Measuring the Economic costs of traffic congestion

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***Abstract*—The main focus of this research is to examine traffic congestion costs related with the road passenger transportation. With the rapid urbanization, it is evident that commercial and socio economic activities tending to centralize only in major cities in a country. This has led to increase in the number of the commuters daily traveling to the cities from peripheries. Further the economies grow and the real income of households & vehicle population are also increasing. As a result, traffic congestion has become a major issue within urban cities. Road traffic congestion interrupts and reduces productivity levels and, it is a symbol of economic inefficiency. In this research, we present a methodological process to estimate congestion cost. The process includes data collection to the analysis of main two cost factors of road traffic congestion. Those cost factors are workforce productivity time loss & the excess fuel energy consumption/operating cost. The significance of this study is that it provides a measure of the real monetary cost of congestion..**

Keywords— Road Transportation; Traffic Congestion; Congestion cost; Transport Productivity; Economic Efficiency

I. INTRODUCTION

Economic cost of traffic congestion is one of the most debatable issues in an economy. It would be safe to assume that economic cost of traffic congestion has been discussed for a long time and the problem still exists although massive investments on road transport sector is underway. Traffic congestion in roads has a massive cost impact on the production and the general and work lives of many people. Traffic congestion has not only impacted passenger transportation but also the freight transportation. Most developing countries including Sri Lanka suffers an enormous financial and labour time losses due to road traffic congestion.. This loss was estimated at Rs. 32 billion rupees per annum. This has risen up to Rs. 40 billons per annum in 2012[1]. That is approximately 1.5% from the Gross Domestic Production (GDP) of Sri Lanka.

Fundamentally road traffic congestion occurs when a volume of traffic generates demand for road space greater than the available road capacity (supply). Although the capacity of the city road network increases by 2-3% annually on average, it is incapable of handling increasing road traffic flows at the rate that is demanded, which is around 10% increase annually [1]. According to automobile registration records in Sri Lanka,

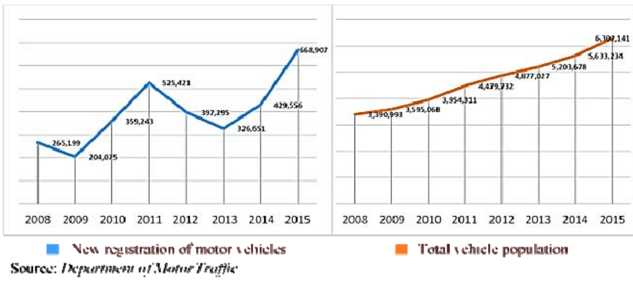


Fig. 1. Variation of vehicle population in Sri Lanka

the automobile ownership is more than 6.3 million. In peak hours, more than 3 million automobiles use road network all over the country. Notably, more than 0.25 million of automobiles are inbound to Colombo city [2].

According to Fig. 1, the number of vehicle imports/vehicles used with per capita is significantly rising in 2011 & 2015. The growth of vehicles per 1000 people from 2008 to 2015 has risen from 171 to 305 [2].

The economy of Sri Lanka has been suffering from rising economic cost from road traffic congestion. These costs include waste (loss) of time, fuel economy and wear and tear of automobiles and accidents. Most significant factors contributing to the problem were poor city planning, inappropriate public transport facilities and insufficient traffic system. However, increase in demand for private automobiles and high usage can be identified as a root cause of the problem. Private motorized transport share has increased due to lower level of service in public transportation industry (inappropriate public transport facilities). The use of public transportation has decreased by 25% from (65%) in 2008 to (40%) in 2016 [3]. The share reduction from public transportation services has been transferred to private automobile like car, van, trishaw and motorcycle which are mainly contributing to increase urban traffic congestion. Currently, 0.1 million of automobiles, 0.13 million of trishaws, 0.04 million of vans and 0.37 million of motorcycles are annually adding to national traffic aggravating traffic congestion issue [3]. The ultimate result is that the government has to allocate a considerable portion of budget on transport infrastructure development projects (to increase supply and the capacities of transport infrastructures). However, in most countries including in developed transport systems, public investment in road capacity improvement is not adequate to curtail the growth of traffic volume [1]. The result has been a relentless increase in traffic congestion. Thus, it is important to estimate the economic value of traffic congestion in Sri Lankan context which will help policy decision making in resource allocation in road infrastructure investment.

According to experts, in peak hour, traffic flow speed from Colombo city limits to sub urban cities has reduced 28kmph to 9kmph in 1997-2001 period [5]. In addition peak hour traffic flow speed within city limits has reduced 32kmph to 6kmph. It is a common situation for most road networks in urban centres. Furthermore, though Expressways provide travel up to 100kmph speed, when inbound/ outbound from urban regions vehicles spend more than 2 hours to travel 20 km. Acceleration & deceleration of vehicles lead to increase in operating costs in terms of fuel, tires and brakes. Similarly the sound effects of road traffic congestion, safety, discomfort and unreliability of the journey and more importantly the time costs to commuters, low level utilization of vehicles and interruptions to the freight flow are major costs of traffic congestion..

Traffic congestion makes both public commuters and private motorists spend additional time on the roads, paying extra for fuel. As the number of automobiles on the roads increases it takes ones journey lengthier and need to spend more time and cost to reach the destination. Sri Lanka has now become a county using 21% percent of fuel for transportation while other neighbouring countries use less (India 7%, Thailand 16% and Malaysia 19%). Most important fact is that this percentage has doubled within past three years [6]. Therefor it is good indicator to measure the level of efficiency of a national transportation system.

A. *The scope of the research*

The scope of this research is to examine ways of estimating the economic costs of road traffic congestion in Sri Lankan context. The purpose of the research is to provide economic criterion to empirically measure the congestion cost.
This study focused on measuring congestion cost on public passenger transportation in Galle corridor, a major highway of Sri Lanka. The study covers the value of congestion delay for personal travel including occupational and commercial trips.

B. *Research Objectives*

- The Main Objective of the paper is to propose an analytical method to measure economic cost of traffic congestion related with passenger transportation. The study achieves the main objective with the help of few secondary objectives. They are;
  - Propose an analytical method to calculate Value of Time (VOT)
  - Propose an analytical method to calculate Additional Fuel Consumption (Operation) Cost (Vocc)
- Examine current economic efficiency level of road passenger transport facilities of Fort to Moratuwa section of the Galle corridor

II. Literature Review

Research on Economic costs related to traffic congestion was carried out by number of researchers using difference techniques/ methodologies. This paper presents a widespread review of the literature on measuring the economic costs of road traffic congestion. Especially those literatures can be categorized according to data collection methods, methodologies that used to approach the context, evaluation & data analysis method, indicators considered, and errors mitigation methods.
The following formula was adopted to calculate traffic congestion cost [2].

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

Where, OC = Opportunity Cost of traffic congestion, VOT_m = Value of time for specific mode m, $Delay_m$ = Travel delay in unit time observed for mode m (estimated at some reference speed), V_m = number of vehicles of type m per day, $Vocc_m$ = Average vehicle occupancy for specific mode m.

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

Where, VOC = Vehicle Operation Cost, FC_m = Fuel cost Rs/hr for specific mode m, and L = length of stretch in Km.

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

Where, Fcq_m = Fuel consumption quantity in litres/km (or Kg/km) of mode m, Fp^{Ft} = Fuel price of specific fuel types Ft = 1, 2, & 3 such as CNG, Gasoline and Diesel respectively in Rs/litres or Rs/kg. μ^{Ft} = proportion of specific mode type m using a particular fuel type for travelling on that road section.
Here, the calculations are carried out separately for difference mode of transport in the traffic stream and the Opportunity Cost of traffic congestion and the excess Vehicle Operation Cost are can separately evaluate. This is ensuring high accuracy of the output.

Data analyse used by Harriet & Emmanuel, (2013) includes the following benchmarks;

- Traffic Flow Volume Analysis
- Key Roads in Order of Congestion Level
- Traffic mix distribution
- Field data (Primary data) analyse

The researchers have used descriptive statistics of simple averages to analyse primary data. The study on influence of the transportation system in Kumasi on Driver's Productivity analysed according to trip classifications [3]. The anticipated and the actual number of trips and income have been analysed in this research.

The following three curves have been used in evaluating economic cost of traffic congestion [4].

- Supply–demand shifts in response to transportation investment
- Hypothetical bid-rent curve
- Conceptual marginal and average travel costs during congested conditions

It is shows that road traffic congestion reasons first-order delays and inefficient commuting times. But, these approximations of cumulative economic impact rely on valuing the opportunity cost of travel delay.

There are six steps have been used in congestion cost estimation process [10]. First three steps represent measurement of traditional user impacts (Trip data, Travel time and distance data & User travel cost calculation). These are additional time and expenditure suffered by users as a result of traffic congestion, and mitigation of those user costs is reflected to be the primary transportation system productivity benefit of transportation volume upgrading projects. Other three steps represent measurement of nonuser economic impacts (Total unadjusted business cost calculation, Activity data, Statistical estimation). These are changes in business costs or revenue subsequent from changes in wage compensation, scheduling, logistics, and market-scale economies as a consequence of changes in traffic congestion density.

III. METHODOLOGY

A road section of Galle corridor (A2), (Moratuwa to Pettah) is selected as the data collection point for this research. It is the main gateway to Colombo from the Southern parts of the country and is a highly demanded section for daily commuting that also integrates various modes and services of transportation to cater the daily definite requirements of commuters. Currently there is a huge traffic flow in Galle road during the peak hours and it is directly causing a higher economic cost of congestion.

A. Data Collection

Primary data was obtained from a socio economic survey that was conducted in the Galle corridor. The socio economic survey includes data related with commuters' travel distance, travel time, working hours, willingness to pay values for saving travel time (if the speed doubles) and from private transport mode users, fuel consumption quantity of the vehicle & the vehicle leasing payment related data were obtained. Those data were used to analyse the value of time of daily commuters, travel distances, average peak & off-peak travel speeds and average vehicle fuel consumption quantities. The survey was conduct for both public and private transport mode users. The survey on bus passengers was conducted during morning peak hours and included randomly selected 30 of daily bus commuters as a sample. The survey on private vehicle users consisted of a randomly selected sample of 30 for each mode of private transport.

Secondary data was obtained from Vehicle counts and bus data received from the Bus Rapid Transit (BRT) surveys conducted by the Department of Transport & Logistics Department, University of Moratuwa on the 4th Sep 2014.

B. Data analysis method

Collected data was analysed using MiniTab and MS Excel for generating descriptive statistics. A formula derived from literature was used to calculate economic value of time loss due to traffic congestion with high accuracy. The method is also reliable as it accounts for different mode of transport separately. As different modes of transportation separately considered, the analysis for bus, trishaw & motor cycle passengers were carried out using willingness to pay (WTP) values, method 1, with the objective of deducing travel time (save the travel time). Other data on passengers those who use cars/vans were analysed using a strategic method (SM), method 2, additionally to the willingness to pay values. In the strategic method, the interviewee were asked about whether vehicle is leased one or not, car type, the leasing institution, the monthly leasing payment amount which they obliged to pay and the number of members in the family. These data is useful to derive the average income of a person in the sample.

IV. RESEARCH FINDINGS

A. Transport system in Galle corridor

The Galle road corridor comprises of only four lanes to the both directions which caters bidirectional vehicle traffic volume of 67,600 vehicles. Among them 3790 are busses which cater 80% of the road passenger volume. In terms of physical geometry, the width of some sections of the road is narrowed up to 20m in the Galle corridor which has increased the peak hour vehicle traffic up to 2900 PCU and reduced the average speed up to 13kmph. The peak hour average bus load factor is 101% which caters approximately 41% of the total bidirectional passenger demand. Current traffic plan in the Galle corridor has been effective to a certain extent by introducing one-way traffic in the parts of the road/sections. Nevertheless, arguably the cost of the additional distance travelled by the vehicles outweighs the benefit earned by the time saving. . It is also found that in most instances inefficiencies of the utilization of current road space have adversely effected to increase congestion and lead to passenger discomfort. It is found that approximately 22% of the time one lane is blocked and 5% of the time both lanes are blocked [11]. The discipline of the bus drivers is also in a very unappreciable condition leading to major accidents and congestion. It is identified approximately 60 bus routes using the Galle corridor. Feeder bus system also shows grave inefficiencies in transferring the passengers to the main busses running in the Galle corridor.

B. Estimation of Economic Costs of Traffic Congestion

a) Vehicle user's data analysis of Galle corridor

Western Province modal share is shown by Table. 1 & the number of passenger data are shown in Table. 2. According to statistical data available in the Department of Census and Statistics, population growth in Sri Lanka recorded from 2014 to 2016 is 0.19%. If the number of passenger growth has same value, the average number of passengers for 2016 can be predicated.

TABLE 1 - WESTERN PROVINCE MODAL SHARE

Western Province	
Vehicle type	***Modal Share***
Bus	*48.1%*
Train	*3.4%*
Car/van	*14.3%*
Motor cycle	*17.9%*
3 wheelers	*16.3%*

a. Source: ComTrans JAICA(2014)

TABLE 2 - GALLE CORRIDOR PASSENGER DISTRIBUTION

Veh. Type	Pax. (2014)	Pax. (2016)
Motor cycle	19,949	19,987
3 wheelers	21,823	21,864
Car/Van	33,802	33,866
Bus	119,016	119,242

b) Analysis of Number of Vehicle in Galle Corridor

The average number of passengers in each mode of road transportation & the average daily bi-directional traffic volume variation in Galle corridor data were obtained from the vehicle counts conducted by Department of Transport & Logistics Management in 4th Sep 2014. Those data represented in following Table 3. If we assumed traffic density growth from 2014 to 2016 is 1.5%, the vehicle capacity for 2016 can be estimated.

TABLE 3 - AVERAGE DAILY BIDIRECTIONAL TRAFFIC VOLUME

Veh. Type	#Veh. (2014)	Avg. #Veh. (2016)	Pax per Veh.
Motor cycle	15,345	15,575	1.28
3 wheelers	11,486	11,658	1.88
Car/Van	16,260	16,504	2.05
Bus	3,790	3,847	31.00

c) Analysis of Average Speed of Galle corridor

Sri Lankan government has regulated driving speed by Motor Traffic (Speed Limits) Regulations, Gazette No. 1763/26 of 2012. It has divided road network into two sections as Built-up areas and Non-Built-up areas. All automobiles operating on the segments of the "Built-up areas" are subjected to 50kmph speed restriction. However, the speed limit with respect to land vehicles, motor tricycles, motor tricycle vans and special purpose vehicles operating on the segment of the built-up roads are specified to 40kmph. All other road segments in Sri Lanka which are not specified in the schedule to these guidelines are known as "Non-Built-up areas". The speed limit relevant to the road segments of the Non-Built-up areas is 70kmph for all categories of automobiles and 60kmph for all motor coaches and lorries.

In this research considers only those regulated speed limits as the maximum utilized speed (design speed) of road sections. The observed average peak and off peak time are used to calculate average peak and off peak speeds. Comparison of these design speeds and actual speeds are represented by the following Fig. 2 & 3.

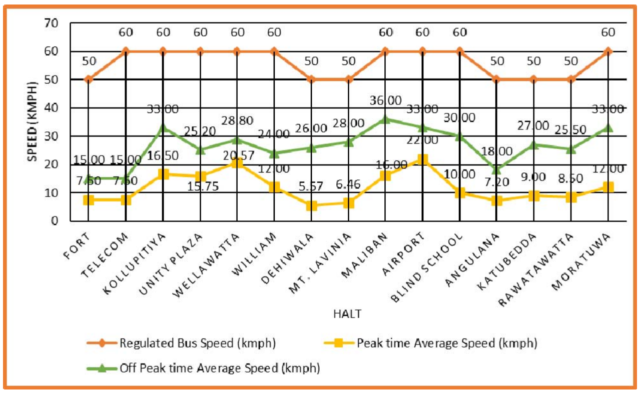


Fig. 2. Average Speed Variation of Buses in comparison to the Regulated Speed Limits

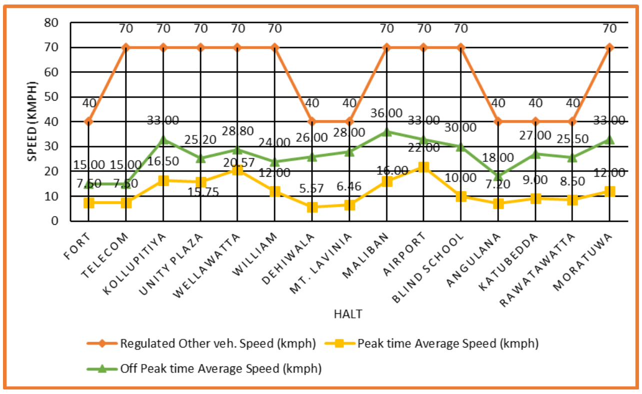
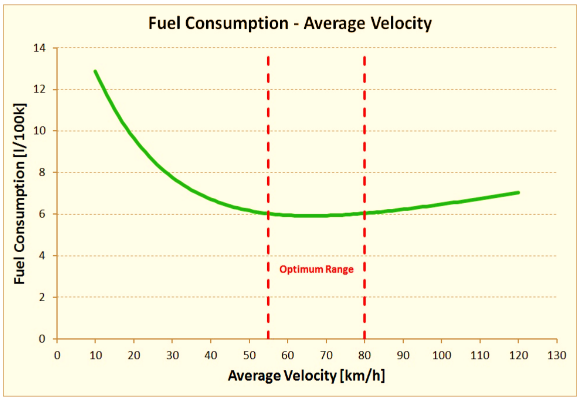


Fig. 3. Average Speed Variation of Private Vehicles in comparison to the Regulated Speed Limits

d) Vehicle Fuel Consumption variation with speed



[a] Source: http://www.myengineeringworld.net/ ("My Engineering World", n.d.)

Fig. 4. Vehicle Fuel Consumption variation with speed

Fig. 4 describes the relationship between fuel consumption of the engine and the average speed of an automobile. The graph is divided into four zones, parallel to four speed ranges,

When considering these figures in relation with Galle road condition, as shown in Figure. 2 & 3 the design speed varies between 40kmph to 70kmph and the actual speed varies between 0kmph to 40kmph. Therefor reduction in speed influences to increase fuel consumption approximately from 16.66 km/l to 12.5 km/l. This means reducing 24.96% of fuel economy of the vehicle for a driving distance (km) for a fuel litre.

Table 4 presents the estimated values for fuel consumption quantity of each different modes of transport. 'µ' factors denote proportion of each modes of transport according to the fuel type. 'µ' factors are calculated using statistical data available in the Department of Motor Traffic, Sri Lanka.

TABLE 4 - FUEL CONSUMPTION QUANTITY & PROPORTION OF EACH MODES OF TRANSPORT ACCORDING TO FUEL TYPE

Modes	µ (Petrol)	µ (Diesel)	µ (Hybrid)	Fcq (Petrol) (km/l)	Fcq (Diesel) (km/l)	Fcq (Hybrid) (km/l)
Car/Van	0.45	0.24	0.31	14	15	16
Three Wheeler	0.94	0.06	-	28	32	
Motor Cycle	1	-	-	47	-	

e) Value of Time Analysis

Value of Time of passengers in buses, motor cycles and three wheelers were estimated using additional willingness to pay values, if they are provided infrastructure facilities/transport services to travel with a speed twice as the to the existing driving speed. Hypothetical relationship with this scenario is that, when commuters can travel with a higher speed, they can save additional money which is now spent as fuel/operating cost & value of productive time loss. In this research we assume that the willingness to pay values is equal to the values of these cost factors.

The Value of Time of car/van users are estimated using a strategic method in addition to the willingness to pay values. In the strategic method, interviewee were asked financing method of the vehicle, that is whether the vehicle is leased one or not, leasing/financial institution, car type, the monthly leasing payment which they obliged to pay and the number of family members. A financing organization deciding a car leasing premium for a person considers number factors such as Monthly income (Salary script of last 3 to 6 months), Average monthly expenditure of the family, other income of the family (Number of people who are doing jobs in the family), loans & leasing already taken and the age. Financial institutions basically provide a person 60% of the monthly income of the family.. Assuming 50% of family members contributes to the family income and other loans (housing 9.05%)(Central Bank Report 2015), the following Equation (4) can be derived.

$$\text{Average Monthly Income of the Person} = (\text{Monthly leasing payment}) \times \frac{100}{50.95} \times \frac{1}{(\#\ \text{Family Members} \times 0.5)} \quad (4)$$

By dividing the average monthly income of a person from the working (earning) time x number of working days of a month, the average value of time of a person can be estimated. Primary data analysis carried out and the result are shown in Table. 5.

TABLE 5 - ANALYSIS RESULTS FOR THE VALUE OF TIME

Mode of transport	Avg. Value of Time (Rs. / Hr.)
Car/Van (WTP)	78.59
Car/Van (SM)	291.51
Bus	28.56
Motor cycle	38.10
Three wheeler	101.17

f) Calculations of the Opportunity Cost of traffic congestion

Using the estimated average peak & off-peak speed, the average time delay for each mode of transport can be derived (Equation 5).

Time Delay = Travel delay in time units

$$= \frac{\text{Total Distance}}{\text{Average Time Speed}} - \frac{\text{Total Distance}}{\text{Average Design Speed}} \quad (5)$$

Using Equation (1) the opportunity costs are calculated. Results are as shown in in Table 6.

TABLE 6 - ANALYSIS RESULTS FOR THE OPPORTUNITY COSTS

Mode of transport	Opportunity Cost (Rs. Mn.)
Bus	3.12
Motor cycle	0.21
Three wheeler	0.22
Car/Van (WTP)	2.00
Car/Van (SM)	7.40

Using Equation (3), the Fuel cost (Rs. /km) (for the bus operation it is used average operating cost) is estimated. Using fuel cost values and the Equation (2), the excess fuel (operating) cost was derived. The analysis results are shown in Table 7.

TABLE 7 - ANALYSIS RESULTS FOR EXCESS FUEL/ OPERATING COST

Mode of Transport	Excess fuel Cost/ operating cost (Rs. Mn.)
Bus	4.73
Motor cycles	0.10
Three wheelers	0.03
Car/Van	0.65

C. Comparison of economic cost of traffic congestion

Vehicular traffic congestion has directly impacted on workforce productivity levels and the fuel consumption. In this research economic values for traffic congestion to assess the potential impacts were estimated. Table 8 shows a comparison of economic cost of traffic congestion in Galle corridor for each mode of transport separately. As for opportunity cost of congestion, it represents the value of loss of productive time and the excess fuel cost. Excess fuel cost represents the cost for additional fuel due to traffic congestion in Galle corridor (for the bus operation it is the additional operating cost). This research employed two methods to analyse car/van passengers' related data. However, the final results of two methods show a higher variation. In the first method, commuters' willingness to pay values represents how they believe worth of their wasted time due to traffic congestion. WTP method derived a lower value for VOT (Rs. 2.65 Mn.). In the second method (SM), analyses their actual worth of wasted time and the method help deriving the actual value of economic cost from the traffic congestion (Rs. 8.05 Mn.).

TABLE 8 - COMPARISON OF ECONOMIC COST OF TRAFFIC CONGESTION IN GALLE CORRIDOR

Mode of Transport (Rs. Mn.)	Bus	Car/Van		Motor Cycle	Three Wheel
		WTP method	*SM*		
Opportunity Cost	3.12	2.00	7.40	0.21	0.22
Excess Fuel Cost	4.73	0.65	0.65	0.10	0.03
Total Cost for Day	**7.85**	**2.65**	**8.05**	**0.32**	**0.25**
Total Cost for Year	**2865.25**	**967.25**	**2938.25**	**116.80**	**90.16**

V. CONCLUSIONS

Sri Lanka is a country suffering from severe traffic congestion mainly in urban centres. Traffic congestion has led to greater losses in the national productivity. Increasing population in the urban areas and, as a result, increasing their mobility needs via public and private transport modes coupled with insufficient infrastructure, poor traffic control, complex land use pattern, hazardous driving behaviour and high density of road users create heavy congestion in urban roads, costing more to the society in terms of longer commuting times (reducing workforce productivity), excess operating (fuel) costs. The personalized transport modes and the informal sector such as cars/van, three wheelers and motorcycles are significantly contributing to this congestion. Metropolitan transport system is a critical feature that may expedite and limit urban economic growth depending on the degree of its management for effectiveness and efficiency.

A. Summary of the Findings

The growth of vehicles per 1000 people has risen from 171 to 305 between 2008 and 2016 in Sri Lanka. The alarmingly the bus to private vehicle ratio is 1:11.37 meaning that 91.92% of private vehicles in operation and shared the road space with public transport in the selected urban corridor. Nevertheless, in term of bus passenger capacity to private vehicle ratio is 1.6:1 that means additional 61.16% of passengers are catered by public bus transportation. This indicates that personalized transports significantly contribute to the traffic congestion making significant losses to the economy. Fig. 5 shows the comparison of daily opportunity cost, excess fuel (operating cost) & total cost of traffic congestion.

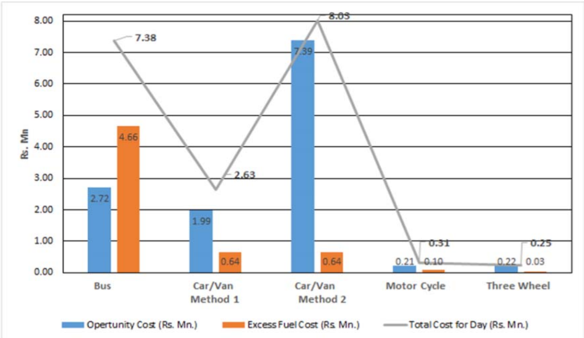


Fig.5 Daily Traffic Cost Variation

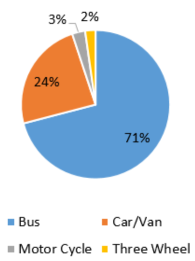


Fig. 6 - Annual Total Traffic Congestion Cost Variation in Galle Corridor (Using WTP method)

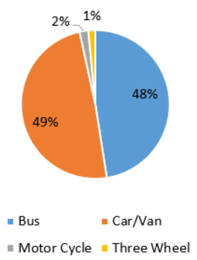


Fig. 7 - Annual Total Traffic Congestion Cost Variation in Galle Corridor (Using SM)

Figure 6 & 7 present mode-wise annual total economic cost of traffic congestion variation for the selected road corridor. Higher percentage of annual traffic congestion cost is born by bus transportation & car/van transportation.

B. Limitations of the Study

Research uses secondary data (vehicle counts) taken from the year 2014. However, the primary data collected by travel time surveys are from the year 2016. To tally passenger capacity for year 2016, the population growth rates of Sri Lanka between 2014 and 2016 was adopted. It is also assumed that the traffic density growth of the selected corridor for the analysis is 1.5% with respect to the year 2014. Those assumptions might reduce the accuracy of the final numerical results; however the methodology of congestion costs estimation remains unaffected. In addition, in calculating VOT, the upper boundaries of speed limits were considered as the design speeds of each road section.

Furthermore, it was assumed that a person can allocate 60% from the monthly total income of the family for the purpose of loans & leasing in the calculation of income of commuters

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REFERENCES

[1] “Massive Rs 32 bln loss due to traffic congestion:Transport expert", *Sundaytimes.lk*, 2016.

[2] "Statistics", *Motortraffic.gov.lk*, 2016.

[3] "Better public transport key to reducing city traffic congestion, experts say | The Sundaytimes Sri Lanka", *Sundaytimes.lk*, 2013.

[4] R. Lindsney and E. Verhoef, "Traffic congestion and congestion pricing," in *Handbook of transport systems and traffic control*, ed: Emerald Group Publishing Limited, 2001, pp. 77-105.

[5] "Sri Lanka BRT system would be fast and cost-effective: experts", *Archive.lankabusinessonline.com*, 2013.

[6] *Rivira Online*, 2015. [Online]. Available: rivira.lk/online/2015/09/09/21225.

[7] M. S. Ali, M. Adnan, S. M. Noman, and S. F. A. Baqueri, "Estimation of Traffic Congestion Cost-A Case Study of a Major Arterial in Karachi," *Procedia Engineering,* vol. 77, pp. 37-44, 2014.

[8] T. Harriet, K. Poku, and A. K. Emmanuel, "An assessment of traffic congestion and its effect on productivity in urban Ghana," *International Journal of Business and Social Science,* vol. 4, 2013.

[9] M. Sweet, "Does traffic congestion slow the economy?," *Journal of Planning Literature,* vol. 26, pp. 391-404, 2011.

[10] Weisbrod, G., Vary, D., & Treyz, G.. *Economic implications of congestion* (2001).

[11] Passenger Transport Solutions for Galle corridor, (2014), unpublished.