1.3. Research Questions	7
1.4. Research Objectives	7
1.5. Justification	7
2. LITERATURE REVIEW	8
2.1. Economic considerations of Transportation	8
2.2. Measuring the impacts of congestion	9
2.3. Criticisms	12
2.4. Suggested solutions	13
2.5. Other methodologies	13
2.6. Current method used for calculating traffic congestion costs in Nairobi (Gonzales, 2009) 14	
2.6.1. Introduction	14
2.6.2. Available data	15
2.6.3. Methodology	15
2.6.4. Criticisms (limitations) of this model	15
3. METHODOLOGY (Mir Shabbar Ali, 2013)	17
3.1. Introduction	17
3.2. Study area	17
3.3. Data collection and processing	18
4. RESULTS AND FINDINGS	21
5. DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS	25
5.1 Introduction	25
5.2 Discussion	25

5.3 Summary	27
5.4 Conclusions	27
5.5 Recommendations for further research	27
Appendices	29
Appendix 1: Questionnaire	29
References	31

Abstract

This paper tells us what traffic congestion is, its severity in Kenya, specifically Nairobi, and its cost to the Kenyan economy. Traffic congestion affects many sectors in many different ways, and also imposes a cost on all of these sectors either directly or indirectly. In this paper, we are specifically focusing on the economic costs that traffic congestion imposes. It highlights the different ways in which statistics and mathematical computations can be used to estimate the cost of traffic and the factors that affect it. It also tells us the causes of this traffic congestion and how these can be reduced, and the advantages of reduced traffic congestion.

In 2014, it was estimated that traffic in Nairobi costs \$570,000 per day. This is a significant amount and can be used productively elsewhere. One of the main reasons of this congestion is seen to be the ever expanding population and hence the increase in the number of vehicles growing at a higher rate than the road capacity. The population in Nairobi has grown from 350,000 in 1963 to about 3.3 million. The number of vehicles in Nairobi was estimated at over 300,000 in 2008. In the same period, there has been limited increase in the existing road infrastructure capacity. (LIVINGINNAIROBI, 2011) This shows us that the problem is one that cannot be ignored and therefore, this problem needs to be tackled as soon as possible. In this paper we will look at the current method used to calculate these traffic costs and the limitations of the current method, and a proposed method that is used to calculate traffic congestion in countries like Pakistan and Netherlands and which has not yet been used in Nairobi.

List of tables and figures

List of tables

Table 1: Parameters used to measure traffic	9
Table 2: LOS ratings	10

List of figures

Figure 1: Average Value of Time for the different vehicle types	21
Figure 2: Average delay for vehicle type in hours, per day.....	22
Figure 3: Average number of vehicles on langata road for different mode types (per day).....	22
Figure 4: Average vehicle occupancy for the different mode types.....	23
Figure 5: Average fuel cost in Kshs for the different mode types per day.....	23
Figure 6: The contribution of different costs to the total cost of traffic congestion	24

1. INTRODUCTION

1.1. Background Information

Traffic congestion costs consist of incremental delay, vehicle operating costs (fuel and wear), pollution emissions and stress that result from interference among vehicles in the traffic stream, particularly as traffic volumes approach a road's capacity (Victoria Transport Policy Institute , 2016).

Congestion can be of two types: recurrent and non-recurrent. Recurrent congestion is traffic that occurs on a regular, daily, weekly, or annual cycle basis, while non-recurrent congestion occurs due to traffic caused by accidents, construction, disabled vehicles, construction, and special events. Some congestion costs incorporate recurrent costs only, while others incorporate both. Some of the common causes of traffic congestion include: peak hour traffic, poor infrastructure, accidents, and variable traffic speeds on congested roads) (C.S-W, 2014).

The Center for Economics and Business Research, a London-based consultancy, and INRIX, a traffic-data firm, have assessed the effect of such delays (traffic) on the British, French, German and American economies. To do as such they quantified three costs: how sitting in movement decreases profitability of the work power(labor force); how increased transport costs push up the costs of products; and the carbon-equal expense of the fumes that exhausts splutter out (Victoria Transport Policy Institute , 2016).

66% of the costs brought about by traffic are the aftereffect of wasted fuel and time that could be better spent somewhere else, and the rest from expanded operational expenses of businesses.

Economist William Vickrey identified six types of congestion as follows:

Firstly, the simple interaction on homogeneous roads- this is when two vehicles that are travelling close together delay each other. Secondly he mentions the multiple interactions on homogeneous roads- this is when several vehicles interact. Next in the list are the Bottlenecks- this is when there are many vehicles that are trying to pass through a narrow or contracted lane/path.in addition to that, we have the "Trigger neck" congestion- this is at the point when an

underlying narrowing produces a line of vehicles interfering with a stream of vehicles not trying to take after the stuck (jammed) schedule. Next in the list is the Network control congestion- this is when traffic controls programmed for peak hour traffic, unavoidably defer off-peak hour activity. Lastly he mentions the congestion due to network morphology, or polymodal polymorphous congestion: where traffic congestion reflects the condition of the movement of cars on all schedules and for all modes. The expense of intrusions for a specific section of roadway increases through likely interventions on the different sections of the road, because of impact of triggered congestion.

Most congestion costs studies focus on the second and third sorts of congestion: congestion emerging from collaborations between different vehicles on a homogeneous road section, and bottleneck congestion.

Especially in urban regions, however, vigorously congested roads are quite often the aftereffect of bottlenecks. These bottlenecks are oftentimes because of because of junctions, in addition to segments with steep angles, reduced carriageway width, decreased number of road works, paths, or accidents. The costs of congestion caused by accidents ought to obviously be accredited to the vehicles due to which that condition arises (Professor Chris Nash, 1999). Congestion tends to increase travel time, unreliability of arrival, fuel consumption, pollution and driver stress, and reduce life fulfillment.

1.1.1. Impacts of traffic congestion

Congestion has many impacts, both positive and negative. The positive impact it could have is that when there is traffic, cars are moving really slowly and hence the chances of accidents and further loss of lives is reduced. The following are some of the ways in which traffic congestions impacts our lives negatively:

Firstly, traffic congestion leads to wasting time of drivers and travelers which is seen as a non-productive action for many people and this leads to a decrease in economic health. Secondly, it causes delays which may bring about late arrival at job, meetings, and training or education, bringing about lost business, disciplinary activity or other individual misfortunes. Another

negative impact of traffic congestion is the inability to forecast travel time precisely, prompting drivers allocating more time to travel “to be safe” (just in case) and less time on productive exercises. Next, wasting fuel increases air contamination and the emissions of carbon dioxide contributing to global warming attributable to increased idling, speeding up and braking. Increased use of fuel in the long run may also cause an increase in the costs of fuel. In addition to that, traffic congestion causes wear and tear on vehicles as a consequence of idling (idling) in traffic, recurrent acceleration and braking, which leads to more frequent repairs and substitutes. This is an extra cost of maintenance and repair. Moreover, traffic congestion also leads to having stressed and baffled drivers, encouraging road fury (leading to accidents) and decreased health of drivers which adds on to the costs (medical costs) one has to incur. Furthermore, we have the issue of emergencies. Blocked traffic may intervene with emergency vehicles that might need to reach a specific destination urgently. Next in the list of the negative impacts we have the spillover effect. This is when the traffic spreads from the congested main routes to secondary roads and side streets, as people try to use these roads as alternative routes to avoid traffic. Lastly, traffic congestion could lead to loss of life resulting into difficulty family livelihood and loss of labor force which leads to a reduction in the economy of the country. This might occur when people are trying to overtake the other and hence end up causing an accident.

Usually, traffic congestion is thought to be a cost that the motorists or drivers bear but they also impose costs on others. Traffic congestion is an example of a cost that is external to individual drivers and yet, to a great extent, internal to drivers as a group. This means that each vehicle user levies and bears the cost.

1.1.2. Variability in traffic congestion

Congestion varies by area, time, and, to a lesser degree, vehicle type. Of specific note is the great variation between smaller centers and larger metropolitan areas. This expense happens essentially during Urban Peak travel.

As mentioned earlier, the estimated traffic congestion costs are very high in Nairobi and this is an indication that action needs to be taken. IBM has carried out studies on the traffic congestion

in Kenya and in 2013 came up with an application that will help drivers to avoid traffic. According to (Laursen, 2013), “Nairobi city has three dozen traffic cameras downtown, but that's not enough information for a city of over three million people. Traffic costs the city US \$600 000 a day, by one estimate. IBM's Nairobi lab, in beta since a year ago, tackled traffic early on and today launched a mobile application to help drivers avoid traffic. The app, called Twende Twende, meaning something like "Let's go" in Swahili, bases its recommendations on a central system that uses image recognition algorithms to process the traffic camera feeds and a separate algorithm to predict traffic on streets not covered by the cameras. Users can get recommendations via SMS or on a map interface”.

1.2. Problem Statement

Traffic congestion has become one of the plagues of modern life in a big city. Traffic congestion has always been a major issue be it in a small street, highway, city or any country. Traffic is rising faster than road capacity. This is not a temporary issue, without measures to lessen traffic, it will continue at the same pace and continue to since it is infeasible to coordinate a road system to unrestricted patterns in traffic growth (N.Katala). Traffic congestion in Nairobi City costs the economy an estimated Sh37 billion annually, an interim report shows. The report prepared by the county's Transport and Urban Decongestion committee attributed this to poor planning of the city that did not factor in steady increase in population and vehicles (Standard Media, 2014). In this paper we are going to try to find out the methodology used to reach at such a figure and whether or not these methods are reliable ways of calculating traffic costs. According to (Sarah McGregor, 2014), the government estimates that traffic jams cost 50 million shillings (\$578,000) a day in lost productivity in the city. These are huge figures and an indication that traffic congestion is a huge problem and necessary action needs to be taken.

1.3. Research Questions

- What is the cost of traffic congestion in Nairobi to the Kenyan economy?
- How can we measure traffic congestion and what are some of the factors that affect traffic congestion?

1.4. Research Objectives

- To determine the cost of traffic congestion in Nairobi to the Kenyan Economy
- To determine the different factors that cause traffic congestion

1.5. Justification

Traffic congestion is not only a problem locally, but globally. Nairobi has been ranked as the fourth most grueling commute of 20 cities surveyed in a new IBM international traffic study (IBM East Africa, 2011). This tells us that it is a huge problem and necessary action should be taken to resolve this problem as soon as possible. This is the reason for carrying out this study. Cities in countries like the Netherlands, India, Japan, China and Pakistan, where the number of vehicles and population is increasing at a higher rate than the road capacity, face many traffic congestion problems. Nairobi in Kenya, has a similar situation and therefore, in this paper we shall base our study on the practices carried out in these countries to measure the cost of traffic congestion that have not yet been carried out in Nairobi. This could mean a more effective way to measure traffic congestion costs, and hence work towards reducing them.

2. LITERATURE REVIEW

There are many papers that have studied on how to measure the cost of traffic congestion. In this part we will discuss some of the writings of some of these papers.

Congestion cost studies, like the Urban Mobility reports, usually argue that congestion significantly lessens the economic profitability. Controlling traffic is very important as it will affect the transport sector and the transport sector is a very important sector that contributes to the economic growth of a country. The following is how transport affects the economy:

2.1. Economic considerations of Transportation

Firstly we need transport for purposes of Production and consumption of Products- Transport is a key need for specialization - permitting production and consumption of products to happen at various areas. Transport is also needed in the Trade and Development sector- Transport has all through history been an incentive to expansion; better transport permits more exchange (trade), land use development and a greater spread of individuals. In addition to that, transport also has an impact on the Economic Growth and Efficiency- Economic development and effect on economic effectiveness have been constantly subject to expanding the limit and reasonability of transport and also security. In any case, the infrastructure and operation of transport greatly affects the area and is the biggest drainer of energy, making transport sustainability a noteworthy issue. Another point to add on to the list of the importance of efficient transport to the economy is that transport causes for mobility related to economic considerations- Modern cultures commands a physical division between home and work, pushing individuals to transport themselves to work environments or study, and also to briefly migrate for other day by day exercises. These reasons are emphatically associated with decisions of economic nature. Lastly, we should also consider the Additional considerations- Traveler transport is also the essence of tourism, a noteworthy piece of recreational transport. Trade requires the transport of individuals to lead business, either to permit face to face communication for imperative choices or to move experts from their standard work environment to destinations where they are required.

This shows us how important transport is to the economy of a country, and traffic congestion affects transport greatly and hence the problem needs to be resolved with no further delay.

2.2. Measuring the impacts of congestion

The following are the most commonly used measures or indicators of traffic congestion:

Roadway volume to capacity ratios (V/C) - A V/C below 0.85 is considered under-capacity, 0.85 to 0.95 is considered near capacity, 0.95 to 1.0 is considered at capacity, and more than 1.0 is considered over-capacity. Traffic congestion function is non-linear, so as a road or street tends to its most extreme limit (maximum capacity), little changes in traffic volumes can bring about proportionately bigger changes in congestion delays. (Victoria Transport Policy Institute , 2016)

The table below shows the different parameters that are used to measure traffic (Victoria Transport Policy Institute , 2016):

Parameter	Typical units	Reciprocal	Typical units
Flow	Vehicles per hour(Veh/h)	Headway	Seconds per vehicle(s/veh)
Speed	Kilometers per hour (Km/h)	Travel time	Seconds per kilometer (s/km)
Density	Vehicles per lane km (Veh/lane-km)	Spacing	Meters per vehicle (m/veh)

Table 1: Parameters used to measure traffic

Another measure of traffic congestion is the Level of Service (LOS) - this is a qualitative measure of traffic service to a given flow rate. LOS is a letter that designates a range of operating conditions on a particular type of facility. Six LOS letters are defined by HCM, namely A, B, C, D, E, and F, where A denote the best quality of service and F denote the worst. These definitions are based on Measures of Effectiveness (MoE) of that facility. Typical measure of effectiveness include speed, travel-time, density, delay etc. (Mathew, 2014).

The table below is a summary of the typical highway LOS ratings:

LOS	Description	Speed (mph)	Flow (veh/h/lane)	Density (veh/mile)
A	Traffic flows at or more than the allowed speed limit. Motorists move between lanes freely.	Over 60	Below 700	Less than 12
B	Slightly full, with some breach of mobility	57-60	700-1100	12-20
C	Passing or changing lanes is a bit inhibited. Posted speeds are maintained, however, the roads are near capacity. This is the target LOS for many urban highways.	54-57	1100-1550	20-30
D	Speeds are low and mobility is reduced. Typical urban peak-period highway conditions	46-54	1550-1850	30-42
E	Irregular flow, speeds differ and very rarely reach the speed limit. This is viewed as a system failure.	30-46	1850-2200	42-67
F	Forced flow, with incessant drops in velocity to almost zero mph. Travel time cannot be predicted.	Under 30	Unstable	67-Maximum

Table 2: LOS ratings

Travel Time Index (TTI) is another measure of the impacts of traffic congestion. This is computed as the ratio of peak to free-flow travel speeds.

Different factors can influence roadway capacity and in this manner also affect congestion costs, including type of vehicle, movement speeds, lane width, and convergence design. Climate, lighting, road surface conditions, cross road and turning volumes, can also influence roadway capacity and thus leading to congestion.

Level-of-service is regularly utilized as an essential pointer of transport framework execution, and to figure out if and how much a designer must pay in transportation advancement expenses. Low Level of Service (LOS), Indication of Congestion for levels E and F (most exceedingly awful levels) implies a lot of wasted time, increased vehicle running costs, increased number of accidents and contamination in addition to expanded aggravation and disappointment. (N.Katala)

Congestion delays can also be assessed using travel reliability indicators:

The 90th or 95th percentile travel time tells us the lengthiest travel time during a ten or twenty day period. Another indicator is the buffer index shows the additional time that the travelers need to add to their travel plan to guarantee that arrival on destination is on-time, calculated as the difference between the 95th percentile and average travel times, divided by the average travel time. For example, a 40% buffer index means that, for a 20-minute free flow trip travelers should budget an additional 8 minutes ($20 \text{ minutes} \times 40\% = 8 \text{ minutes}$) to ensure on-time arrival. The extra minutes are called the buffer time. The frequency that congestion exceeds a threshold can also be used in the assessment of congestion delays. This is expressed as the percentage of days travel times surpass some standard, such as peak-period speeds slower than a target.

Finding a solution to the problem of traffic congestion is not so easy. Constructing more roads or broadening existing ones can urge more vehicles on to the streets, says Dominic Jordan, INRIX's central information researcher. For sure, investment, growth in employment and light GDP are all factors that cause an increase in traffic and related costs: when individuals feel wealthier, they spend too much on cars and petrol. Smart road networks that charge street road users for travelling at occupied periods or that push drivers, utilizing electronic signs, to drive at a more uniform pace, could be of help. More electric cars will cut down carbon emanations, while driverless ones might be able to one day dispatch traffic jams to history. (C.S-W, 2014)

2.3. Criticisms

The most common indicators of traffic congestion as mentioned above, such as LOS and TTI have been criticized for the shortcomings such as the following omissions and biases:

They measure the congestion intensity instead of the congestion costs- consequently, they do not take into account the extra delay or transport costs caused by dispersed growth and hence reduced transport options, which in return increases the per capita vehicle travel. Indicators, like the TTI suggest that congestion decreases if uncongested travel increases since congested travel is isolated by more aggregate vehicle-miles.

Another limitation of the indicators is that the estimates for delay are not so realistic since they use free flow conditions (LOS A) to estimate delays instead of using the urban-peak roadway conditions (LOS C) which is a more realistic estimate and apply moderately high travel time cost values (normally 35-60% of average wage rates for individual travel, and more for business travel).

In addition to that they only take into account the effect traffic congestion has on the drivers or motorists, they do not take into account the delays that wider roads and increased traffic imposes on the non-motorized travelers.

They also do not take into account the technological advancements such as variable valve timing and fuel injections, which are an indication of reduced congestion and hence reduced costs. They still use the out-of-date fuel and emission models, which makes them inaccurate to a great extent.

2.4. Suggested solutions

Taking into account the problems stated above, the following are a few ways in which congestion costs can be measured in a more comprehensive and objective way:

In the evaluation of the congestion costs using these indicators, instead of using indicators that measure the congestion intensity (LOS and TTI), use indicators such as the total or per capita congestion costs. This will lead to more accurate costing.

Measuring the effect of traffic congestion on the non-motorized people as well, in addition to the motorists will also help in the computation of more reliable estimates of the costs.

Moreover, the fuel and emission costs should be calculated based on the latest and most recent technology that will take into account the current trends and hence make the estimated costs more viable.

In addition to that, using motorists' actual willingness-to-pay (WTP) instead of estimates of total travel time cost values is another way of improving on the accuracy of the figure.

Ensuring that the congestion costs is not added when estimating both travel time and vehicle operating costs when computing aggregate transport costs, as this will result in double-counting, will also help make the estimate of costs more accurate.

Lastly, consider and compare different strategies to reduce traffic congestion. For instance, roadway expansion ought to be contrasted with improvements to alternate modes and request management strategies.

2.5. Other methodologies

One methodology is to decide the price needed to decrease traffic volumes to ideal roadway capacity, which demonstrates consumers' willingness-to-pay for extended mobility and in this way the real cost they place on delay. Another methodology is to compute the minimal impacts every vehicle entering the traffic stream levies on other road users, considering the speed flow

relationship of every road segment. However, the data required for such investigation is rarely accessible so most estimates depend on simplified models that measure incremental delay, vehicle expenses and emissions over some baseline. Monetized values are allocated to the extra time and emissions. Higher travel time unit costs (dollars per hour) are some of the time applied to congested conditions to reflect extra driver anxiety and undependability.

Different techniques are used to compute congestion costs. Most depend on the difference between peak and some reference point travel speed. A typical reference point is free-flow speeds (LOS A), but this technique has been criticized since it would be economically inefficient to give adequate road capacity to permit free flow traffic under urban-peak conditions. An all the more economically ideal benchmark is LOS C/D (45-55 mph on roadways), since this has a tendency to maximize traffic throughput and fuel proficiency, and normally reflects client willingness to-pay, expecting that most drivers would incline toward slightly lower peak-period traffic speeds in return for much lower road user expenses.

2.6. Current method used for calculating traffic congestion costs in Nairobi (Gonzales, 2009)

2.6.1. Introduction

One of the models used in Nairobi currently, proposed by a student from the University of Nairobi. However, IBM is coming up with other new ways of doing so. In this section we will not discuss the latter. We will discuss the model mentioned earlier. This model is the premise for the investigation of the current conditions and the impacts as travel demand increases. Micro-simulation programming is used to demonstrate point by point vehicle interactions and random deviation in the behavior of various drivers. The software is used to simulate traffic data which is totaled to see the network traffic conditions perceptibly and produce a representation of vehicle mobility and traffic congestion on the system.

2.6.2. Available data

The simulation model depends on information given by Columbia University's Center to Sustainable Urban Development (CSUD), the University of Nairobi, and the Kenya Institute for Public Policy Research and Analysis (KIPPRA). The data is accompanied with data in the Japan International Cooperation Agency's (JICA) 2006 report entitled "The Study on Master Plan for Urban Transport in the Nairobi Metropolitan Area in the Republic of Kenya" (Katahira and Engineers International, 2006). Aerial photos from Google Earth and Microsoft Live were likewise used to estimate network properties where other data was not accessible. The network geometry was resolved using GIS information. Network attributes, for example, free flow speed, road capacity, and jam spacing were assessed using data from the JICA report.

2.6.3. Methodology

The model was created and run using the microscopic simulation programming software CORSIM. Since this product was designed basically for use by the United States Federal Highway Administration, adjustments were expected to validly simulate the traffic in Nairobi. Nairobi traffic drives on the opposite side of the road than the United States, so the system was flipped, as if viewed in a mirror, to represent right-handed driving in the simulation. The model considers two classes of vehicles: cars and Matatus. The car streams depend on the origin-destination (OD) flows amongst generation and attraction nodes. Matatus were demonstrated as short buses operating on fixed routes.

2.6.4. Criticisms (limitations) of this model

Simulating traffic on a network that matches the genuine geometry, signage, and path design in Nairobi produces unrealistic traffic behavior, this is because CORSIM assumes a North American working environment and driving style. Another limitation of this model is that the

vehicle operation of Matatus is altogether different than that of typical fixed route buses. This means that the method of estimation is not so accurate and that a better model needs to be developed.

3. METHODOLOGY (Mir Shabbar Ali, 2013)

3.1. Introduction

The technique used consists of gathering data for free flow speed, traffic volume, congestion delay and value of time. The cost of congestion is additionally evaluated through a simulation of the study. This is done by making a model in excel which will be used to evaluate the cost of traffic congestion. The plan is to distribute questionnaires to people who travel and face traffic, and collect the necessary data needed to calculate the cost of traffic. There are some assumptions that are made when creating the model to calculate the cost of traffic congestion. These assumptions include:

- The number of cars that can be on langata road during the rush hour are 1636 cars. This figure was gotten by dividing the length of the road by the summation of the average length of the car and the average spacing between cars during the rush hour.
- Average distance to destination was simulated (randomized), and averaged between 0.1km to 5km.
- Approximate litres of fuel wasted in traffic was simulated and averaged to give 0.1 litres to 2 litres. (RACQ, n.d.)
- The number of passengers in car range from one to five, in a bus range from one to ten, and in a matatu range from one to twenty five.

3.2. Study area

The area of study of this paper is going to be one of the busiest roads in Nairobi, Langata road, where the problem of traffic congestion is very large, and needs to be given attention to.

3.3. Data collection and processing

The project methodological framework is to envelope the data collection, data processing, data analysis and the final step of congestion estimation and valuation, which depends on the gathered data. This is clarified in the following paragraphs below.

For data collection, a questionnaire will be distributed to people who use langata road and face traffic. This questionnaire can be found in the Appendix of this document, on page 29 of this document. The information gotten from these is going to be the flow speed, traffic volume, congestion delay and value of time.

The information is gathered for people facing traffic during the morning rush hour, from Bomas of Kenya, the beginning of langata road, to the Nyayo stadium, the end of langata road. The plan is to distribute at least fifty to a hundred questionnaires, so as to get as many responses as possible, and ensure reliability of the results.

Volume data is categorized into various travel modes, for example, Cars, Motorcycles, Matatus, Pickup, Busses, Trucks and Trailers, Bicycles and Taxis. The delay study is conducted through the questionnaires as well. The delay time is ascertained in light of the definition that aggregate collected time of the vehicle for which it is stuck in traffic on langata road. Special emphasis is given on the precision of the delay data thus it is computed manually using the excel model created.

Estimation of the Value of Time (VOT) is likewise assessed using the questionnaire. The questionnaire provides information about commuter's mode choice and different attributes of the travel modes such as travel cost, travel time and waiting time in case of Public and Para transit types of mode (Mir Shabbar Ali, 2013). The thought is to assess VOT of people travelling in various modes using an indirect method which depends on evaluating mode-specific utility equations that incorporates travel time and travel cost parameters, as part of the model structure. The evaluated VOT values are used to estimate opportunity cost component of traffic congestion cost.

Fuel efficiency and fuel consumption data for different types of modes, prevailing in that road stretch, is gathered to estimate vehicle operating cost component of traffic congestion cost. (Mir Shabbar Ali, 2013)

Equation (1), (2) and (3) represents the expressions utilized to compute opportunity and vehicle operating costs.

$$OC = \sum_{m=1}^m (VOT_m * Delay_m * V_m * VoCC_m) \quad (1)$$

Where,

OC= Opportunity Cost of traffic congestion

VOT_m= Value of time for specific mode m, which is gotten by using the following formula:

VOT= Achievement (monetary terms) if there was no traffic + Willingness of a person to pay to forego traffic – Production lost in traffic (in monetary terms) - Cost of traffic in monetary terms (to the person, usually in terms health, stress) - Approximate travelling costs per day (usually the fuel costs)

Delay_m = Travel delay in time units observed for mode m (the average time spent in traffic)

V_m=number of vehicles of type m per day on the road

VoCC_m = Average vehicle occupancy for specific mode m – this is the average number of passengers per mode type. (European Environment Agency, 2015)

$$VOC = L * \sum_{m=1}^m (FC_m * Delay_m * V_m) \quad (2)$$

Where,

VOC= Vehicle operating Cost,

FC_m = Fuel cost in KShs/Hr for specific mode m,

V_m = as mentioned earlier is the number of vehicles of type m per day on the road

Delay_m = As mentioned earlier, is the travel delaying time units.

L= length of stretch in Km.(in this case it is 8.6 Km, from Bomas of Kenya to Nyayo stadium)

Where, **FC_m** is calculated using equation (3).

$$FC_m = \sum_{Ft=1}^3 (Fcq_m^{Ft} * Fp^{Ft} * \mu^{Ft}) \quad (3)$$

Where,

Fcq_m = Fuel consumption quantity in litres/km or Kg/km of specific mode m

Fp^{Ft} = Fuel price of specific fuel types KShs /litres. In this case we use the price of petrol to be 84.25 Kshs and the price of diesel to be 70.37 Kshs. (Daily Nation, 2016)

μ^{Ft} = Proportion of specific mode type m using a particular fuel type for travelling on that road stretch.

4. RESULTS AND FINDINGS

The initial plan was to get data from reliable sources like IBM or Kenya bureau of statistics and other similar sources. However, this was not possible and hence the methodology had to be changed to actually collecting raw data using questionnaires.

As mentioned in the methodology above, the target number of responses was between fifty and a hundred. The results were positive where responses were gotten. This is a good figure and helps in ensuring reliability. The responses collected from these questionnaires were assessed with regards to the methodology and a figure of **Kshs 40,613,704.44**.

Based on the equations stated above to calculate the cost of traffic congestion, and the different components of these formulae, the results of the data collected from the questionnaires was as follows:

Firstly, the value of time (VOT), was calculated using the data collected by the questionnaires. The following is the general result of how much different people using different modes on langata road value their time:

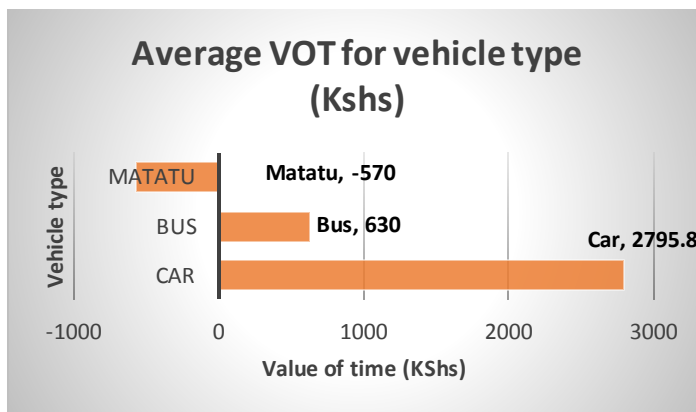


Figure 1: Average Value of Time for the different vehicle types

Next, the results gotten for the delay time of different modes of transport (average), is as follows:

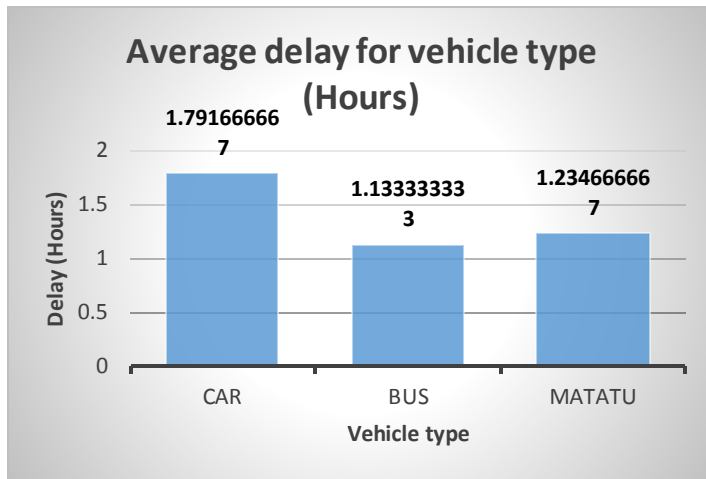


Figure 2: Average delay for vehicle type in hours, per day

The proportion of the number of vehicles on langata road for different vehicle types was found to be as follows:

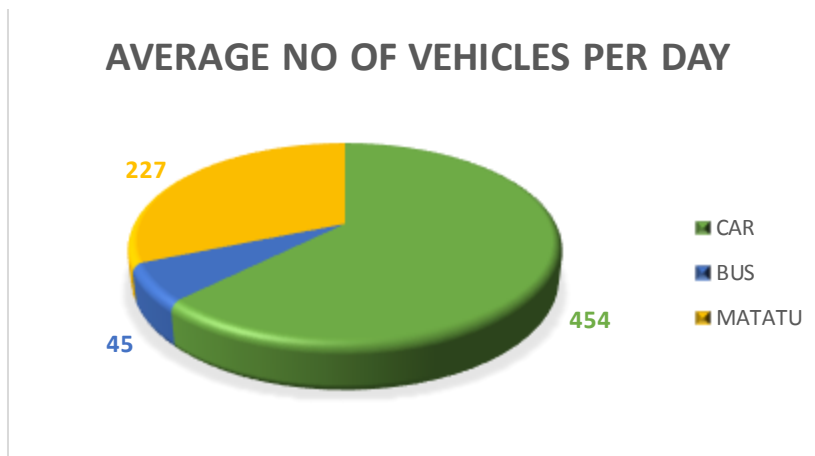


Figure 3: Average number of vehicles on langata road for different mode types (per day)

The average vehicle occupancy (Average number of passengers per mode type), based on the data collected was as follows:

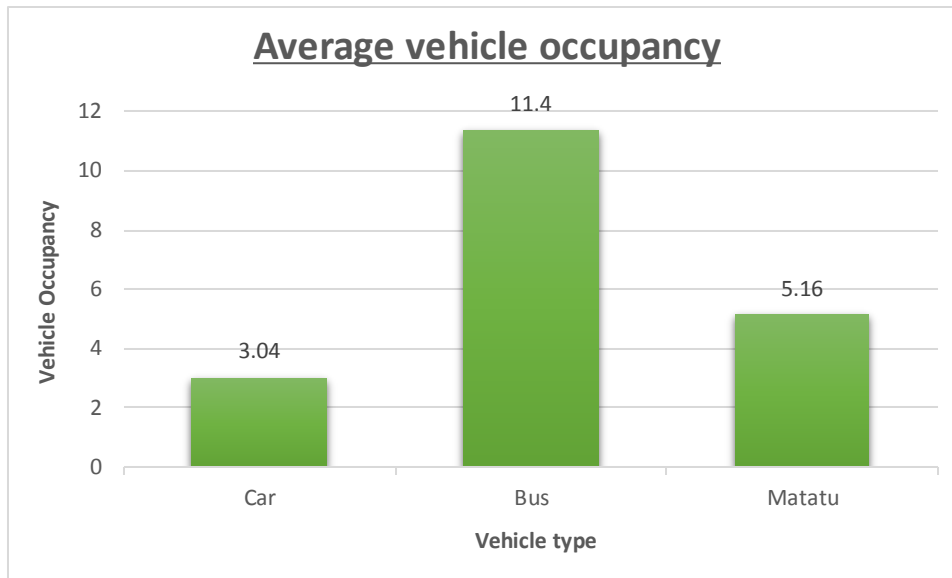


Figure 4: Average vehicle occupancy for the different mode types.

The fuel costs, based on the assumptions stated, and the data collected, for the different mode types were as following:

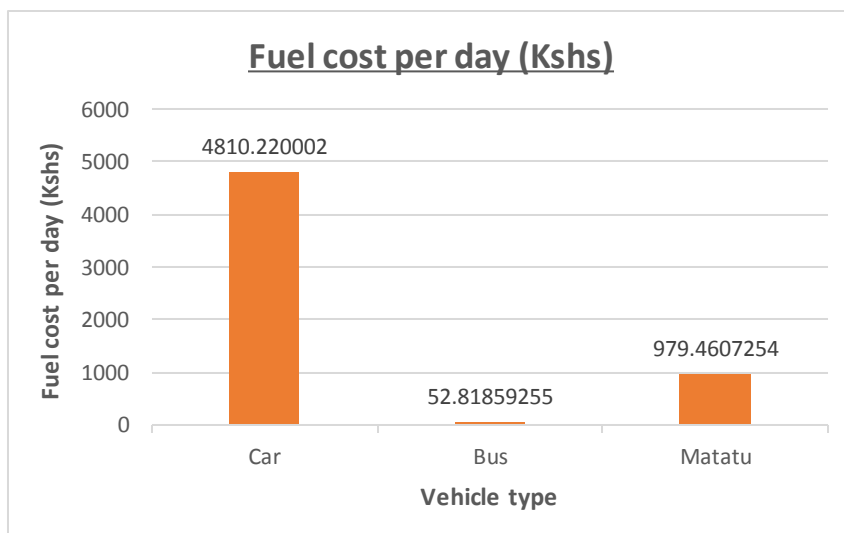


Figure 5: Average fuel cost in Kshs for the different mode types per day

And finally, the cost of the different components of the cost of traffic congestion per day were as follows:

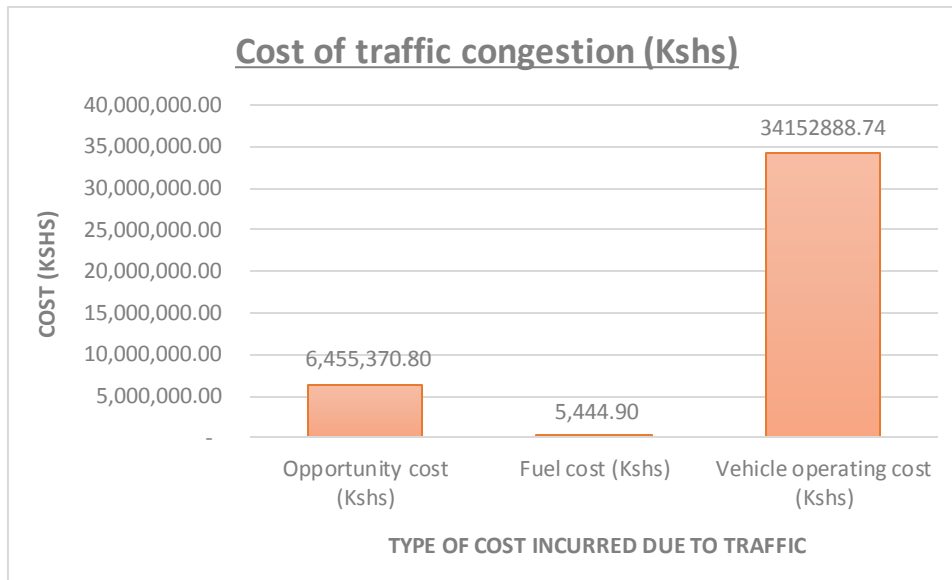


Figure 6: The contribution of different costs to the total cost of traffic congestion

Summing the above three different components of the costs of traffic congestion gives us the total cost of traffic congestion per day on langata road to be **Kshs 40,613,704.44**

5. DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

In this chapter, we are going to assess and analyse the results stated in the above chapter, and discuss some of the consequences and implications of these results and how they relate to our problem statement and research objectives and questions. We will also talk about some of the ways in which this project could be improved (recommendations).

5.2 Discussion

In this section we will analyze our results of the study that were stated in the previous chapter.

We first start with the average value of time for each vehicle type. We can see from the above that cars have the highest VOT (Kshs 2795.80), followed by bus (Kshs 630) and matatus have the least VOT (Kshs -570). One of the possible reasoning for these figures could be the following: As we know, matatu drivers are harsh drivers and usually don't really sit in the traffic, they like overtaking and passing by the traffic, therefore time spent in traffic is not really a big issue to people who use matatus for transport. On the other hand, we know that most of the people with cars are middle-class and high-class, and usually literate people. This means that most of them follow rules and do not overtake and hence are stuck in traffic for hours, therefore they value their time more than the others mentioned above. The proportion of people using buses are pretty low and hence leading to the low value of VOT that we got.

Next, we look at the average delay for each vehicle type. We can see that the delay for each vehicle type is not so different from each other. There are minor differences. This could be due to the vehicles all travelling on the same road, hence delays are approximately similar. In this case again, people using the cars have the highest delays, followed by matatus and then buses.

The number of different types of vehicles on langata road is what we are going to look at next. We can see that the highest proportion of vehicles on langata road are cars (63%), followed by

matatus (31%), and the finally, the least proportion of vehicles are the buses (6%). Most of the people travelling on Langata road comprises of people living in either Karen, Langata, and Madaraka. Most of the people living in these areas are middle class and high class people, and so are expected to have a car, therefore explaining why the highest number of proportion of vehicles are cars. Others, without cars prefer matatus over buses since they are cheaper and more readily available, explaining the proportions.

Next, we look at the average vehicle occupancy for the different vehicle types, which is as mentioned earlier, the average number of passengers per vehicle type. In this case, buses have the highest value of average vehicle occupancy, followed by matatus and then cars. The reasons for this could be the fact that buses can hold the most number of passengers, followed by matatus, and relatively the least by cars.

We next look at the fuel costs per day for each vehicle type. Just as the trend has been for the other factors, cars once again have the highest amounts of fuel costs, followed by matatus and then buses. It might be possible to link these to the delay time in traffic and the proportion of people using the specific vehicle type, both mentioned earlier.

Finally, we have a look at the different components of traffic congestion costs, which as stated earlier are the opportunity costs, fuel costs, and the vehicle operating costs. It can be seen that the vehicle operating costs are the highest. This may be due to the wear and tear of the car and other reasons due to which the car's condition deteriorates and hence has to be repaired and maintained. The second highest is the opportunity cost, followed by the fuel cost.

Summing all these costs together brings us to a total amount of traffic congestion cost of **Kshs 40,613,704.44**. This is a huge figure and signifies the problem of traffic congestion and signals that traffic reduction methods really need to be put in place. This is a figure for only one road, per day. We can just imagine how much we would be losing in total including all the roads in Nairobi, and even worse in Kenya. These are huge amounts of money lost which can be put to better productivity, increasing the GDP of Kenya, and transform it to a very developed country in the world.

5.3 Summary

In summary, the main objective of this study was to calculate the cost of traffic congestion in Nairobi to the Kenyan economy, taking Langata as a sample, which we have done by using the methodology stated above, and from our findings, we can see that traffic congestion is a huge problem in Kenya and is associated with huge losses, which is a huge loss to the economy of Kenya. This is a signal that actions need to be taken to reduce the problem. The secondary objective was to determine the different factors that cause traffic congestion which we have covered in the earlier chapters, where we found out that the main reasons of traffic congestion in Kenya is the ever growing population of Kenya, and hence more cars being bought and no increase in the roads, leading to congestion.

5.4 Conclusions

In conclusion, we can say that the problem of traffic congestion is one that cannot be left to continue, as it will become a hindrance to the success and development of the country. And that the government should look in to the matter and put funds aside to fund projects that will reduce the traffic congestion in Kenya.

5.5 Recommendations for further research

This model is not at all perfect and has many mistakes due to lack of time and other factors, and can be made better in many ways to give a more accurate and reliable figure for the cost of traffic congestion. Some of which include:

Firstly, this project requires a lot of time to be carried out in a sufficient manner. Due to lack of time, also the study had to be narrowed down to one road only. With adequate time, a better and wider study can be carried out.

Next, also this study requires a lot of data to be collected, and even a longer time to assess this data and use it to calculate the cost of traffic congestion. Again due to lack of time, this could not be done and for some parts of the data, assumptions had to be made.

Although the assumptions do make sense, there are still some aspects of these assumptions that are not so convincing, since there was not enough time.

Moreover, it is better if data can be gotten from a reliable source, which would give all the data and in bulk, and also has accurate data, unlike collecting from a small sample using questionnaire.

Finally, it would be good to be in touch with an organization that is in charge of the travel and transportation system, since they can help analyze data better, and the results of the study could be used to improve the traffic of our country.

Appendices

Appendix 1: Questionnaire

ESTIMATING THE COST OF TRAFFIC CONGESTION IN NAIROBI TO THE KENYAN ECONOMY

Questionnaire

We are working on calculating the cost of traffic congestion on the Kenyan economy and need your help.

Kindly fill in the questionnaire with honesty and sincerity and help in this project.

Your contribution is highly appreciated.

- 1) Occupation:
- 2) How often do you travel (to work or anywhere else)? (Tick one below)
 - Daily
 - Weekly
 - Monthly
 - Yearly
 - Others (please specify).....
- 3) What mode of transport do you use when you are travelling?
.....
- 4) What are your approximate travelling costs per day?
.....
- 5) How much time do you usually spend waiting in traffic?
.....
- 6) How much would you be willing to pay in KShs for you not to face traffic?

.....
7) How much on average do you lose per day by spending time in traffic (by work/production lost)?

.....
8) What is the cost of traffic per day according to you? (eg. Cost of fuel lost? Any other cost you face? Specify)

.....
.....
.....
9) How much more do you think you can achieve per day if there was no traffic? (a monetary value if possible)

.....
10) What effects do you think being in traffic (both morning and evening) has on your production during the day and your well-being after? (eg. Tiredness, fatigue)

.....
.....
.....

Thank you for your cooperation and time.

References

- C.S-W. (2014). The cost of traffic jams. *The Economist*, 1.
- Daily Nation. (2016, May 14). *Energy regulator increases fuel prices*. Retrieved from Daily Nation: <http://www.nation.co.ke/business/Fuel-prices-go-up/996-3203326-i8msadz/index.html>
- European Environment Agency. (2015). *Occupancy rates of passenger vehicles*. Retrieved from European Environment Agency: <http://www.eea.europa.eu/data-and-maps/indicators/occupancy-rates-of-passenger-vehicles/occupancy-rates-of-passenger-vehicles>
- Gonzales, E. J. (2009). Multimodal Transport Modeling for Nairobi, Kenya: Insights and Recommendations with an Evidence-Based Model. *UC Berkley Center for Future Urban Transport*, 15-23.
- IBM East Africa. (2011, September 12). *Nairobi among cities with worst jams*. Retrieved from BUSINESS DAILY: <http://www.businessdailyafrica.com/Corporate-News/Nairobi-among-cities-with-worst-jams--/-/539550/1234892/-/item/0/-/ridsfoz/-/index.html>
- Laursen, L. (2013, November 5). *IBM Nairobi Lab's First Offering is a Traffic-Dodging Mobile App*. Retrieved from IEEE SPECTRUM : <http://spectrum.ieee.org/tech-talk/computing/software/ibm-nairobi-labs-first-offering-is-a-trafficdodging-mobile-app>
- LIVINGINNAIROBI. (2011, January 17). *Traffic in Nairobi- Traffic situation*. Retrieved from Living in Nairobi: <http://www.jambonairobi.co.ke/info/traffic-nairobi/traffic-situation/>
- Mathew, P. T. (2014, August 5). *Lecture notes in Traffic Engineering And Management*. Retrieved from Capacity and Level of Service LOS: https://www.civil.iitb.ac.in/tvm/1111_nptel/551_CapLOS/plain/plain.html
- Mir Shabbar Ali, & M. (2013). Estimation of Traffic Congestion Cost-A Case Study of a Major Arterial in Karachi. *ScienceDirect*, 39-40.
- N.Katala, E. J. (n.d.). THE COST OF TRAFFIC CONGESTION AND ACCIDENTS TO THE ECONOMY IN TANZANIA. *THE COST OF TRAFFIC CONGESTION AND ACCIDENTS TO THE ECONOMY IN TANZANIA*, 1.
- Professor Chris Nash, & M. (1999). CALCULATING TRANSPORT CONGESTION AND SCARCITY COSTS. *FINAL REPORT OF THE EXPERT ADVISORS TO THE HIGH LEVEL GROUP ON INFRASTRUCTURE CHARGING*, 10.
- RACQ. (n.d.). *Understanding Fuel Consumption*. Retrieved from RACQ- Understanding Fuel Consumption: <https://www.racq.com.au/cars-and-driving/cars/owning-and-maintaining-a-car/fuel-saving-tips/measuring-fuel-consumption>
- Sarah McGregor, & D. (2014, March 26). *Traffic Costs Nairobi \$570,000 a Day as No. 2 Africa Hub*. Retrieved from Bloomberg: <http://www.bloomberg.com/news/articles/2014-03-25/nairobi-traffic-loses-570-000-a-day-as-no-2-africa-hub>

Standard Media. (2014, August 28). *Nairobi City traffic jam costs Kenya 37 billions shillings annually*. Retrieved from Opinion Lifestyle-This is Africa: <http://thisisafrica.me/nairobi-city-traffic-jam-costs-kenya-37-billions-shillings/>

Victoria Transport Policy Institute . (2016). Transportation Cost and Benefit Analysis II – Congestion Costs. *Transportation Cost and Benefit Analysis II – Congestion Costs*, 5.5-1.