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Drive Cycle of Heavy Vehicles in Dhaka City: A Case Study

M. Fahim Asif Khan, Mirza Farhan Hasin, Md. Jubayer Hossain, Anjan Goswami, and Mozammel Mia*

Department of Mechanical and Production Engineering,
Ahsanullah University of Science and Technology (AUST), Dhaka-1208, Bangladesh

ABSTRACT

In this present work, a case study of non-legislative drive cycle for heavy vehicles in Dhaka, the capital of Bangladesh, has been presented. The methodology is as follows (i) two major routes were chosen (ii) the data was analyzed in terms of speed-time and acceleration-time profile graphically (iii) lastly, the findings were compared with international drive cycles. For measurement purpose, a GPS device, having low response time, was used for recording the time-distance values. It has been found that the average speed for heavy vehicles was 7.949 km/h which is significantly lower compared to other international drive cycles. Furthermore, it was noticed that for 89.156627% of travel time the speed was below 30 km/h, for 4.8192771% of travel time the speed was between 30 to 60 km/h and for 6.0240964% of travel time the speed was between 60-90 km/h. The research outcomes can be of direct interest to the Bangladesh Road and Transport Authority (BRTA), Dhaka Metropolitan Police (DMP, Traffic) and other transportation authorities to effectively plan Dhaka city's traffic system.

Keywords: Drive cycle; Speed-time profile; Heavy vehicle; Dhaka City.

1. Introduction

Dhaka city, the capital of Bangladesh, a country in south-east Asia, is a place of work and habitat of over18 million people [1]. Within very small geographical area of 1528 km^2, the population density is 28748 per sq. km [1]. Despite this fact, the city of Dhaka is one of the fastest growing megacities in the world. Oddly, this huge populace moves from one place to another for their necessity – mostly by public and private transport systems such as car, bus, bike etc. Over population and less space, together, contribute to frequent traffic jam. As such, countless amount of valuable and workable time is wasted on the roads. Moreover, the consumptions of fuel in idle condition of vehicles and associated emission of exhaust gases such as CO_2, HC, CO, NO_x etc. are higher than the usual condition. These emissions are harmful for the environment and one of the major causes of global warming. In USA 28% of greenhouse gases are emitted by their transportation sector[2].

Traffic condition influences the economical and environmental state of a country. When the traffic condition is congested, vehicles remain idle for most of the travel time, which leads to higher consumption of fuel, an uneconomic state. Moreover, a person has to stay in road for a long period which leads to the wastage of his workable time and causes metal agony. In 2017, World Bank reported that traffic jam in Dhaka eats up 3.2 million working hours per day[3]. Moreover, when a vehicle remains idle, it emits more exhaust gases. These harmful gases disrupt the environmental balance drastically. Bangladesh Atomic Energy Commission reported that automobiles in Dhaka emit 100 kg lead, 3.5 tons SPM, 1.5 tons SO_2, 14 tons HC and 60 tons CO in every day[4].

To control the contribution of transportation to environmental and economical degradation, measuring the traffic performance has to be taken as an initial step to eventually control such degradation. Reportedly, one of the most effective ways to understand the traffic performance is by constructing a drive cycle. Drive cycle is defined as a series of data points representing the speed of vehicle versus time sequenced profile developed for a certain road, route, specific area or city[5]. It represents the driving pattern of a road along with various parameters i.e. speed, acceleration, distance, time etc. Driving patterns influence exhaust emissions and fuel consumption[6, 7].

The necessity of constructing a drive cycle is perceived through the ages by different countries. By means of that, some well renowned drive cycles have been constructed and followed by most nations around the world. New European Driving Cycle (NEDC) and FTP-75 are highly accepted drive cycle and followed by the nations or states of Europe and America respectively. However, it is to be noted that every route is unique by itself. Therefore, the driving pattern of all the roads is unlikely to be represented by a single common drive cycle. Otherwise, underestimation or overestimation takes place due to lack of precision. In order to overcome this gap many countries have stopped following a common drive cycle and devised their own drive cycle.

Ho et al. [8] conducted a study on the Singapore Drive Cycle (SDC). In order to attain 7-11% carbon emission reduction by 2020, authors realized the shortcoming of following the NEDC and developed one drive cycle. It was a 2400 second speed versus time profile to represent the driving pattern for passenger cars in Singapore. Microscopic estimation model showed that as compared to SDC, the NEDC underestimates most of the vehicular emissions (fuel, CO_2, HC and NO_x by 5%, 5%, 22% and 47% respectively) and overestimates CO by 8%. The SDC is thus more suitable than the NEDC that is currently in use in Singapore to generate more accurate fuel consumption and emissions ratings.

* Corresponding author. Tel.: +88-01911099149
E-mail addresses: hossain.jubayer@gmail.com

Fotouhi and Montazeri-Gh [9] developed a drive cycle for the city of Tehran by using a new approach based on data clustering. Majority of the drive cycles are developed using the random approach method of combining a number of micro trips and a repetitive process is then executed to determine the most representative cycle. Instead of adopting this typical approach, they conducted a new method with less computation. It is a 1533 second speed time series, with an average speed of 33.83 km/h and a distance of 14.41 km. Kamble et al. [10] developed drive cycle for city of Pune, India. In Pune drive cycle five important parameters of time-space profile was considered in methodology. Therefore, it made the drive cycle a more accurate representation of their heterogeneous traffic behavior.

Considering the fact that, the most popular medium of transportation in Indian subcontinent is public bus; a drive cycle for heavy vehicle is needed to be constructed. In order to achieve this target, a drive cycle for intra city buses has been developed in Chennai, India by Nesamani et al. [11]. The emission rate and fuel consumption by buses of Chennai are estimated with European Drive Cycle, which does not go with their road pattern. Therefore overestimation and underestimations are originated. In order to precise the estimation; they constructed a specific drive cycle for intra city buses. Along with other parameters, they have determined the percentage of creeping mode, cruise mode and average running speed to increase the accuracy of their work. Furthermore, they have divided the data into 6 groups including three peak and non-peak periods and three different road widths and analyzed in accordance to it.

Despite serious urgency for developing a drive cycle for public bus transportation mode in Dhaka city, hardly there is any recent useful study on its drive cycle. Although a drive cycle has been constructed some years ago by Adnan et al.[12]for passenger cars, it is essentially required to be updated due to changes in routes, addition of new routes and flyovers. In this respect, the objective of this research work is to construct a recent and practical drive cycle of heavy vehicles *i.e.* public buses for two major routes of Dhaka city and to further analyze and compare the results.

2. Methodology

Among different available modes of transportation i.e. bus, compressed natural gas driven vehicles, private cars, motor cycles, the current study was conducted on buses only. This is due to the fact that bus is one of the mostly used modes of transportation – a mode that associates low transportation cost. Moreover it is highly convenient among students and low-earners in respect of availability and affordability. It is to be noted that with the increase of number of buses (as well as other models of vehicles) the new routes are not increased. As such, the existing routes are used by this increased number of vehicles. This outnumbering of buses is causing congestion of traffic and uncomfortable movement. Based on this scenario, the study concentrated on tracking the driving pattern of public bus and analyzing the outcomes to reach a conclusion. To conduct the study, the methodology is divided in 4 steps.

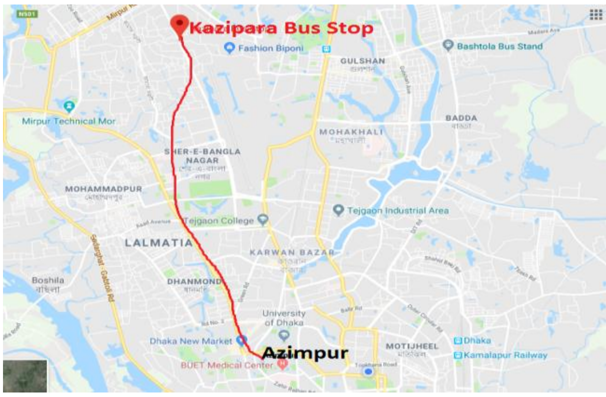

Fig.1 Route navigation of Kazipara-Azimpur-Kazipara

2.1 Route selection

Two different routes were selected to cover the range of distances to be travelled as shown in Figure 1. The route selection was conducted based on strategic planning to make the center point at Kazipara so that the vehicles can move along two opposite directions from the center. In one side, the vehicles moved along Kazipara-Uttara route, and on the other side, the vehicles moved along Kazipara-Azimpur. It is to be noted that these routes are two of the busiest routes in city of Dhaka.

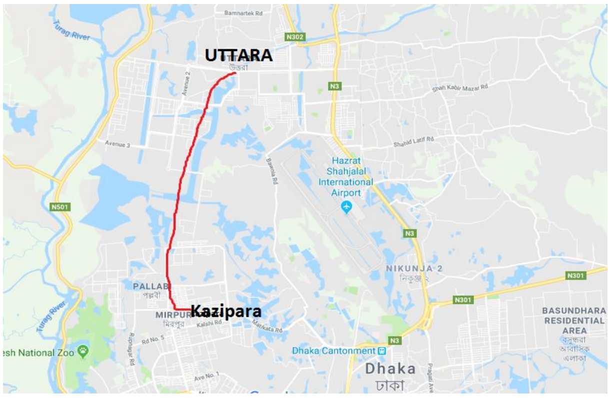

Fig.2 Route navigation of Kazipara-Uttara-Kazipara

Table 1 Characteristics of the vehicle

Vehicle name	Engine capacity	Type
Eicher Skyline	3289 cc	Passenger Bus

2.2 Data collection

The characteristics of the used buses are listed in Table 1. Two typical public buses were equipped with GPS device (Etrex-10) to record the distance with respect to time. To make the data collection robust, the data was recorded in two different time of the day. This variation in time of data collection facilitated the opportunity to accommodate the frequent changes in the vehicles speed and acceleration throughout the day. It is to be mentioned that the data was collected as an up and down method i.e. during the forward trip and backward trip of the same route.

2.3 Analysis

After collecting all the measured raw data from the GPS device, the values were graphically analyzed. From the analysis, all the necessary parameters such as velocity and acceleration had been derived and calculated. For a clear vision of the driving pattern, some graphs such as velocity versus time, acceleration versus time, and percentage versus speed range were drawn from those values.

2.4 Drive cycle generation

Lastly, the driving cycle was developed that best represent the driving pattern of the selected routes (roads) in Dhaka city. To choose the method, it is kept in consideration that the outcomes are maintaining high level of accuracy but it is easy to calculate. Hence, the average velocities for each of the two routes were calculated from the measured values of time and travelled distance. Afterward, an overall average velocity from the average velocities of both routes was calculated. Finally, between the two routes, the route that is carrying the closest value of average velocity to the overall average velocity was taken as the standard to develop the drive cycle for the city of Dhaka.

3. Results and discussion

The decisive parameters of the selected two routes (e.g. ‘Kazipara-Uttara-Kazipara’ and ‘Kazipara-Azimpur-Kazipara’) are listed in Table 2. Both of these average values are astonishingly low. The average speed of the bus along the Kazipara-Uttara-Kazipara is only 75%

Table 2 Value of the parameters of each route

Parameters	Kazipara-Uttara-Kazipara	Kazipara-Azimpur-Kazipara
Total Distance (km)	30.04	18.60
Total Time (hour)	3.43	2.69
Average Speed (km/hr)	8.77	6.91

higher than the average walking speed of a human while the other route (Kazipara-Azimpur-Kazipara) resulted in an average speed that is 40% higher than the typical human walking speed. It can also be seen that the average speed along the Kazipara-Uttara-Kazipara route is higher than the average speed of Kazipara-Azimpur-Kazipara route. By taking average of all the average velocities of the two routes, the overall average velocity came out 7.95 km/h. This statistics raises serious concern about these routes’s sustainability in terms of environment, economy and development.

For further analysis of the selected routes, the data is presented for the Kazipara-Uttara-Kazipara route as the standard route for having the average velocity of 8.77 km/h that is closest to the overall average velocity. Moreover, to be precise, the driving cycle has been formulated for a micro-trip of this route consisting of 4 standard operations such as idle mode, acceleration mode, deceleration mode and cruising mode. Figure 3 exhibits the standard speed-time profile *i.e.* the drive cycle for bus. The trip is 4.108 km long having travel time 1249s. The average speed of this cycle is 11.84 km/h which is a little higher than the overall average velocity 8.77 km/h. It can also be observed that the speed hardly remains constant. At several times the speed of bus was 0 km/h. It is also appreciable that at two different time segments the speed increased significantly. For the first case, approximately at 440s of the travel time, the speed of the bus started to increase gradually till it reached at maximum speed approx. 68 km/h at the travel time of 480s. After that the speed started to plummet reaching zero speed at travel time of approx. 570s. A similar rise-and-fall pattern of speed can be observed in between 1130s to 1229s. These two sudden increases of travel speed can be accredited to the congestion free road at that time. For Pune, India the average speed as reported as 19.55 km/h. Hence, the average speed of Dhaka city is approx. 40% below that of Pune, India. With respect to European drive cycle, the average speed of Dhaka city is 65% less [10]. The outcome is the combined result of two separate activities, boarding and alighting passengers at

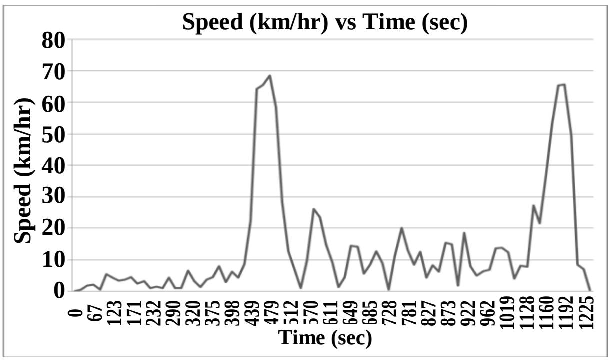

Fig.3 Speed (km/hr) versus Time (sec) Graph

numerous points, and the congested traffic that resisted the vehicle from running at a constant speed. Figure 4 shows the acceleration pattern for the elementary micro-trip *i.e.* drive cycle. A number of sharp spikes *i.e.* sudden accelerations and decelerations are observed suggesting high emission at this phase. This sudden acceleration-deceleration can be imputed to the short span of free road, sudden change of lanes of other vehicles, appearance of slow moving vehicles etc. As can be seen from Figure 3, from 0s to 300s, the acceleration-deceleration was somewhat close to zero. However, after that time period, there is a sudden acceleration followed by deceleration. Even beyond that period, the acceleration-deceleration is quite abrupt and in great magnitude. Two major decelerations can be found at approx. time period of 510s and 1210s.

Figure 5 demonstrates the percentage of time the bus was run at different speed range. Note that the speed range is taken as increment of 10 km/h. Astonishingly, for 63.86% time the bus ran below 10 km/h speed. This value of speed is quite unorthodox when it is compared to different drive cycles of the world. As it can be also seen that the percentage of time the vehicle is run is declining with the increase of speed. As such, the percentage of time that the vehicle was run in between 30-60 km/h is lowest. But, the speed spectrum (40-60 km/h) is typically considered as fuel efficient speed zone. Evidently, as the bus in Dhaka city is running with that much low speed for that amount of time, then the fuel as well as operating cost becomes higher for the bus.

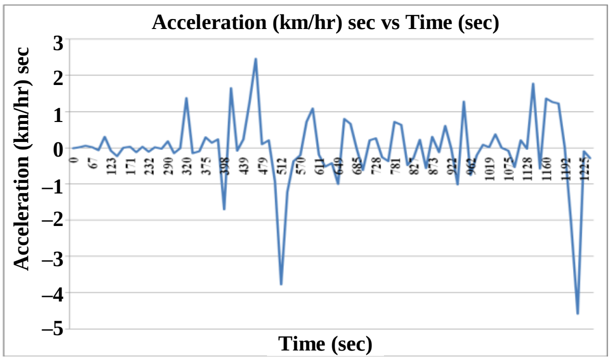

Fig.4 Acceleration (km/hr)/sec versus Time (sec)

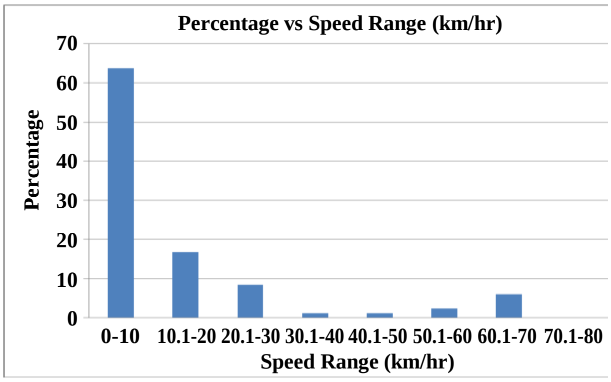

Fig.5 Percentage versus Speed Range Graph

In parallel, the increased fuel consumption is causing environmental degradation.

A broader classification of the speed distribution is shown in Figure 6. From this figure, it is blatant that, for almost 89.15% of the travel time the speed of the vehicle remained between 0-30 km/hr. And only for the rest 10.85% of the travel time the speed exceeded it.

4. Conclusion

From the current study, it has been found that the overall average speed for heavy vehicle (bus) is 7.95 km/hr. However, for the micro-trip of bus *i.e.* drive cycle, the average speed was found as 11.84 km/h. The speed remained below 30 km/hour for 89.15% of travel time and it was above 60 km/hour for about 10.85% of travel time.

This average speed is drastically low for heavy vehicles in Dhaka city, especially when compared with international drive cycles. Consequently, the comfort traveling is compromised, valuable time is wasted, environmental harm is caused, and most importantly the sustainable city development is hampered.

Hence, to cope up with sustainability index of city development, proper steps need to be taken by the administration to duly regulate the buses by following the results of drive cycle of Dhaka city. In fact, it can be further improved to make it comparable with international drive cycles.

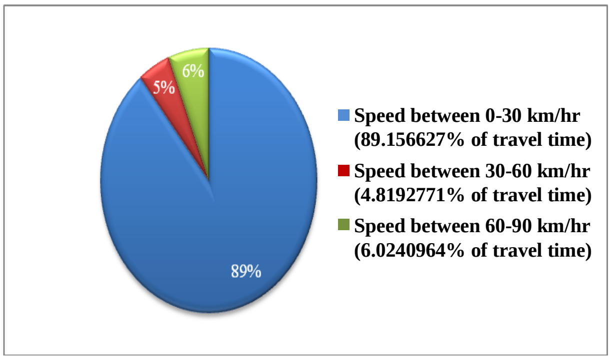

Fig.6 Speed Range Percentage

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