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Analysis of Idling Fuel Consumption and its Emission, Smoke Opacity Trend and its Reduction Possibilities of Pubic Vehicles Run by Khwopa Bhaktapur Minibus Yatayat Pvt. Ltd.

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Abstract

The air quality index of Kathmandu Valley is poor because of air pollution from automobile. Idling of vehicles creates more pollution than in driving. So it is necessary to reduce the idling. Idling of passenger vehicle is mainly due to waiting for passengers at the bus stops, stop at red lights, stopped by traffic and during traffic jam. Idling takes nowhere but it contributes to energy consumption without any useful output. Many researchers have found that idling harm to the total life cycle of engine and increases cost of maintenance.

The paper analyzes the idling fuel consumption and emissions of public vehicles of Khwopa Bhaktapur Minibus Yatayat Pvt. Ltd. and will quantify the reduction possibilities of emission due to idling. For that idling time data records of all routes were collected and fuel consumption were measured using top up method. These data were used to calculate the total idling time in trip, fuel consumption, GHG emissions and financial loss in the routes. In addition, the smoke opacity was measured in different age of the vehicles. Idling time were as high as an hour in a trip in a route. The traffic idling contributes 27% to 42.5%. The idling time per kilometer varies from 0.0159h to 0.0263h in a trip. The maximum traffic was in the evening time and the bus stop idle was in the day (11:00 a.m to 5:00 p.m).

The fuel consumption is increased with the increase in vehicle age. The idling fuel consumption vary from 185 ml/h of new bus to 742 ml/h for a ten years old, hence the average fuel consumption is 495.17 ml/h considering all models. The average idling fuel consumption in a trip vary from 237.3 ml/h to 509.8 ml/h per bus. The GHG emission was 0.62 kg to 1.34 kg per trip in the routes of KBMY respectively. Using 3 minutes of limit, the fuel consumption and emissions in a trip could be reduced from 26 ml to 422 ml and 0.132 kg to 1.264 kg per trip respectively. Rs. 55,13,061 out of Rs. 10,934,692 of financial loss could be saved in routes annually.

The k-value was partially depending upon the age and follows the two period moving average trend. Therefore, in this research, the k-value were varying from 0.81 m-1 in new bus to 3.09 m-1. for nine-year-old bus. After full engine remake, even the 20 years old vehicle passes the emission standards. In the context of k-value, the proper maintenance and servicing of the vehicle is more important than the natural age of the vehicle in respect of smoke opacity value.

Keywords

Idling time, k value, fuel consumption, Route

1. Introduction

1.1 Background

Public transport is a shared passenger transport service having some set fares, generally operates on fixed routes and available for everyone. In Nepal public transport begins with the establishment of Nepal Transport Service in September 1959 serving 10000 people with 11 buses from Kathmandu to Patan. In 1961/2 Sajha Yatayat, 1975 Electric Trolley start service for public of Kathmandu Valley. They cannot retain their glory post 1990 because of the poor management and the political interference and brought more operator in operation as public transportation.

Out of 9,310,480 tons of oil equivalent (ToE) of energy consumed for first eight months, among which 18.23 % were petroleum products in 2019/20 [1]. Nepal's total energy consumption was 12.87 million ToE in fiscal year 2016/17, out of the total energy consumption, 2.088 million ToE were due to petroleum products

[2]. The petroleum used had been increased to 16.2% of total energy consumption in 2016/17 [2]from 8.2 % in 2008/09 annually [3]. All petroleum products are imported in to Nepal. The considerable amount is used for automobiles, followed by industry. The per capita diesel import is the highest among others i.e. 57.7 L in fiscal year 2018 [1]. According to Nepal Oil Corporation, in fiscal year 2074/75 to 2076/77, the import of Diesel fuel were 1,588,869 kL, 1,724,917 kL and 1,473,536 kL which were 14.08% less than previous year [4]. Moreover, the rate of fuel has been increasing day by day, which increases financial loss and price hike in everything. Still we cannot stop using fuel and the vehicles so, any means to reduce the consumption and import of fuel has become essential. Hence this study was carried out to analyze the exhaust fuel consumption and its emission and some reduction possibilities.

Nepal government had indirectly imposed 20 years of age for public vehicles from 1st march 2017 gazette notice. The natural aging of the vehicle results the reduction in the performance of the vehicle because of the poor inspection and maintenance of the vehicle which ultimately results in high emission. The idling fuel consumption of the vehicle tends to increase due to aging of the engine and emission too. The servicing and maintenance of the vehicle may increase or decrease the fuel consumption depending upon its work ever practiced and complexity of the engine maintenance. Idling also reduce the engine life and maintenance too. Till now there is no any significant research on the fuel consumption with the natural aging of the vehicle in idle mode.

1.2 Objectives of the study

The purpose of current study is to analyze exhaust fuel consumption and its emissions of public vehicles run by Khwopa Bhaktapur Minibus Yatayat Pvt. Ltd. (KBMY) in k-value and GHG of public vehicles in idling mode according to its natural age.
Specific Objectives

- To analyze the idling time in all routes run by KBMY Pvt. Ltd.
- To study fuel consumption trend for different age of vehicles.
- To analyze environmental impacts due to idling.
- To quantify the reduction possibilities due to idling
- To quantify financial losses due to idling.
- To analyze the proper phasing out age of the vehicle as per emission standards.

2. Literature Review

The number of bus and minibus registered in all over Nepal have reached 51672 and 27346 respectively in last fiscal year 2075/76. A report by [5] have forecasted that total trips in the valley would be 5,456 thousand/day in 2022 by 1.59 times of the vehicles in 2011 [5]. That indicates that the number of vehicles plying in the road of Kathmandu valley and its emission definitely increases contributing degrading air quality of valley. Various researches from Nepal and abroad have been conducted to measure the air pollution around the Kathmandu valley and found the major air polluter in Kathmandu Valley is transport sector. Most of these studies also focused in health and environmental impacts. Since 1992, the government have applied laws to control the vehicular emissions, but not updated thereafter.

The practice of idling engines has been around since the first diesel trucks were made in the 1930s and continues today.In today's world, things have changed and engines have more efficient designs. In case of modern vehicles, it is better to drive for warming up the vehicle [6, 7]. Some of the idling facts are proven by many reports. According to [6, 8] Idling fuel usage varies from 0.2 to 0.5 gal/h (0.751 L/h to 1.893 L/h) for LD passenger vehicles across a range of sizes, and increased with idling speed. The vehicle warms up faster when driving than it does when idling". [9] successfully tested total of 346 vehicles from different vintages and types under hot stabilized conditions using fuel flow detector and found mean value of fuel consumption is predominantly dependent on engine capacity and vehicle technology and varies from 144 ml/h to 900 ml/h for the observed vehicles tested in different vehicle categories across different cities. "There is a huge variation in fuel consumption of vehicles across different cities under same vehicle category and found that vehicles which are more than 10 years old showed a distinct increase in fuel consumption among four wheelers and bus. Both vehicle technology and vehicle mileage contribute to significant variation in fuel consumption at idling. Lower fuel consumption at idling due to improved vehicle technology as well as traffic control measures will translate into significant improvement in air quality." [9]

The study carried out by [10] in 19 heavy-duty trucks, including 15 diesel and 4 gasoline trucks, found that the gasoline trucks consumed substantially more fuel at an hourly rate (0.84 gal/h) than their diesel counterparts (0.44 gal/h) during idling. According to a review study by [11] "When idling speed is increased fuel injection rate is also increased significantly.Truck running at 1000 rpm consumed nearly double the fuel than that of a truck running at 600 or 750 rpm." The fuel consumption during 5 miles of driving is equivalent to just 10 minutes of idling per day will consume more than 27 gallons of fuel per year.

Idling for more than 10 seconds consumes more fuel than restarting it [11, 8]. The operator manual of TATA recommends to stop the engine and start it again, if you have to wait for more than a minute, e.g. at Traffic Signals [12].

[13] found that the truck idling emits, annually, 11 million tons of carbon dioxide (a major greenhouse gas), 180,000 tons of nitrogen oxides (precursor to ozone formation), 5,000 tons of fine particulate matter (likely carcinogen), and other harmful air toxics.

[14] Investigate the influence to driving conditions on primary emissions and SOA (Secondary Organic Aerosol) formation from diesel vehicle exhausts. The SOA production at idling is approximately 2.5 times as high as those at 20 km/h or 40 km/hr. Total carbonaceous aerosols, including BC, POA and SOA, from diesel vehicles at 20 km/h and 40 km/h were 60 -75% of those at idling. The emission factors of total particle numbers decreased by 38%, when fuel is upgraded from china 3 to china 5"

[15] Found that emission test data 'before' and 'after' repairs, following a failed emissions test. About 55% of gasoline vehicles and nearly 75% of the diesel vehicles failed the roadside emissions checks. Most of the vehicles failing the roadside emissions tests were poorly maintained and generally overloaded. These roadside test data indicate that diesel vehicles are the main culprit contributing to air pollution in Kathmandu valley. The main factors causing excess smoke emissions from diesel vehicles are improper setting and control of the air–fuel ratio, incorrect fuel injection timing, and inadequate intake air due to dirty filters. These factors are a result of improper maintenance and deliberate engine tampering to coax more power out of an engine beyond its rated capacity. According to [15], the smoke density for diesel vehicles ranges within 65-75 Hartridge Smoke Unit (HSU), as per the vehicle condition.

[16] found that increased vehicle use and an aging vehicle population are responsible for up to 70% of air pollution in some cities in Asia. Periodic service checks of a vehicle's engine performance as well as road worthiness are necessary for maintaining engine and emission control system efficiency. In order to maintain their performance, all vehicles must undergo periodic service as recommended by the vehicle manufacturer [16].

[17] found that the maintenance and repair units are numerous but the customer has the final word for maintenance rather than service counseller's skill. [18] Investigated the effect of both the fuel and the lubricating oil quality on deposits, wear and exhaust emissions in the presence of a high EGR rate, with specific attention to the emission variation during aging. The combination of the mineral oil and the low quality fuel caused the highest emission of particulate that can be reduced only by changing to the use of the high quality fuel and/or the synthetic oil. The increasing trend of emissions is more due to the oil aging than to the engine aging [19]. had studied the idling fuel consumption in the route of BMSS in Kathmandu Valley, Nepal and found that the traffic idling time was 18% to 32% and traffic idling were high at the day and evening time. The idling fuel consumption increases with the increase in the engine capacity. The total idling fuel consumption in a route were 5235 L to 11420 L and a total of 31830 L diesel fuel annually. It also found that the idling GHG emissions were 0.31 kg to 0.478 kg per trip in five selected routes [19]. This research is the elaborative form of the [19] with the consideration of the ageing of the bus. There were many studies about the traffic idling study at traffic intersections, but there are not any study or research has been conducted about idling fuel consumption with the consideration of the ageing and opacity characteristics, emission in any route in Nepal.

3. Methodology

Using the random sampling method, the primary data had been collected. Among 296 vehicle registered on date 15th Shrawan 2076, there were 202 number of TATA, 76 of Mahindra, 1 of Eicher, 3 of Force and 2 of Ashok Leyland with different model years ranging (2006 to 2019) and different model. Most of them are not older than six years. TATA has various model

(TATA 709 Ex/38, TATA 712 Ex/38 and TATA Ultra) of bus with various age with same engine capacity. There are 11 routed run by this company. Among all routes using Cochran's formula [20], out of 296 buses only 168 buses should be taken randomly.

Table 1: Routes run by Khwopa Bhaktapur Minibus Yatayat Pvt. Ltd.(KBMY)

SN	Route		No. of Vehicle	avg of per day	avg distance km/trip	sample no.
	From	To				
A	Dudhpati	Ratnapark	15	5	28.5	15
B	Kamalbinayak	Ratnapark	60	4	30.6	35
C	Changunarayan	Ratnapark	15	3	41.8	9
D	Duwakot	Ratnapark	15	3	37.6	14
E	Biruwa	Ratnapark	16	5	27.2	14
F	Kamalvinayak	Gongabu	100	2	43	23
G	Telkot	Gongabu	10	2	58	13
H	Doleshwor	Gongabu	15	3	47.6	10
I	Dudhpati	Lagankhel	20	5	31.7	15
J	Dudhpati	Kalanki	15	3	45.8	15
K	Dudhpati	Swoymbhu	15	3	45.8	14
	Total		296			177

One hundred and seventy-seven buses are taken randomly for recording the idle time by a bus in these route using stop watch. The idling time less than 10 seconds has been excluded. The idling data at bus stop includes the unnecessary waiting at bus stops. As the buses stop, not only at the specified stops, it also stops at on the way for passengers in the route, so the data of idling at bus stops also includes the bus stops on the way. In the same way, idling at traffic includes idling time at traffic lights, traffic police, zebra crossings, idling due to blockage of the road by other buses, accidents etc. These data were tabulated and analyzed using excel as statistical tools. For measuring idling fuel consumption for different age of vehicle, three buses as per accessible of each manufacturing year were taken randomly. Again, 32 buses from KBMY and 36 buses from Araniko Yatayat of different age had been taken randomly for measuring the smoke opacity k value. The five bus with engine overhauled was taken as a sample to measure the smoke opacity to know whether the engine overhaul affect the k value. The fuel consumption at idle mode was measured using the top-up method and smoke opacity was measured using Bosch EAM 111 Opacimeter Emission Analysis Meter 0684103111. The trend developed had been used to calculate the fuel consumption by other brand's vehicles. Further this data will be used for finding greenhouse emission and financial loss due to idling in all routes.

3.1 Fuel Consumption. GHG Emissions and Financial Loss

The total idling time is the summation of going and returning. The morning average (5:00 A.M to 11:00 A.M.), day average (11:00 A.M. to 5:00 P.M.) and evening average (beyond 5:00 P.M.) idling time were determines using Excel 2016. Then the average idling time was converted to fuel consumption and fuel consumption is converted into the GHG Emission and financial loss is calculated accordingly by a bus per day in different routes.

Fuel Consumption by a bus per trip (ml/trip) = average idling time in hour/trip * fuel consumption per hour

Fuel Consumption by a bus per day (L/day) = average idling time in hour/trip * fuel consumption per hour * number of trip/ day

Idling emission of the diesel vehicles were measured by smoke opacity k value and equivalent CO_2. In case of Nepal there are not any measuring instruments available for measuring pollutants so secondary method to determine the pollutants was used. The Carbon dioxide (CO_2) emission for a liter diesel fuel is taken as 2.64 kg [21]

GHG emission by a bus in a trip (kg/trip) = 2.64 * fuel consumption by a bus per trip/1000

GHG emission by a bus in a trip (kg/day) = 2.64 * fuel consumption by a bus per day

For financial analysis, the fuel consumption cost of each bus per day in every route have been analyzed. The following formula was used to determine cost of fuel consumption by bus per day. Cost of fuel loss by bus per day (Rs. /day) = cost of fuel /L* fuel consumption by a bus /day These data were further used to determine the fuel consumption, GHG emissions and financial loss in a year.

3.2 Reduction Possibilities

First, the time of idling equivalent to a single restart calculated with. Then, using this time of idling as base or minimum time of idling before restarting, the maximum possibility of reduction of idling were determined and its saving of fuel, GHG emissions and financial saving were determined. As this time was less and little impractical, another idling time was chosen which require less restart a day and more practical. Then, again the saving of fuel, reduction of GHG emission and cost saving were determined. The restarting fuel consumption was taken from the previous research by [19].

4. Results and Discussion

Most of the buses registered in KBMY were TATA. There are many numbers of buses of five to six years old.

4.1 Idling Time

The average idling time per km in a trip were 0.017 h, 0.025 h, 0.016 h, 0.0223 h, 0.0216 h, 0.0189 h, 0.0167 h, 0.0197 h, 0.263 h, 0.0214 h and 0.225 h in route A, route B, route C, route D, route E, route F, route G, route H, route I, route J, and route K respectively. Hence, the highest vehicle idle time was in route I (i.e. Dudhpati to Lagankhel) and the lowest idling time was in route A (i.e. Dudhpati to Kamalbinayak).

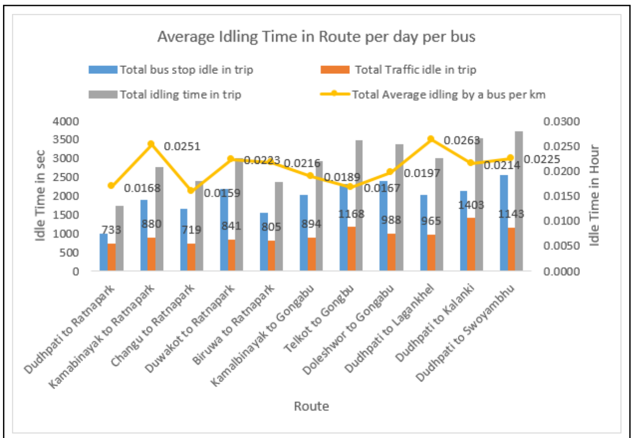

Figure 1: Total average idle time in different route by a bus per trip

The average traffic idling time were 733, 880, 719, 841, 805, 894, 1168, 988, 965, 1403 and 1143 seconds at Dudhpati to Ratnapark, Kamalvinayak to Ratnapark, Changu to Ratnapark, Duwakot to Ratnapark, Biruwa to Ratnapark, Kamalvinayak to Gongabu, Telkot to Gongabu, Doleshwor to Gongabu, Dudhpati to Lagankhel, Dudhpati to Kalanki and Dudhpati to Swoyambhu respectively. The traffic idling at Dudhpati to Kalanki route was high because there was very high traffic at Kotesor, Kharibot Intersection, Satdobato Gwarko, Ekantakuna, Balkhu. The lowest Traffic was at Changunarayan to Ratnapark among all route. With the same final destination of Ratnapark, Kamalvinayak to Ratnapark had the high traffic of 880 seconds because of increases in the number of road intersection and blockage in the road by crossings mainly at Kamavinayak Bhaktaur and the minimum was 719 seconds for Changunarayan to Ratnapark. With the same final destination of Gongabu, Telkot to Gongabu for 1168 seconds and minimum was from Dolesot to Gongabu for 965 seconds.

The maximum idling time at Telkot to Gongabu was high because the route was lengthy and the road intersection at Kamalvinayak and the Nagarkot buspark blockage the road at Kamalvinyak intersections. The maximum traffic idling time was at Dudhpati to Kalanki and Dudhpati to Swoyambhu route for 1403 seconds and 1143 seconds respectively. The highest traffic was due to the high number of road intersections and the long route length.

The average idling at the bus stops during a trip were 993, 1968, 1666, 2175, 1558, 2032, 2370, 2390, 2033, 2121 and 2563 seconds in route A, route B, Route C, Route D, Route E, Route F, Route G, Route H, Route I, Route J and Route K respectively. Hence the total idling time were 720, 2760, 2386, 3016, 2363, 2927, 3479, 3378, 2998, 3523 and 3706 seconds in Route A, Route B, Route C, Route D, Route E, Route F, Route G, Route H, Route I, Route J and Route H respectively. The number of trip and number of bus allocated in route are different so the average idling in the route was different. Although the distance of the route I is short with respect to Route J, Route K and Route H. but due to the large number of passengers in Route I and there were more buses and trips to serve those passengers. Therefore, the buss waited at different bus stops for longer time in route I: Dudhpati to Lagankhel. Although the buses waited for less time at bus stops, due to many stops in lengthy Route G, Route H, Route J and Route K, the total average idling at bus stops were higher in those routes.

Although the Route C, Route D, Route G, Route H, Route J and Route K were lengthy, still due to higher trips per day in Route I the average idling time was higher than other routes. The traffic idling was lowest in Route C whereas the maximum in Route J with respect to total idling. The traffic idling was 42.5%, 34.8%, 30.1%, 27.9%, 34.1%, 30.2%, 35.4%, 29.3%, 32.2%, 39.8% and 30.8% in Route A, Route B, Route C, Route D, Route E, Route F, Route G, Route H, Route I, Route J and Route H respectively.

4.2 Smoke Opacity K value of the public buses run by KBMY

The desired standards for k value in Nepal for turbocharged vehicle is $2.44m^{-1}$ which is very far from euro 6 or Bharat stage 6 standards, currently plying in the road worldwide. Fig 2 shows the opacity value variation with the age of the vehicle. The new vehicle seems to less polluting than the older.

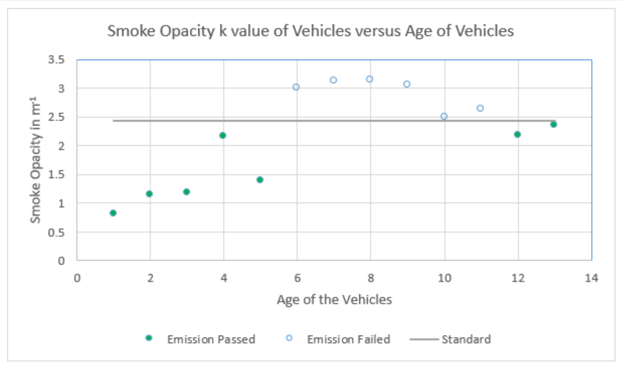

Figure 2: Average value of k on public buses run by KBMY

The lowest value of k is $0.81m^{-1}$ which is one-year-old bus. The highest average value of k is $3.17m^{-1}$ which crosses the emission standards of $2.44m^{-1}$. With the fear of not getting the green sticker the old vehicle owner maintained the vehicle and success in getting sticker even the bus is older. Even the bus 13 years old, the emission standard is passed and get green sticker if the bus is properly maintained. In this study it was found that 20.83% of the bus failed the emission test. It is because there were mostly new buses rather than old bus. The smoke opacity fit the two period moving average trend. The k value of newer bus is low because the owner does servicing and maintenance in the company with the servicing scheme got in the time of purchase. After some years, after completion of the schemes' they got in the time of purchase they are not interested in the servicing in the authorized company. The price and the time taken in servicing in the authorized company and local company is different. Because of the cost constraint, drivers prefer to do servicing and maintenance in the local workshop.

The Table 2 shows that the smoke opacity k value by the bus after the overhaul of the engine. The drivers and bus owner do not overhaul the engine until the engine face the critical situation. They do engine overhaul when the engine throws lubrication oil or leakage of oil from engine, consumption of high

Table 2: Routes run by Khwopa Bhaktapur Minibus Yatayat Pvt. Ltd.(KBMY)

Year	KiloMeter	k1	k2	k3	Average K	Engine Remark
2007	2.88 lakh in 1st at age of 5	1.38	1.38	1.47	1.41	2 years
2008	89,000 in 1st at age of 3	1.32	1.18	1.26	1.26	2 years
2009	43,45,601	1.25	1.15	1.35	1.25	2 years
2010	50,18,378	1.50	1.45	1.14	1.37	2 years
2013	2,47,953	1.28	1.27	1.18	1.25	1 years

lubrication oil than used to, abnormal noise from the engine, heavy white, black smoke with full of diesel smelling, excessive fuel consumption and unusual knocking and chattering in bearing. There is no any definite km reading to do the engine overhaul. Even engine may be overhauled before 90,000 km travelled. In the ring road of Kathmandu Valley, the engine can successfully drive above 43 lakhs km without any engine rebuild. So there is no any definite time of engine rebuilds. It depends upon the condition of driving patterns and behavior of driver handling vehicles, maintenance practices they followed, the quality of lubrication oil. Generally, the investment value of the automobile is returned their investment within 5 to six years so, the owner prefers to buy new one after five years and not to prefer rebuilding engine in the route run by KBMY. In Nepal, there is no any automobile manufacturing industry so the huge amount of money has been invested to import of the vehicle. "Nepal imported a total of 3,18,477 vehicles in the last fiscal year [22]. Import of one TATA pubic vehicle cost average 40 lakhs, 20 lakhs for chassis and 20 lakhs for body building of the bus. This data shows that more than billions of Nepali currency flow out the country in the name of automobiles. So to save such huge amount of money for importing new vehicles we can use the vehicle at optimum level by making some provision on revising some emission norms for engine overhauled vehicle. After the engine overhauling, the k value was found improved to meets the emission standards. There was not any definite age and specified km travelled by a bus. The buses owner experienced the engine are overhauled even after 40,000 km travelled in hilly regions of Nepal.

4.3 Idling Fuel Consumption with the Age of the Bus

The fuel consumption during the idling is just the waste. As idling takes nowhere the fuel consumed during the idling waste money, reduce the fuel economy and creates the pollution around the vehicle.

The consumption of the fuel in idling consume high fuel because in idling there is rich mixture inside the engine to complete the combustion and power stroke. There are pollutants surroundings nearby. Previous literature shows that idle fuel consumption increases with the increase in the engine capacity, is high in the older vehicles. The fuel consumption was measured by top up method because of unavailability of the special equipment. The test result was shown in the Figure 3.

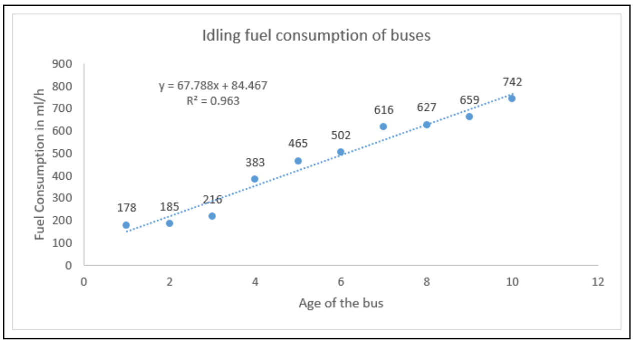

Figure 3: Relationship between the age and the idling fuel consumption of the bus

The relationship between idling fuel consumption and the age seems linear. The trend was seeming to be linear with R^2 =0.963 i.e. fuel consumption is correlated with the age of the bus. The older bus seems consume much more fuel than the newer. The lowest fuel consumed was vary from 178 ml/h in new bus to 742 ml/h in ten years old bus. If that bus is idled for one hour in the trip it wastes 178 ml of fuel, and money adding to the tear and wear of the engine. This changes were caused by the changes in the fuel technology and fuel pump technology. The advancement in fuel pump technology and aging affect the fuel consumption in the vehicles with reference to the time. In euro I vehicle there was mechanical line pump with of nearly 180 hp, in euro II the pump used was rotor pump with the injection pressure of 300- 350 bar and in the euro III the fuel pump used was rotor pump with (EDC) Electronic Diesel Control with the injection pressure of 900-1000 bar and the vehicle manufactured with euro IV standards is provided with the Common Rail Direct Injection (CRDi) technology with injection pressure of 1600-1800 bar. The CRD was provided with the SCR and with EGR with water cooled technology to reduce the emission level. The mini buses 709 EX/38 manufactured before 2012 is of euro II standards with rotor pump attached, which injection pressure is much higher than the line pump of euro I so certain level of fuel and emission was reduced in euro II. Again the bus 712 Ex/38 manufactured beyond 2012 is of Euro III or BS III standards with the rotor pump and EDC fuel technology with high injection pressure which makes the engine more efficient and further reduced the fuel consumption and emission level.

Although both euro 2 and euro 3 vehicles used rotor pump due to change in injection pressure it has been found that fuel consumption of euro 2 vehicles consume more fuel than euro 3. The fuel consumption of old buses is very high because the pump can be adjusted and the driver and the technician had adjusted the fuel flow. The idling fuel consumption is also depending on the engine condition.

After determining the idling fuel consumption by a bus per hour, this data was used to find the idling fuel consumption in the routes. The idling fuel consumption in trip by a bus different routes in average and at different time period are as shown in Table 3. During the study, it was found that the average idling fuel consumption was maximum in route K: Dudhpati to Swoyambhu, bus stop and traffic as well and the minimum traffic idling fuel consumption was at Route C: Changu to Ratnapark. The bus stop idling fuel consumption was minimum at route A: Dudhpati to Ratnapark. The fuel consumption at bus stop was even higher at day time and at traffic was higher at evening time

Table 3: Average idling fuel consumption (ml) by a bus in a trip in different routes

Route	Average(ml)		Morning(ml)		Day(ml)		Evening(ml)	
	Bus Stop	Traffic	Bus Stop	Traffic	Bus Stop	Traffic	Bus Stop	Traffic
Route A	136.5	100.8	133.5	74.8	133.7	106.9	92.1	144.2
Route B	258.6	121.0	257.8	153.7	276.6	107.9	220.7	179.1
Route C	229.2	98.9	203.4	47.3	262.2	111.5	229.6	113.2
Route D	299.2	115.7	260.5	57.0	342.0	165.6	280.6	168.3
Route E	236.2	55.4	190.1	39.8	255.6	130.3	250.0	177.4
Route F	279.6	123.0	251.6	71.0	319.5	141.4	271.3	162.6
Route G	318.0	160.6	162.1	39.6	366.1	173.1	311.3	208.3
Route H	328.7	1736.0	288.7	60.8	353.8	134.2	299.6	214.5
Route I	279.7	132.7	245.4	65.7	311.5	156.0	253.6	199.6
Route J	291.7	192.9	234.2	81.0	330.3	228.5	273.0	217.9
Route K	352.6	157.2	300.8	145.3	372.9	161.3	291.3	208.9

The traffic idling fuel consumption was maximum at day time in route J, whereas the maximum fuel consumption at bus stops was in route K at morning. The fuel consumption in the morning was minimum at traffic idle. However, in overall, the idling fuel consumption at bus stops in the morning were almost same as day time. These data clearly show that the bus stops were not dependent on the traffic volume whereas the traffic idling were completely dependent on traffic volume in the road, so the traffic fuel consumption were low in the morning and high at day and evening.

4.4 GHG Emission due to idling

GHG emissions follows the fuel consumption trend. The maximum average idling GHG emission was 0.931 kg per trip by a bus in route K: Dudhpati to Swoyambhu whereas the minimum idling GHG emission was 0.360 kg per trip in route A. The maximum GHG emission at bus stops was 0.984 kg in route K per trip at day time and 0.822 kg in route G per trip in the evening. Similarly, the maximum traffic idling GHG emission was 0.603 kg per trip at day time and minimum was 0.197 kg per trip in the morning. The average GHG emission due to idling by a bus in a trip is shown in Table 4. The GHG emission

Table 4: Average GHG emission due to Idling by a bus in a trip in route.

Route	Average(kg)		Morning(kg)		Day(kg)		Evening(kg)	
	Bus Stop	Traffic	Bus Stop	Traffic	Bus Stop	Traffic	Bus Stop	Traffic
Dudhpati to Ratnapark	0.360	0.266	0.352	0.197	0.353	0.282	0.243	0.381
Kamalbinayak to Ratnapark	0.683	0.319	0.681	0.406	0.730	0.285	0.583	0.473
Changu to Ratnapark	0.605	0.261	0.537	0.125	0.692	0.294	0.606	0.299
Duwakot to Ratnapark	0.790	0.305	0.688	0.150	0.903	0.437	0.741	0.444
Biruwa to Ratnapark	0.623	0.146	0.502	0.105	0.675	0.344	0.660	0.468
Kamalbinayak to Gongabu	0.738	0.325	0.664	0.188	0.843	0.373	0.716	0.429
Telkot to Gongbu	0.839	0.424	0.428	0.104	0.967	0.457	0.822	0.550
Doleshwor to Gongabu	0.868	0.359	0.762	0.161	0.934	0.354	0.791	0.566
Dudhpati to Lagankhel	0.738	0.350	0.648	0.174	0.822	0.412	0.670	0.527
Dudhpati to Kalanki	0.770	0.509	0.618	0.214	0.872	0.603	0.721	0.575
Dudhpati to Swoyambhu	0.931	0.415	0.794	0.384	0.984	0.426	70.769	0.552

due to the idling by the bus run by KBMY in the route per day is shown in the Fig 4.5. There were 3.133 kg, 4.00 kg, 2.60 kg, 3.29 kg, 3.85 kg, 2.13 kg, 3.79 kg, 3.68 kg, 5.44 kg, 3.84 kg and 4.04 kg in a day in Route A, Route B, Route C, Route D, Route E, Route F, Route G, Route H, Route I and Route J respectively. Same as idling time and fuel consumption the GHG emission was maximum at route I and minimum at route C. The idling fuel consumption by bus in a day in the route run by KBMY is shown in Figure 4.

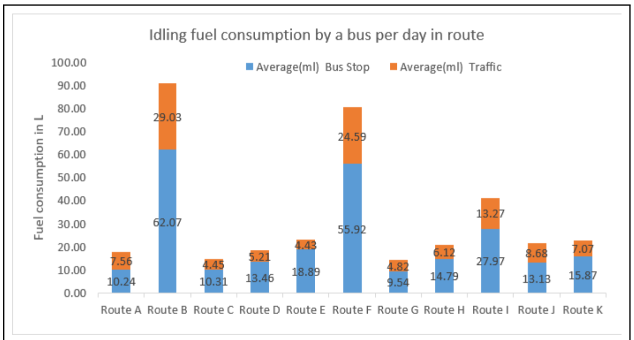

Figure 4: Fuel Consumption in a route by bus per day

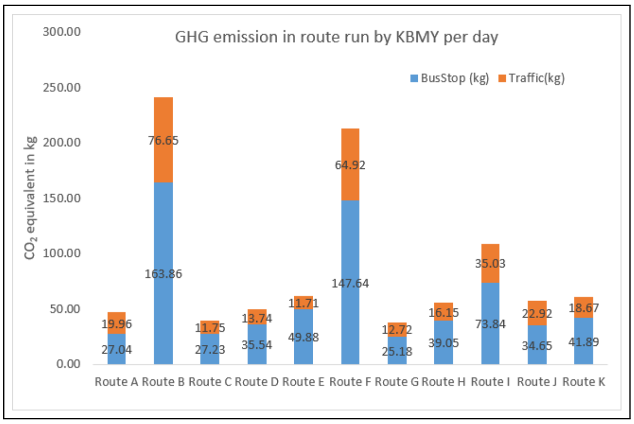

Figure 5: GHG Emission by bus in route run by KBMY per day

Although the daily fuel loss and GHG emission was very low for a bus, for all the buses running in that route and for a year, it will be accountable. The maximum idling fuel consumption was 25,764.74 L per year in Route F due to high number of buses and trips running in the route. Similarly, minimum fuel consumption was 4,725.16 L per year in route C: Changu to Ratnapark due to less number of buses and trips. Although the route J and route K was the longer among other routes the fuel loss per year was quite low because of less number of trip in these route. In addition, the loss of the fuel has no any output so it was total loss. Hence, the total idling fuel loss in the all routes was 117,577.34 L per year. Similarly, the maximum and minimum idling GHG emissions were 42,504.00 kg in route F and 7,731.30 kg in route C respectively. Hence, the total GHG emissions due to idling in all the routes was 310,404.18 kg (CO_2) per year.

4.5 Financial loss due to idling per year

After determining the idling fuel consumption and emissions, the cost or loss of the idling were calculated. The cost of diesel at the time of the financial analysis was Rs. 93 at Thankot outpost area (NOC, 2018). Using the rate of diesel, the idling cost of fuel at different routes were determined. The total idling cost in a trip for a bus were Rs. 22.07, Rs. 35.30, Rs. 30.51, Rs. 38.58 and Rs. 27.11, Rs.37.44, Rs.44.51, Rs.43.22, Rs.38.35, Rs.45.0 and Rs.47.4 in the route A, route B, route C, route D, route E, route F, route G, route H, route I, route J and route K respectively. The cost of idling for a bus in the different routes were Rs. 110.37, Rs. 141.21, Rs. 91.55, Rs. 115.74, Rs. 135.58, Rs 74.87, Rs 133.52, Rs 129.65, Rs 191.74, Rs 135.21 and Rs 142.22 per day by a bus in the route A, route B, route C, route D, Route E, route F, route G, route H, route I, route J and route K respectively. The maximum and minimum cost were in Route B and Route C respectively.

4.6 Reduction possibilities

The minute amount of fuel in segregation in cumulative form a big aggregate. There were lots of loss of fuel and GHG emissions in idling in different routes, which ultimately increases the trip cost and financial loss too to the driver and owner and indirectly cost for passengers too. So it was necessary to determine whether these losses can be reduced or not. When the buses stopped at the bus stops and traffics it need to be restarted and consumed some amount of fuel. So every stopping of idling needs restarting. This means that 100 % saving of the fuel and emissions from idling is impossible. For that, the restarting fuel consumption was taken from previous research [19]. The starting fuel consumption was equivalent to the idling for 9.76 second. So this clearly shows that the idling less than 10 second did not need to be restarted. It is wise to restart at the bus stops and traffics only for 10 seconds of idling.

Therefore, during this study, the possible savings was determined for 30 seconds. As it was less practical that every stops require restarting so possible saving was determined, for more practical time of idling, as 3 minutes. This will require less number of restarts in a trip. It had been found that idling for more than 30 seconds were maximum at route K and minimum at route E. If the buses were, start off for every 30 seconds of idling or higher, more than 70 % of idling time can be saved in a trip in route A, more than 80% in route C and route E and more than 90% in remaining all the routes. But this would have led to restart at almost every stops and major intersections. In a trip for the different routes, the number of restart would be more than 20 restarts. This might hamper the life of starter motor and the battery. However, the idling saving at 3 minutes were reduced drastically than 30 seconds of idling saving. Except for route D and route K, the saving reduced by more than 50% in all the routes. Also the saving at traffic idling had become almost impossible. If the buses were restarted at 30 seconds of idling limit and 3 minutes of idling limit at traffic and bus stops in a trip, the possible saving of the fuel, GHG emissions and financial loss reduction in a trip were as shown in Table 5, Table 6 and summary of research is shown in Table 7 respectively. Even if there was 30 seconds idling limit, there was no possible saving in traffic in route A: Dudhpati to Bhaktapur. The maximum saving of fuel is 532 ml in total per trip was achieved vehicle stop at 30 seconds and again restart it. The minimum saving of fuel was 78 ml per trip in route Dudhpati to Ratnapark and maximum saving was in route Dudhpati to Swoyambhu. All the bus stop idle time had possible savings both in 30 seconds and 3minutes of idling limit.

Table 5: Reduction in fuel consumption in at 30 seconds and 3 minutes of idling

Route	Idle Reduction at 30 s(ml)			Idle Reduction at 3 min(ml)		
	Bus Stop	Traffic	Total	Bus Stop	Traffic	Total
Dudhpati to Ratnapark	78	65	234	26	0	26
Kamalbinayak to Ratnapark	235	97	361	83	0	164
Changu to Ratnapark	187	61	294	30	0	161
Duwakot to Ratnapark	264	82	381	98	67	256
Biruwa to Ratnapark	183	77	300	27	0	151
Kamalbinayak to Gongabu	243	84	374	24	0	178
Telkot to Gongbu	289	129	450	79	0	269
Doleshwor to Gongabu	304	110	440	56	77	280
Dudhpati to Lagankhel	252	146	427	107	0	282
Dudhpati to Kalanki	269	167	460	95	39	210
Dudhpati to Swoyambhu	318	173	532	118	0	422

If the idling is limited for 3 minutes. There are only three (route D, route H and route J) where there are possibilities in saving of traffic idle time. Maximum of 77 ml of fuel in traffic can be save in trip by a bus in route Doleshwor to Gongabu. The maximum saving of fuel i. e. 422 ml can be achieved in a trip by a bus in route K: Dudhpati to Swoyambhu. Table 6 shows the fuel, GHG savings and financial savings at 3 minutes of idling limit is almost 50 % of savings at 30 seconds idling limit. It can save only 26 ml of fuel out of 237 ml while in 30 seconds of idling limit it can save 233 ml out of 237 ml fuel consumed in the trip in route A due to idling. The highest fuel saving can obtained in route K in a trip and the lowest is in route A. Similarly the GHG emission flow the same trends. It can reduced 1.113 kg of GHG out of 1.346 kg in a trip in route A,

Table 6: Reduction possibilities of fuel consumption, GHG emission and Financial loss at two scenario

Route	Reduction Possibilities at 30 s			Reduction Possibilities at 3 min		
	Fuel consumption (ml)	GHG Emission (kg)	Financial Savings (Rs.)	Fuel consumption (ml)	GHG Emission (kg)	Financial Savings (Rs.)
A	233.782	0.617	21.742	26.401	0.070	2.455
B	361.459	0.954	33.616	164.331	0.434	15.283
C	293.947	0.776	27.337	161.412	0.426	15.011
D	380.992	1.006	35.432	256.162	0.676	23.823
E	300.221	0.793	27.921	151.018	0.399	14.045
F	373.689	0.987	34.753	178.323	0.471	16.584
G	449.676	1.187	41.820	268.727	0.709	24.992
H	440.141	1.162	40.933	279.961	0.739	26.036
I	427.050	1.127	39.716	282.315	0.745	26.255
J	459.869	1.214	42.768	209.633	0.553	19.496
K	531.083	1.402	49.391	421.541	1.113	39.203

while in 30 seconds of limit it can reduce emission of 1.402 kg. The financial saving of Rs. 15 can be saved out of Rs. 35 in 3 minutes idling limit while in cas of 30 seconds idling limit it can save Rs.33 in a trip in route B.

Idling and its effect in a route per km

The drivers cannot avoid the idling due to the traffic and the blockage in the roads so there is some idling in the road. In this study the idling for 10 seconds was ignored. The idling time in the kilometer is shown in the Table 4.

Table 7: Idling Effects per km in the route run by KBMY

Route	Distance in a trip	Idling per km(h) in trip	Fuel Consumption (L)	CO_2 equivalent (kg)	Cost (Rs)
Dudhpati to Ratnapark	28.5	0.0168	0.0083	0.0220	0.7746
Kamabinayak to Ratnapark	30.5	0.0251	0.0124	0.0329	1.1575
Changu to Ratnapark	41.8	0.0159	0.0079	0.0207	0.7301
Duwakot to Ratnapark	37.6	0.0223	0.0110	0.0291	1.0261
Biruwa to Ratnapark	27.2	0.0216	0.0107	0.0283	0.9970
Kamalbinayak to Gongabu	43.0	0.0189	0.0094	0.0247	0.8707
Telkot to Gongbu	58.0	0.0167	0.0083	0.0218	0.7674
Doleshwor to Gongabu	47.6	0.0197	0.0098	0.0258	0.9080
Dudhpati to Lagankhel	31.7	0.0263	0.0130	0.0343	1.2098
Dudhpati to Kalanki	45.8	0.0214	0.0106	0.0279	0.9841
Dudhpati to Swoyambhu	45.8	0.0225	0.0111	0.0294	1.0352

The number of bus assigned and the number of trip a bus can be performed in a day is not same in all routes run by KBMY. So the idling time varies greatly in the routes. For comparing idling time and its effect the idling time per kilometer was calculated and its effects accordingly. As the idling time in traffic is lower than the bus stops idling. The idling time per kilometer was contributed mainly due to the bus stops. The lowest distance in a trip is in route A and the longest distance in a trip is in route Telkot to Gongabu. Even though the distance is longest in the route the idling time in a kilometer is lower than others because these route do not have to face huge traffic after leaving Kamalbinayak. The lowest idling route was route C: Changu to Ratnapark because in there was no traffic intersection after leaving the Dekocha but distance between Dekocha to Changu is 11 km contributes low idling per kilometer. And the most idling was in route I: Dudhpati to Lagankhel because of the heavy traffic in Koteshwor and Satdobato traffic intersection. The narrow road nearby Satdobato in the gateway to Lagankhel in this route contribute more traffic in this route. The idling fuel consumption varies from 0.0159 h in route Changu to Ratnapark to 0.0263 h in route Dudhpati to Lagankhel. The fuel consumption varies from 79 ml/h Changu to Ratnapark to 130 ml/h in route Dudhpati to Lagankhel. The GHG emission varies from 20.7 gram Changu to Ratnapark to 34.3 CO_2 equivalent in route Dudhpati to Lagankhel and the financial loss varies from 73 paisa Changu to Ratnapark to Rs. 1.21 in route Dudhpati to Lagankhel.

4.7 Summary of the research

Table 8: Summary Chart of the research

Route	Idling Time in a trip (h)	Idling per km in a trip	Annual Fuel Consumption (L)	Annual GHG Emission (kg)	Annual Financial Losses (Rs.)	Reduction Possibilities in a Year: Fuel Consumption (L)	Reduction Possibilities in a Year: GHG Emission (kg)	Reduction Possibilities in a Year: Financial Savings (Rs.)
Dudhpati to Ratnapark	0.479	0.0168	5696	15038	5,29,762	970	2560	90,175
Kamavinayak to Ratnapark	0.767	0.0251	29153	76964	27,11,221	12621	33319	11,73,720
Changu to Ratnapark	0.663	0.0159	4725	12474	4,39,440	2324	6136	2,16,162
Duwakot to Ratnapark	0.838	0.0223	5974	15771	5,55,556	3689	9738	3,43,052
Biruwa to Ratnapark	0.589	0.0216	7464	19706	6,94,183	3866	10206	3,59,544
Kamalbinayak to Gongabu	0.813	0.0189	25765	68019	23,96,121	11413	30129	10,61,376
Telkot to Gongbu	0.966	0.0167	4594	12129	4,27,259	2580	6811	2,39,919
Doleshwor to Gongabu	0.938	0.0197	6692	17666	6,22,317	4031	10643	3,74,924
Dudhpati to Lagankhel	0.833	0.0263	13195	34836	12,27,160	9034	23850	8,40,169
Dudhpati to Kalanki	0.979	0.0214	6979	18423	6,49,008	3019	7969	2,80,740
Dudhpati to Swoyambhu	1.029	0.0225	7340	19379	6,82,665	6070	16025	5,64,528
Total	**8.894**		**117577**	**310404**	**1,09,34,693**	**59616**	**157387**	**55,44,310**

Table 8 shows that the higher vehicle idling per kilometer is in route 0.026 h is in route J: Dudhpat to Lagankhel, 0.025 h in route B: Kamalbinayak to Ratnapark and 0.022h in route K: Dudhpati to Swoyambhu. It is because in these route passenger density is very high and the number of intersections are higher so the traffic is also high. Again the number of passenger in these route is higher among others route and in the same time number of trips are higher in route B rand route I so the fuel consumption, GHG emission and Financial losses are higher correspondingly.

As 30 seconds of idling limit is not even practical, even though it saves a lot, with 3 minutes of idling limit, 970 L, 1262 L, 2324 L, 3689 L, 3866 L, 11413 L, 2580 L, 4031 L, 9034 L, 3019 L and 6070 L of fuel can be saved in route A, route B, route C, route D, route E, route F, route G, route H, route I, route J and route K annually. Again, the GHG emission of 2560 kg, 33319 kg, 6136 kg, 9738 kg, 10206 kg, 30129 k, 6811 kg, 10643 kg, 23859 kg, 7969 kg and 16025 kg in route A, route B, route C, route D, route E, route F, route G, route H, route I, route J and route K can have reduced annually. Similarly, the financial savings of Rs. 90175, Rs. 1173720, Rs. 216162, Rs. 343052, Rs. 359544, Rs. 1061376, Rs. 239919, Rs. 374924, Rs. 840169, Rs. 280740 and Rs. 564528 in route A, route B, route C, route D, route E, route F, route G, route H, route I, route J and route K can be saved annually. In the routes run by KBMY the average of (970 L to 11413 L) fuel, (2560 kg to 30129 kg) of GHG emission and (NRs. 90,175 to NRs. 10,61,376) of saving can be achieved per year. In total, out of 1,17,577 L, 59616 L of fuel, 157387 kg of GHG emission out of 3,10,404 kg an NRs. 55,44,310 can be saved out of NRs. 1,09,34,693 can be saved with the effective implementation of 3 minutes idling limit in the route run by KBMY. The average of 50 % of fuel and financial saving van be achieved if anti idling rules can be implemented.

5. Conclusions and Recommendations

5.1 Conclusions

The urbanization and the increased number of vehicles in Kathmandu valley has reduced the air quality. The government had initiated the phase out the 20 years old public buses to reduce the pollution. And this research has done to know the impact of aging on idling fuel consumption and emission. In context of Nepal, due to cost constraint the vehicular emission reduction is difficult, hence idling reduction i.e. low carbon technology is the most effective method. The result of this study shows that it is possible to reduce fuel consumption and GHG emission through idling reduction.

- The total idling time at different bus stops and traffics were as high as an hour in a trip (i.e. 0.47h – 1.029 h) per trip. Among which 27% to 42.5% of idling time were due to traffic only and remaining were due to bus stops.
- The traffic idling was high at day and evening time whereas the idling at bus stops were high at morning and day in all routes of KBMY.
- Idling fuel consumption increases with the age of engine linearly
- The opacity value is partially related with the age. The two period moving average trend was found in the opacity value of buses.
- The k-value (smoke opacity) of overhauled engine for the 20 year's old buses, are below the Nepali Vehicle Emission standard. Hence, the age of the vehicle is not only responsible factor for the smoke opacity.
- The total fuel consumption in a route were 5696L to 25765 and a total of 117555L
- The idling GHG Emission accumulated in route were 15038 kg to 68019 kg and a total of 310404 kg in a year
- With 3 minutes of idling limit, a total of 59616 L out of 117577 L fuel, 157387 kg out of 310404 kg GHG and Rs. 55,44,310 out of Rs. 1,09,34,693 can be saved yearly.

5.2 Recommendations

This study has shown that there is possibility to save the fuel consumption and can decrease GHG emission by reduction in idling at bus stops and traffics. Therefore, for saving the fuel consumption, GHG emission and the trip cost, policies and regulations has to be form and implemented to promote the idling reduction. The vehicle owner and drivers should be aware of idling myths, which are not true for the modern vehicles. They should aware about the financial losses due to the fuel waste and the chances of technical failure they would bear due to the idling in the trip and route. For that along with the above study further study related to the idling reduction technology is necessary. Further work is recommended as follows:

- Further study is required about the idling and restarting mechanical effects to engine and the vehicle, so that correct time of restarting which affect the fuel consumption and mechanical parts can be determined. It may be possible that the idling may affect the engine more than restarting or vice versa, which could have led to change in effective restarting time with respect to idling time.
- Further study is required about the idling fuel consumption variation with changing the fuel types, weight, loads and its effects in building up of the carbon and fuel residue on engine.
- Further study is required about the fuel consumption and the pollution caused by very old vehicles and the appropriate management of older vehicles plying on the road.

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