

Road Traffic Congestion Induced CO₂ Emission: Evidence from Kandy City in Sri Lanka

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Abstract

Transportation plays a significant role in carbon dioxide (CO₂) emissions. This paper examines traffic congestion and its impact on CO₂ emissions in Kandy city. Data were collected between November and December 2018 using road monitoring surveys which includes vehicle counting and time recording. The results show that cost of extra fuel consumption due to traffic congestion is Rs. 12.94 million during 12 hour day time which account Rs. 4.72 billion per year. The total CO₂ emission weight is estimated 263.48 tons per day which is 96,170 tons per year. Approximately 55 % of the total emission is contributed by the bus, lorry and truck while combined effects of car, cabs, jeep and wagon is more than 27%. The study also identifies the contributing of CO₂ emission by diesel, petrol and hybrid vehicle separately in the study area. The results of the study provide the direct evidence on the magnitudes of the unnecessary fuel loss and magnitude of the CO₂ emission due to road traffic congestion in Kandy city in Sri Lanka.

Keywords: *Traffic congestion; Loss of fuel; CO₂ emission; Kandy city*

Introduction

Road traffic congestion is a situation in which demand for road space exceeds supply. It occurs when the road capacity does not meet traffic demand at an adequate speed, traffic controls are not effectively used, or there is an incident on the road due to an accident or disabled vehicle. Congestion can occur during any time of the day and along any type of roadway while it has an impact on both the speed of travel as well as on the *reliability* of travel conditions. Road traffic congestion in urban areas is often the outcome of successful urban economic development (Chakrabarty and Gupta, 2015). However, congestion prevents us from moving freely while

generating direct additional cost elements such as travel time delay, travel time unreliability, excess fuel consumption, CO₂ emissions.

With the rapid urbanization, it is evident that commercial and socio-economic activities tend to centralize only in major cities in a country (Vliege et al. 2000; Ali et al. 2014). This has led to increase the number of commuters daily travelling to the cities (Harriet et al. 2013). As a result, while the economy is contributed by way of increasing production and real income of household, the accumulation of vehicle population creates a huge burden to the society which is not understood properly by the urban planning authorities in most developing countries. Road traffic congestion directly increase a loss of resources including extra time and fuel (Hartgen and Fields, 2009; Harriet et al. 2013). Moreover, it creates huge external costs in terms of excess fuel consumption and contributing to higher emission level which directly has some impacts on society in the forms of increasing health issues and global warming.

Total vehicle population in Sri Lanka has dramatically increased with a compound annual growth rate of 10 % between 2012 and 2016 (Karunaratna et al. 2018). The growth of vehicles per 1000 people from 2008 to 2015 was raised 171 to 305 (Department of Motor Traffic, 2016). This growing trend in vehicle population provides important implications on Sri Lankan society, economy and environment. A larger portion of vehicles in Sri Lanka are driven in major cities and much of the issues related to the transport sector in Sri Lanka are associated with urban environment. The traffic congestion on streets in major cities in the country is getting worse each day as people shift from unorganized, outdated and overcrowded public transport modes and started to use their private vehicles. Low travel speed due to the traffic congestion results in high CO₂ emissions to the environment, loss of productivity and production, deteriorating the health capital and increasing the other costs components such as adaptation (for example living closer place to the city). All these have resulted in a massive environmental, financial, health and man-hour loss, waste of fuel, wear and tear of vehicles (Jayasooriya and Bandara, 2017).

Given this background this research attempts to estimate cost of excess fuel consumption and amount of extra carbon emission due to road traffic congestion in Kandy city in Sri Lanka using survey data collected in 2018. Methodology used by Kakouei et al. (2012), Ali et al. (2014) is used to calculate extra CO₂ emission of traffic congestion. The results of this study will help understand the magnitudes of the unnecessary fuel loss due to vehicle congestion in Sri Lanka.

Literature Review

A number of studies have already been undertaken to investigate the various aspects of urban traffic congestion and its impact on individual, businesses and the economy as a whole (Arnott et al. 1993; Shefer, 1994; Lindsey and Verhoef, 2000; Weisbrod et al. 2003; Small et al. 2005; Brownstone and Small, 2005; Parry et al. 2007; Barth and Boriboonsomsin, 2008; Palma and Lindsey, 2009; Harsman and Quigley, 2010; Duranton and Turner, 2011; Song and Miller, 2012; Gallego et al., 2013; Cerruti, 2013; Gibson and Carnovale, 2015). In general, all these studies have repeatedly identified road traffic congestion as one of the major factor for emissions in the world. These studies mainly described the undesirable effects of traffic to their environments, like air degradation due to vehicle emission and traffic noise pollution along with the congestion.

Arnott et al. (1993) analyzed the impact of road traffic congestion on urban society and its economic implication using a detailed analysis of the structural model. Vliege et al. (2000) and Shefer (1994) identifies the gap between private and social cost of vehicle travel and resulting negative externalities such as air pollution, noise pollution and productivity loss. According to Faiz et al. (1996) and Chen et al. (2007) the emission levels depend heavily on traffic-flow characteristics, such as average flow speed, the frequency and intensity of vehicle acceleration and deceleration, the number of stops, and vehicle operating mode. De Vlieger et al. (2000) studies the environmental effects of driving behaviour and congestion by considering passenger cars. According to this study an intense traffic congestion can increase fuel consumption by 20 – 45.

Barth and Boriboonsomsin (2008) found that traffic congestion induced transportation plays a significant role in carbon dioxide (CO₂) emissions. Eliasson (2008) evaluated environmental effects of the pilot test of congestion charging in Stockholm and found that possible emissions reduction by changing the scenario was reduced 2 to 3%. Hartgen and Fields (2009) examines the impact of congestion on accessibility to key employment centers and destinations within an urban region while Shukla and Alam (2010) study the relationship of traffic and emissions in a dynamic urban traffic condition in Delhi. They found high emissions level during accelerations. Maparu and Pandit (2010) found the delay in minutes on the different corridors of Kolkata to range from 20 minutes to about 60 minutes indicating a considerable congestion on the roads of Kolkata.

Anas and Lindsey (2011) discuss the major negative externalities of transportation such the costs of greenhouse gas emissions, air pollutants, noise pollution and accidental costs of congestion. Wolff (2011) studied the impacts of low-emission zones (LEZs) areas on air pollution and the spatial substitution effects in green versus dirty vehicles. Danielis et al. (2011) and Cerruti (2013) analyze the impact of a vehicle pollution charge on nitrogen oxides concentration in Milan. Carrillo and Malik (2013) estimated the impact of driving restrictions on vehicle flows and carbon monoxide emission. Viard and Fu (2014) evaluate the environmental benefit and economic cost of Beijing's driving restrictions. According to this study air pollution falls 19 % during every-other-day and 7 % during one-day-per-week restrictions. Bento et al. (2014) discusses the welfare effects of urban traffic congestion while Song et al. (2015) developed the delay correction model (DCM) to predict emissions from buses traversing intersections based on traffic variables. Rodríguez et al. (2016) studies the influence of driving patterns on vehicle emissions using data from Latin American cities.

The review of previous literature shows that research in this area are numerous and number of researchers have used different techniques and methodologies to measure CO₂ emission of road traffic congestion. However, it is clear that most of these studies have tended to simply analyze CO₂ emission using secondary data in more sophisticated cities in developed countries. Therefore, these studies have only provided limited information to

make appropriate policies on road traffic congestion in developing countries. This study will partly attempt to fill this void in the literature by estimating the CO₂ emission of road traffic congestion in Kandy city using survey data in Sri Lanka.

Methodology

The method used to estimate cost of excess fuel consumption and CO₂ emission is primarily based on the methodology developed by Kakouei et al. (2012) and Ali et al. (2014). For estimating the cost of excess fuel consumption of the traffic congestion, we first separated all the vehicles into four groups namely diesel (d), petrol (p), hybrid (h) and electric. We found 14 vehicle categories for diesel vehicles, 7 vehicle categories for petrol vehicles, 5 vehicle categories for hybrid vehicles and 2 categories for electric vehicles¹⁶. Then within diesel vehicles, different type of vehicles (mainly based on engine capacity) is identified. Accordingly we have identified 19 vehicle types for diesel vehicles while the number is the same for petrol and hybrid vehicles. Then total number of vehicles entering to the city in each three hours time slots under each vehicle type is recorded. After sorting out the vehicle type, we first estimated the fuel expenditure for each vehicle type for travelling one kilometre in each road corridor under the free flow. The following Equation 1 is used for this purpose.

$$FEFF_i = TFC_i \times D \dots \dots \dots (1)$$

Where, FEFF_i is the fuel expenditure (Rs.) that is needed to travel a specific distance on a road corridor for a particular vehicle category (i) under free flow. TFC_i is the total fuel cost (Rs./per Km) of the ith vehicle category and D is the total travel distance(number of Km) in a specific corridor.

$$TFC_i = \sum_t^m (FC_t \times NOV_t) \dots \dots \dots (2)$$

Where FC_t is the fuel expenditure¹⁷ (Rs/per Km) of the t vehicle type in a specific vehicle category and NOV_t is the total number of vehicles entering

¹⁶ Electric vehicles were dropped from the analysis as they did not use petrol or diesel.

¹⁷ Fuel expenditure is estimated for each vehicle type. For this purpose we first estimated number of liters (quantity) required to travel one Km distance using the standard

to the city in a specific time period in t vehicle type. We next estimated the fuel expenditure to travel the same distance under congested situation. Total fuel expenditure due to the traffic congestion (FETC_i) of ith vehicle category in a specific transport mode can be estimated using following Equation 3.

$$FETC_i = \left(\frac{FEFF_i}{TFF} \right) \times ATT_i \dots\dots\dots(3)$$

Where FEFF_i is the time (in minutes) that is needed to travel a specific distance on a road corridor for a particular vehicle category (i) under free flow, TFF is the average number of minutes taken to travel the same distance of a road corridor under free flow and ATT_i is the total number of minutes taken to travel the same distance of a road corridor under traffic congestion by ith vehicle category. Accordingly, total extra fuel cost (EFC) of ith vehicle category of a specific transport mode due to traffic congestion can be estimated by using Equation 4.

$$EFC_i = FETC_i - FEFF_i \dots\dots\dots(4)$$

Using estimates taken from Equation 4 extra fuel consumption quantity due to traffic congestion can be estimated as follows.

$$EFQ_i = \frac{EFC_i}{FP_j} \dots\dots\dots(5)$$

Where EFQ_i is the extra fuel consumption quantity (liters) of the ith vehicle category and FP_j is the fuel price per liter (Rs.) of j fuel type (diesel or petrol). The estimation of the extra fuel consumption quantity is done for the each vehicle category in each time slots of a given day for the different fuel types as well as corridors separately. Finally total is taken for the three corridors.

This study estimates the total fuel expenditure due to delay related to the deviation from actual time taken from free flow. Then these cost components are converted into liters of different fuel type. In order to estimate total CO₂ emission, CO₂ Emissions Footprint Calculator used by Kakouei et al. (2012) is used. Accordingly, burning a litre of diesel produces around 2.64 kgs of

(recommended) fuel consumption rate. Then the quantity is multiplied by average (survey period) fuel price to identify the fuel consumption expenditure per Km for each vehicle type.

carbon dioxide, whereas petrol has lower carbon content and produces about 2.392 kgs¹⁸. Accordingly, CO₂ emission by *i*th vehicle category (CO_{2i} - metric tons) is estimated by multiplying extra fuels quantity consumed (by each vehicle category) from emission per liter burning of petrol or diesel and dividing by 1000,000. This is given in Equation 6.

$$CO_{2i} = \frac{FQ_i \times Emission(per\ /\ liter)_i}{1000 \times 1000} \dots\dots\dots (6)$$

This study will use primary data along with secondary data. Primary data were obtained from two surveys. First survey was the road monitoring survey while second survey was the time monitoring survey. Data collected from the vehicle monitoring survey covering three road corridors of the Kandy city in November and December 2018 is mainly used to identify the number of vehicles entering the city each day. Also, a time monitoring survey carried out during the same month is used to estimate the delay time (different between the actual time taken and regulated time) for each vehicle categories.

Results and Discussion

The details of those three main corridors are given in Table 1. Table 2 summarizes details about the number of vehicles entering to the city from three main corridors. According to the Table 2, total number of vehicles entering from 3 main corridors between 6.00am and 6.00pm is 52,987 per day and approximately 45 % of the vehicles enter the city from corridor 1 while 29 % and 26 % enter from corridor 2 and 3 respectively. Further out of different vehicle categories cars (23 %), three wheel (20 %) and motorcycles (29%) show relatively higher percentages. The presence of significant amount of motorcycles, three wheel and cars is mainly due to inconvenient public transport system prevailing in Kandy.

¹⁸ In general 1 liter of diesel weighs 835 g and it consists for 86,2% of carbon, or 720 g of carbon per liter. In order to combust this carbon to CO₂, 1920 g of oxygen is needed. The sum is then 720 + 1920 = 2640 g of CO₂/liter diesel. Further, 1 liter of petrol weighs 750 g. Petrol consists for 87% of carbon, or 652 g of carbon per liter of petrol. In order to combust this carbon to CO₂, 1740 g of oxygen is needed. The sum is then 652 + 1740 = 2392 g of CO₂/liter of petrol.

Table 1: Details of the Corridor

| Name | Details |
|-----------------|--|
| Corridor 1 (C1) | Peradeniya Town and Kandy Clock Tower / Hospital 6.5 Km- Free flow 13 minutes |
| Corridor 2 (C2) | Katugasthota Town and Kandy Market Station 5.4 Km- Free flow 14 minutes |
| Corridor 3 (C3) | Thennekumbura Bridge and Kandy Market Station 6.0 Km- Free flow 16 minutes |

Note: Corridor 1 is a part A1 and AB42 while Corridor 2 is a part of B70 and A9. Corridor 3 includes a part of A26.

It is evident that during 6am and 9am 32 % of total vehicles enter the city and further between 12 noon and 3pm approximately 28 % of vehicles are entering to the city. Accordingly, these two time slots can be considered as the peak-hours in the city area.

Table 2: Number of Vehicles Entering from Three Main Corridors

| Category | Corridor 1 (%) | Corridor 2 (%) | Corridor 3 (%) | Total |
|-------------|-------------------|-------------------|-------------------|----------------|
| Bus | 50.46 | 26.44 | 23.11 | 3,484 (6.58) |
| Lorry | 44.14 | 33.44 | 22.43 | 1,953 (3.69) |
| Truck | 38.26 | 37.83 | 23.91 | 230 (0.43) |
| Bowser | 39.68 | 14.29 | 46.03 | 126 (0.24) |
| Car | 48.85 | 26.57 | 24.57 | 12,265 (23.15) |
| Cabs | 52.01 | 33.17 | 14.81 | 621 (1.17) |
| Jeep | 41.78 | 29.57 | 28.66 | 1,982 (3.74) |
| Wagon | 52.38 | 28.51 | 19.11 | 1,638 (3.09) |
| Van | 37.10 | 35.26 | 27.64 | 4,356 (8.22) |
| Ambulance | 44.07 | 30.51 | 25.42 | 59 (0.11) |
| Three wheel | 50.48 | 25.43 | 24.09 | 10,543 (19.90) |
| Motorcycle | 38.62 | 32.42 | 28.96 | 15,625 (29.49) |
| Others | 41.90 | 37.14 | 20.95 | 105 (0.20) |
| Total | 23,801 (44.92) | 15,537 (29.32) | 13,649 (25.76) | 52987 |

Note: Under the brackets of last column gives the percentage of each vehicle category out of total number of vehicles. Brackets of the last row reports the % of vehicles coming from each corridor.

Large numbers of schools, hospitals, government offices are located along the road sides of these three main corridors. Due to this fact a significant number of office vans are also seen frequently during peak hours which carry school children and office workers from the residence to relevant schools or workstations. Total number of vans entering to the city is around 4,356 which account approximately 8 % of the total vehicle flow with 12 hours in a given day.

The average time to travel one kilometer distance can mainly depend on the vehicle type as well as the time of the day. Under free flow average time taken to travel one Km along Corridors 1, 2 and 3 are 2, 2.6 and 2.7 minutes respectively. Table 3 reports the average number of minutes taken to travel one Km distance during a particular day between 6.00am and 6.00pm along these three corridors. It was clearly observed from the table the bike (except ambulance) has lesser delay while bus as well as trucks has largest delay with respect to the reference speed which in mainly due to their size.

Table 3: Average time taken to Drive along the Corridors (minutes/ per Km)

| Vehicle Category | Corridor 1 | Corridor 2 | Corridor 3 |
|------------------------|------------|------------|------------|
| Bus | 9.69 | 10.42 | 8.00 |
| Lorry, Truck Bowser | 9.31 | 10.60 | 7.13 |
| Car, Cabs, Jeep, Wagon | 8.00 | 8.69 | 6.58 |
| Van | 8.46 | 8.29 | 6.54 |
| Three Wheel | 5.35 | 4.35 | 3.83 |
| Motorcycles | 3.58 | 4.54 | 3.42 |
| Ambulance | 2.88 | 2.73 | 2.54 |
| Others | 9.15 | 9.35 | 7.96 |

Note: Ambulances are exceptional as they are not expected to follow the rules applied to drive on the road.

As the next step of the analysis we estimated the total costs of extra fuel consumption due to traffic congestion per day. For this purpose, we divided all the vehicles into diesel, petrol and hybrid. Under each fuel type different types of vehicles based on average fuel consumption and engine capacity were identified. This information helps to identify the total fuel cost of a particular vehicle type that is required to run a specific distance of a road corridor. Then the required fuel cost is estimated under free flow and actual

time taken. The difference between those two gives us the fuel cost due to traffic congestion. The estimated fuel cost under different time slots as well as different vehicle categories are given in Table 4.

Table 4: Estimated Value of the Extra Fuel Consumption

| Vehicle Category | Diesel Vehicle | Petrol Vehicle | Hybrid Vehicle | Total |
|------------------|----------------|----------------|----------------|-----------|
| | | | | 2,538,722 |
| Bus | 2,538,722 | | | (39.19) |
| Lorry, Truck | | | | 686,511 |
| Bowser | 686,511 | | | (10.59) |
| Car, Cabs, | | | | 2,066,806 |
| Jeep, Wagon | 477,363 | 1,230,903 | 358,539 | (31.90) |
| | | | | 65,3876 |
| Van | 464,876 | 182,899 | 6,100 | (10.09) |
| | | | | 1,778 |
| Ambulance | 1,778 | | | (0.03) |
| | | | | 315,337 |
| Three Wheels | | 315,337 | | (4.86) |
| | | | | 170,667 |
| Motorcycles | | 170,667 | | (2.63) |
| | | | | 43,909 |
| Others | 43,909 | | | (0.67) |
| | 4,213,161 | 1,899,807 | 364,640 | |
| Total | (65.04) | (29.33) | (5.63) | 6,477,609 |

Note: Under the brackets of last column gives the percentage of expenditure out of total expenditure for extra fuel consumption. Brackets of the last row reports the % distribution of extra fuel expenditure among different fuel type.

The information given in Table 4 represents the difference in cost taken to travel a given section of roadway during free flow and real time. It is evident that the estimated cost of extra fuel consumption is Rs.6.47 million per day which will be Rs. 194.10 million per month and Rs. 2.36 billion per year for one direction travel delay (only entering to the city). The analysis also finds that approximately 65 % of the total excess fuel costs is coming from diesel vehicles while others contribution is approximately 35 %. Also combined effects of bus, lorry, truck and bowsers are more than 50 % of the diesel

vehicles. The total combined costs of car, cabs, jeep and wagon which are mostly privately used vehicles appear as 32 % of the total costs.

Table 5: Total Extra Fuel Consumption (litters)

| Vehicle Category | Diesel Vehicle | Petrol Vehicle | Hybrid Vehicle | Total |
|------------------|----------------|----------------|----------------|----------------|
| Bus | 21,484 | | | 21,484 (42.06) |
| Lorry, Truck | | | | |
| Bowser | 5,809 | | | 5,809 (11.37) |
| Car, Cabs, | | | | |
| Jeep, Wagon | 4,039 | 8,385 | 2442 | 14,867 (29.11) |
| Van | 3,934 | 1,245 | 41 | 5,221 (10.22) |
| Ambulance | 15 | | | 15 (0.03) |
| Three Wheels | | 2,148 | | 2,148 (4.21) |
| Motorcycles | | 1,162 | | 1,162 (2.28) |
| Others | 371 | | | 371 (0.73) |
| | 35,654 | 12,942 | 2,484 | |
| Total | (69.80) | (25.34) | (4.86) | 51,080 |

Note: Average diesel price per liter was Rs. 118.16 and average petrol price per liter was Rs. 146.79 in 2018.

As the next step of the analysis extra fuel consumption is estimated and these estimates are given in Table 5. Average fuel consumption quantity of classified modes and their proportions are also shown in same Tables. Total extra fuel consumption by all vehicles are 51,080 liters in a given day. Accordingly, the estimated extra fuel consumption quantities due to the existing traffic congestion are 35,654 liters of diesel and 14,426 liters of petrol. Contribution of 3,484 buses for the total fuel consumption is 42 % while the combined effects of 16,506 car, cabs, jeep and wagon is 29.11 %. Increasing fuel consumption on the road mean emissions increase and air quality will only get worse. Therefore, as the final step of the analysis we estimated the extra CO₂ emission due to road traffic congestion. These estimates are given in Table 6.

Table 6: Total Extra CO₂ Emission due to Road Traffic Congestion (MT)

| Vehicle Category | Diesel | Petrol | Hybrid | Total |
|------------------|---------|---------|--------|---------------|
| Bus | 57.15 | 0 | 0 | 57.15 (43.38) |
| Lorry, Truck | | | | |
| Bowser | 15.45 | 0 | 0 | 15.45 (11.73) |
| Car, Cabs, Jeep, | | | | |
| Wagon | 10.75 | 20.06 | 5.84 | 36.65 (27.72) |
| Van | 10.46 | 2.98 | 0.10 | 13.54 (10.28) |
| Ambulance | 0.04 | 0 | 0 | 0.04 (0.03) |
| Three Wheels | 0.00 | 5.14 | 0 | 5.14 (3.90) |
| Motorcycles | 0.00 | 2.78 | 0 | 2.78 (2.11) |
| Others | 0.99 | 0 | 0 | 0.99 (0.75) |
| | 94.84 | 30.96 | 5.94 | |
| Total | (71.99) | (23.50) | (4.51) | 131.74 |

Note: These CO₂ emission estimates are only for the delay of the vehicle that are entering to the city.

Given the standard emission rates, the CO₂ emission caused by excess fuel consumption due to congestion is estimated. The total CO₂ emission weight is estimated 131.74 tons per day which is 48,085 tons per year for the 3 main corridors when considering the vehicles that are entering to the city during 12 hours a day. Approximately 43 % of the total emission is contributed by the bus while combined effects of car, cabs, jeep and wagon is more than 36 %. As shown in Table 6, about 93 % of all CO₂ emissions in Kandy are produced by 9 vehicle categories which includes bus, lorry, truck, bowser, car, cabs, jeep, vagon and van while the three wheel and motorcycles has lower CO₂ emission than other vehicles. Furthermore, it is found that the structural characteristics of the city such as number of crossing roads, the number of vehicles parked along the roadsides, crossing rail tracks, closer location of schools, hospitals, temples, availability of number of small temporary shops (small hut-type shops) along the roadsides, narrow crossing bridge and availability of main junctions have resulted in increasing traffic congestion significantly in the study area.

Conclusions and Policy Recommendations

The main purpose of this research is to estimate cost of extra fuel consumption and extra CO₂ emissions of road traffic congestion using survey data in Kandy city in Sri Lanka. Data collected from several surveys covering in November and December 2018 is used to estimate cost of extra fuel consumption and CO₂ emission due to traffic congestion in the study area. Results show that approximately 53,000 vehicles are entering to the Kandy city area during 12 hours (day time) of a day from three main corridors. This can be approximately doubled when considering total number of vehicles that are entering to the city as well as exiting from the city. Accordingly the estimated extra fuel consumption quantities due to the existing traffic congestion are 35,654 liters of diesel and 15,426^{liters} of petrol for 12 hours duration per day. The value of extra fuel consumption due to existing traffic congestion in the city area is Rs. 194.10 million per month. If we convert extra fuel consumption into CO₂ emission the total CO₂ emission is estimated 3,952 tons per month in the city area. Approximately 72 % of the total emission is contributed by the diesel vehicles. The contribution of bus, lorry, truck and bowser to the total CO₂ emission is approximately 73 % while combined effects of car, cabs, jeep and wagon is more than 37 %. These figures can be approximately double if entering as well as exiting vehicles are taken into account in the study area.

This research finding will contribute to pay immediate attention for this issue (which is hidden) while achieving environmental improvement in the urban areas in Sri Lanka. In the long term for reducing CO₂ emissions from the transportation sector, policy makers should pay their attention to introduce more efficient vehicles and the use of alternative fuels. In terms of alternative fuels, many carbon-neutral options are available today. In general, results of this study will provide an opportunity to make necessary policies that provide incentives to protect urban environment that generate regional as well as global benefits in the future.

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