Pollution,1(4): 441-449, Autumn 2015

Driving patterns as a contributing factor to light-duty vehicular emission in the Kumasi metropolis

Owusu- Boateng, G. [1*] and Nabena, F.E. [2]

[1]Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

[2] Gbaran Infill Project, NLNG Supplies Project, Shell Petroleum Development Company, Nigeria

Received: 16 Feb. 2015 Accepted: 23 May. 2015

ABSTRACT: Exhaust emissions contribute greatly to air pollution, the social cost of which may occur as danger to human health, attracting huge medical expenses, causing absenteeism and hence loss of productivity. These are incentives to reduce exhaust emissions to the barest minimum. Two major cities in Ghana, Accra and Kumasi, are struck by vehicular traffic jams especially during rush-hours and are grappling with the situation perceived to be worsened by driving pattern, a travel-related characteristic with a tendency to increase vehicular emission and hence, atmospheric pollution. Driving patterns were studied in the Kumasi Metropolis using questionnaires purposively administered to drivers who visited the Driver and Vehicles Licensing Authority. Parameters were analyzed with SPSS. Results indicate that drivers plied highway (90.0%), feeder (6.7%) and urban (3.3%) roads. Drivers (90%) had no knowledge of how driving patterns contribute to emissions, effect of idle and hot emissions and hot-and-cold starts dynamics. This could explain the failure of drivers to allow vehicle engines to stabilize for over 5 min and also to put off engines when stuck in traffic. Drivers changed speed as often as 4 times/km due to vehicle congestion and intermittent traffic lights, intersections and roundabouts. This may explain the difficulty in maintaining constant speed; thereby compelling drivers to exhibit frequent gear-changing behaviours as well as unstable and inconsistent speed profiles, as the commonest driving patterns. Such characteristics potentially increase energy consumption, emission level and abatement cost significantly and therefore, call for intensified educational programmes aimed at curbing this environmental peril.

Keywords: air pollution, driving patterns, engines, exhaust emissions.

INTRODUCTION

Air pollution is quite expensive to curb. The social costs of poor quality air are reflected in unfavorable meteorological conditions which restrict the dispersion of the pollutants, once emitted into the atmosphere. It also causes adverse health effects, the medical economic value of which is difficult to estimate (Haug et al., 2011), in addition to agricultural and property destruction. The expectation is that air pollution and other environmental concerns need to be addressed, in order to efficiently manage public health costs and lessen a potential impediment to effective economic growth. However, the management in turn is constrained by the economy of resource utilization (Levy et al., 2000; Samet et al., 2000; Schwartz, 2000).

[*] Corresponding author Email: Godfredowusuboateng @yahoo.com

Over the years, the contribution of surface transportation to emission of greenhouse gases has been established to be significant (Watkiss and Downing, 2008). The social costs of transportation may include a regular external un-priced component (Mayeres, 2000). The phenomenon has triggered the search for means of cutting down the consumption of fuel which has been strongly associated with aggravation of the situation. In this quest, some have advocated for greater building and usage of lighter and smaller vehicles without compromising safety, whiles considering the possibility of exploring alternative technologies, including cars powered by hybrid and fuel cells.

In Ghana, there is a great influx of fairly used cars daily (Nesamani et al., 2007; Agyeman Bonsu et al., 2010). This explosive growth is becoming a big problem in the cities. The major cities like Accra and Kumasi are trying to cope with the chaotic automobile traffic. The traffic congestions are extremely bad in these cities and traffic during the rush hours is really slow (Agyeman Bonsu et al., 2007). Nesamani et al. (2006) found that the average speed in Chennai city is less than 20 kmph during peak hours. The volume of gases emitted at that point in time by vehicles can cause serious health problems. The financial and human considerations together are powerful incentives for trying to limit exhaust emissions. Adequate attention has not been accorded to reduction of traffic congestion; although it is an effective means of reducing CO_2 emissions. This makes the call for congestion mitigation programs that give prominence to reduction of CO_2 emissions, a legitimate one. However, the quantum of fuel that is consumed and the amount of CO_2 produced is a function of several factors including individuals' driving behaviour, vehicle and roadway types, and traffic conditions. Reducing fuel consumption and associated greenhouse gas (GHG) emissions—particularly carbon dioxide (CO_2)—from motor vehicles has been one of the important goals for a variety of sustainable transportation programs (Li et al., 2009). Driving pattern, for instance make a better input into the system of modeling for estimation of the amount of CO_2 emission than some other parameters such as trip distance.

The activities that occur during driving include idling, accelerating, cruising, and decelerating. These activities as judged by a driver who may exhibit behaviours such as aggression, defensive, mildness, etc and make different degrees of input in the overall emission output. Again, it is well known that driving patterns such as speed profile; acceleration and choice of gears greatly influence fuel consumption and vehicle exhaust emissions (Vicente et al., 2013). Driving disorder, such as having difficulty in staying in the required lane, abrupt lane changes and driving on the shoulder are grouped under the heading "lateral discipline of driving" and are typical consequences of many dangerous driving situations. Two categories of cost characterize the cost implications in urban air quality management: 1. that originating from elevation of air pollution and 2. those emanating due to implementation of an abatement program. Real world driving has frequent speed fluctuations as well as sharp acceleration and deceleration. Sharp acceleration could increase emission rates by increasing the air/fuel ratio (Bokare and Maurya, 2013).

This might be due to a number of factors such as variation in road characteristics, traffic characteristics and roadway environment. All these retard the effort to improve local air quality. The increase in traffic volume and change in travel-related characteristics, vehicular emissions and energy consumption have increased significantly (Nesamani et al., 2007; Soole, 2013; Cascetta, 2010).

Driving patterns such as speed and acceleration profiles are of importance when studying the environmental effects of traffic. In urban areas, driving patterns vary a great deal. However, knowledge of driving pattern characteristics that cause increased environmental effects is limited. Nonetheless, the commonest means of determining driving patterns is to use a vehicle with a data logging equipment to register parameters, for example speed. Opinions, activities, behaviours and the rationale behind them have not usually been given much consideration. However, this study, against the backdrop of the above usual situation, focused on assessing the most common driving patterns of vehicle drivers in the Kumasi Metropolis that contribute to increase in concentration of vehicular emissions

MATERIALS AND METHODS

Study area

The study was carried out in the Kumasi Metropolis, the second largest city in Ghana. With the existence of tertiary, secondary and first cycle schools, manufacturing industries, forests, recreational centers, banks, shops etc in the city, majority of education and business trips, shopping and recreational activities are done without waste of time. Kumasi depends on road network for intra-city commuting. It has some arterial roads connecting the Central Business District (CBD) at Adum with the outlying residential and industrial suburbs of the city. As capital city of the region, Kumasi Metropolis has the highest population. With an area of 254 km^2, it has a population density of about 8,100/km^2. The high population density that characterizes the city and therefore its surroundings, has been attributed to its strategic location, road network (Fig. 1) and status as the regional capital, hosting majority of the business and commercial activities that occur in the region.

Fig. 1. Map of Ghana showing study area, Kumasi

Kumasi is very important because it is a nodal city where a very significant proportion of the centers for activities and services including health care, culture, education and sports are cited, as well as major arterial routes linking the national and international cities. It has the second largest economy in the country after the Greater Accra Region. For these reasons, national and international migration is frequent in the city which attracts people from the sub-region. The location of Kumasi with its road network and status as a brisk administrative and commercial centre, has made the city a destination of both internal and international migrants. In the year 2002, the Government of Ghana introduced the Metro Bus Services popularly called Metro Mass in the city for public transportation, as a measure to enhance travelling, especially during rush hours.

Data collection

Different methodological approaches were used for studies on driving pattern, especially its contribution to vehicular emission. Such methods include laboratory bench testing and chassis dynamometer, on-board measurements and road measurements. Laboratory measurements are suitable for specific driving conditions, since the vehicle is fixed with many influential parameters (Andre, 2004; Frey and Chen, 2002). Data for the study were obtained through questionnaires, interviews and personal observations. Respondents were sampled from the premises of the Driver and Vehicles Licensing Authority (DVLA). The DVLA is the body at the premises of which drivers of different automobiles come to license new vehicles and renew expired licenses. This study site is the Ashanti Regional Headquarters of the division and therefore, a large number of drivers visit the premises. This in turn provided sample adequacy for the study. Before administration of the questionnaire, the required official protocols were observed and permission sought from the management of the DVLA. Sixty (60) sets of the questionnaire were administered to randomly selected vehicle drivers (respondents), who visited the DVLA premises on the various sampling days. Care was taken to ensure maximum participation. The measure used to achieve this included explanation of the purpose of the exercise to respondents. Personal interviews were also used to support the questionnaire in obtaining the information that the study sought to elicit.

The questionnaire focused on information relating to driving pattern. These included choice of road-type plied, factors that influence choice of road such as conditions of roads, speed profiles, gear-changing behavior during acceleration and deceleration knowledge on hot and cold starts, weather, road width, road surface, traffic signals, frequency of intersection, traffic signals, frequency of vehicles maintenance, contribution of their driving patterns to vehicular emissions and seating capacity. Personal observation of trends in vehicle driving patterns such as cold and hot starts was also made in the study. Other parameters such as pedestrian activity, psychology and physiological states, traffic density, distraction (through conversation, radios, the use of phones captured in the questionnaire were not the main and immediate focus of the study but could influence the driving pattern. Drivers were interviewed to obtain information that could not be captured by the sampling and questionnaire.

RESULTS AND DISCUSSION

Types of road plied by drivers

The urban road was the most plied road among the three roads considered in the study. Except for six (60 vehicles representing 10%, all the vehicles plied the urban roads (Table 1).

Table 1. The relative proportions of vehicles that plied three road-types

Road-types	Number of vehicle drivers	Percentage of vehicles
Urban	54	90.0
Feeder	4	6.7
Highway	2	3.3

The drivers explained that the conditions of roads influence their choice of road-type plied. In this respect, issues of concern included, road surfacing, road width, speed limits, road maintenance, presence of congestion, and time of the day. Related to this factor is another factor namely route choice which, according to commercial drivers is influenced by availability of passengers, vehicle size, trip purpose and road network. Several factors affect the route choice decisions of drivers ((Erke et al., 2007; Zhang and Levinson, 2008; Zhong et al., 2012). This may have an impact on the efficiency of vehicular movements.

The density of traffic in an area affects the concentration of vehicular emissions in the area. This is also related directly to the number of vehicles plying a road. With the majority of vehicles plying urban roads (Table 1), one will not be wrong in suggesting that the contribution of air pollution in the Kumasi Metropolis and associated air pollution could be high. Again, vehicular emission levels from urban road transportation could be generally higher in urban areas than from highway and feeder roads. The effects of a high degree of atmospheric pollution include lungs and heart diseases, and sometime premature deaths and high morbidity. This, in turn necessitates the institution of measures for good driving behaviour.

Observance of speed limit by vehicle drivers

Forty-eight (80%) drivers noted that they do not exceed the seating capacity, 11.7% observed and adhered to the seating capacity while the remaining 8.3%, did not always do so (Fig. 2).

Observance of seating capacity by vehicle drivers

In order to make up for lost income which results from traffic congestion, drivers adopt prominent strategies among which is increasing seating capacity (Fig. 2). About a quarter, 14, representing 23.3% of drivers who plied the usually congested roads regularly exceeded the seating capacity while 21 (35%) do so intermittently. The remaining 25 (41.7%) observed the seating capacity (Fig. 3). According to drivers who usually exceeded the seating capacity, this was necessary to meet the cost of running their vehicles, since traffic congestion limited the number of trips they could make per given period of time and hence financial loss. The tendency of such behaviour to promote emissions, has however not been an issue to drivers. Mock (2011) recounted the possibility of two vehicles with the same number of seats or the same boot volume, to have significantly different CO_2 emissions, cautioning that any use of the number of seats or boot volume would require a careful definition of these variables. This and other technical issues support the call for intensified education on issues of vehicular emission.

Barth and Boriboonsomsin (2009) justified the need to combat traffic congestion by listing reasons such as waste of time and money, increasing risks of accidents and promotion of localized pollutants such as particulate matter and the most serious long-term consequence; increased emission of greenhouse gases. The wastage of fuel, an already scarce commodity that occur can however not be discounted.

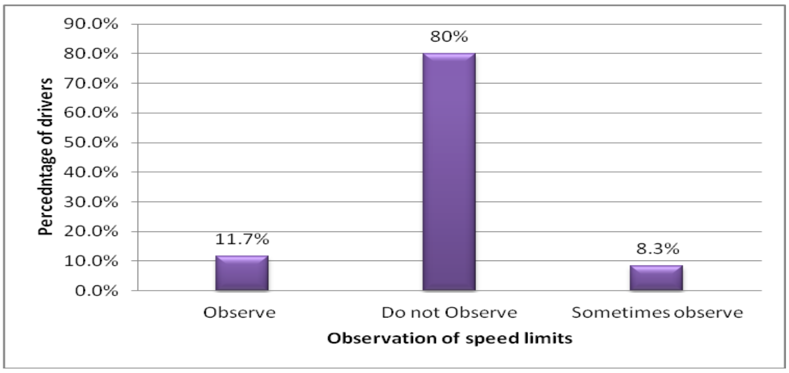

Fig. 2. Observance of speed limit by vehicle drivers

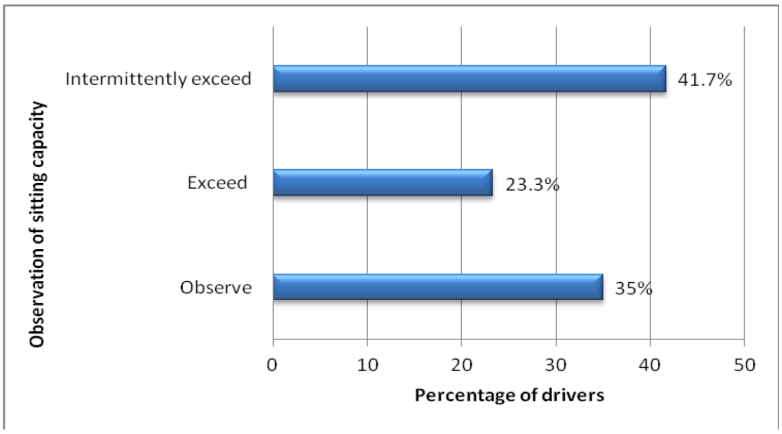

Fig. 3. Adherence to rules on seating capacity by vehicle drivers

Maintenance of vehicles

The frequency of maintenance of vehicles was generally low. Only two vehicle drivers undertook regular monthly vehicle maintenance. The rest undertook maintenance irregularly (whenever their vehicles developed fault). The number of times that drivers undertook maintenance was directly related to duration. Thus, the shorter the period, the lower the number of vehicles that undergo maintenance (Fig. 4). The results however depict the period within which the vehicle operators appreciate the occurrence of fault and therefore, were likely to visit the mechanic workshop but not necessarily periods for established scheduled maintenance.

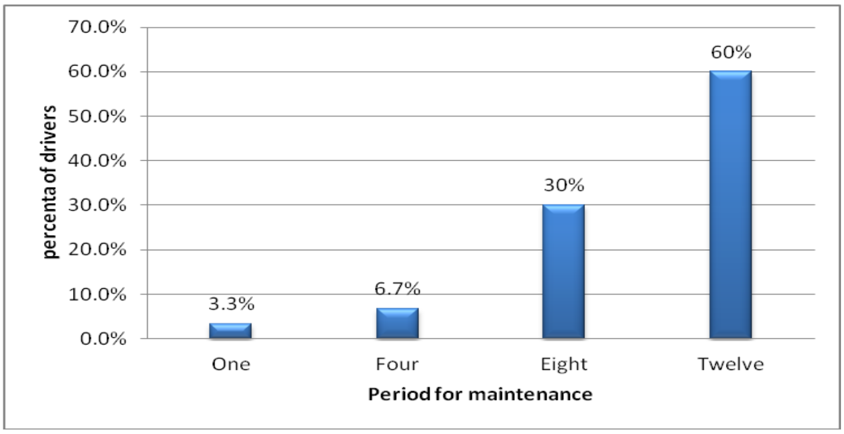

Fig. 4. Frequency of vehicle maintenance by drivers

Knowledge of start conditions (cold and hot starts)

Majority (90%) of vehicle drivers did not have any knowledge of hot and cold starts. Neither did they have any knowledge on the contribution of their driving patterns to increased vehicular emissions. Conscious of the tendency of traffic to build-up in the mornings, drivers hurriedly moved their vehicles (in their bid to avoid being caught up in such traffic situations) without allowing enough time for initial engine warm-up and stabilization. It has been observed that 80% of drivers switch off their vehicles, when stuck in traffic. Most drivers moved their vehicle almost immediately after the ignition keys are turned on (Fig. 5). This results shows the weakening of engines and hence their performances. In vehicles that use catalytic converters, during cold starts, catalytic emission control systems do not provide full control until they reach operation temperatures and richer mixtures. In situations where full control is exerted, differences in the catalysts may offset any increase in fuel consumption. Another effect is increase in cold start emissions. According to the USEPA, hot start test begins exactly 10 min after the engine is fully warmed up and there is no requirement of mixture enrichment to achieve this.

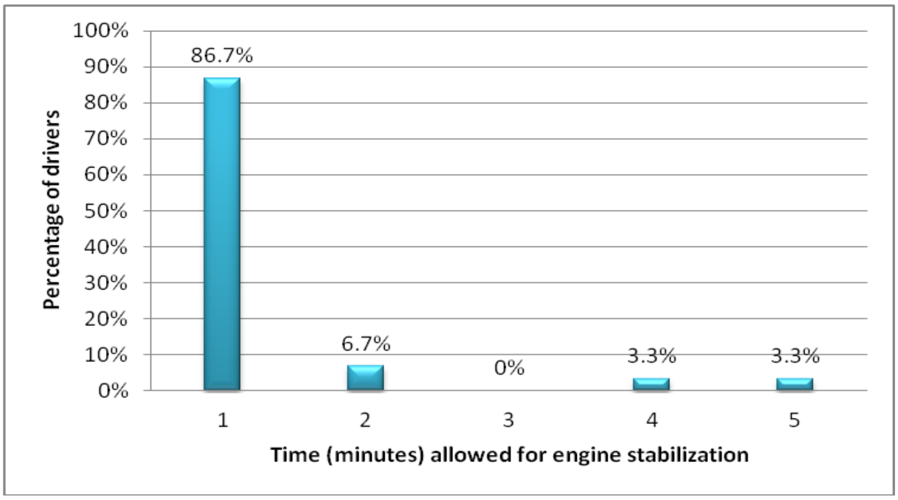

Fig. 5. Length of time allowed by vehicle drivers for engine stabilization

Driving pattern including speed profiles affect the fuel consumption as well as total emissions (Ahn et al., 2002). Driving patterns in urban areas vary greatly, affecting the amount of exhaust emission and fuel consumption. Differences in driving patterns may swamp any increases in fuel consumption due to catalysts. El-Shawarby et al. (2005) noted that traffic density, number of intersections, speed limit, modal mix, street functions and type of landuse influence driving patterns, and suggested their consideration for inclusion in the development of new driving cycles; the sequence of vehicle operating conditions (idle, acceleration, steady state and deceleration) developed to represent typical pattern in an urban area (Brundell-Freij and Ericsson, 2005)

Speed profile

Majority of the vehicles considered in this study did not speed much. Also, only four (6.7%) drivers were slow in changing speed. The remaining 56 drivers (93.3%) often and randomly changed speed. This may have a profound effect on emission rates. This observed speed profile is attributed to the existence of intermittent traffic lights, intersections, roundabouts and vehicle population congestions, making it difficult in maintaining constant speed and therefore, forcing drivers to exhibit frequent gear-changing behaviors, unstable and inconsistent speed profiles as the most common driving patterns. This observation is similar to that by Nesamani et al. (2007) who noted that with increase in traffic volume and change in travel-related characteristics, vehicular emission and energy assumption have increased significantly. Also, when a vehicle is at high speed, emission tends to be lower than when the vehicle moves at snail speed (within certain limits).

At very low average speeds which generally represent stop-and-go driving, it is established that vehicles do not travel far, causing elevated levels of emission rates per mile (Int Panis et al., 2006). Such situations typify scenarios when the vehicle engine continue running without movement by the vehicles, therefore increasing their emission rate per mile to infinity. Paradoxically, when vehicles travel at much higher speeds, very high amounts of engine loads and commensurate high quantities of fuel are spent. This leads to correspondingly high CO_2 emission rates. In between these two scenarios is a moderate speed and a corresponding moderated fuel and CO_2 emission. Barth and Boriboonsomsin (2009) established a distinctive parabolic shape emissions-speed curve, with high emission rates on both ends and low emission rates at moderate speeds of around 40 to 60 mph. If congestion reduces the average vehicle speed below 45 mph (for a freeway scenario) CO_2 emissions increase (Greenwood et al., 2007; Vicente, 2013). Vehicles spend more time on the road, which results in higher CO_2 emissions. This is one of the situations that make a call on authorities for congestion-mitigation programs, in order to reduce CO_2 emission directly. Moreover, in situations where average speed reduces from 70 mph to a slower speed of 45 to 55 mph due to moderation in congestion, the response is CO_2 emissions reduction. This notwithstanding, elevation of average traffic speed to above about 65 miles per hour due to congestion mitigation causes increase in CO_2 emissions. El-Shawarby et al. (2005) observed lower rate of emissions at speed ranging from 60 to 90 km/h outside of which a considerable increase in emissions occur.

CONCLUSION

Light duty vehicle drivers that ply the three road types; 1. highway, 2. urban and 3. feeder roads daily, do not have adequate knowledge about their contribution to air pollution through inappropriate driving patterns. Frequent gear-changing behaviour, unstable and inconsistent speed profiles due to intermittent traffic lights, intersections, roundabouts and vehicle population congestions are the most common driving patterns identified. The phenomena call for intensified public education campaigns for drivers to be abreast with maintenance of consistent speed profiles and exhibition of good vehicle maintenance habits and hence, reduce air pollution. Also, smoothing the *stop-and-go* pattern of traffic for free flow of vehicles at a relatively constant speed, by re-engineering the traffic situation in the metropolis will be helpful in reducing vehicular emissions.

REFERENCES

Agyemang-Bonsu, W.K., Tutu-Benefoh, D. and Asiamah, H., (2007). Ghana Vehicular Emission Report, Accra, Ghana. Environmental Protection Agency, Accra.

Agyeman Bonsu, W.K., Dontwi, I.K., Tutu-Benefoh, D., Bentil, D.E., Boateng, O.G., Asubonteng, K. and Agyemang, W. (2010). Traffic-Data Modeling of Vehicular Emissions using COPERT III in Ghana: A case study of Kumasi. American Journal of Scientific and Industrial Research. Am. J. Sci. Ind. Res., 1(1), 32-40.

Ahn, K., Rakha, H., Trani, A. and van Aerde, M. (2002). Estimating Vehicle Fuel Consumption and Emissions Based on Instantaneous Speed and Acceleration Levels. J. Transp. Eng., 128 (2), 182–190.

Andre, M. (2004). The ARTEMIS European driving cycles for measuring car pollutant emissions. Sci Total Environ., 334-335(1), 73 –84.

Barth, M. and Boriboonsomsin, K. (2009). Energy and Emissions Impacts of a Freeway-Based Dynamic Eco-Driving System. Transportation Research Part D: Environment 14, 400-410.

Bokare, P.S. and Maurya, A.K. (2013). Study of effect of speed, acceleration and deceleration of small petrol car on its tail pipe emission. International Journal for Traffic and Transport Engineering, 3(4), 465 - 478

Brundell-Freij, K. and Ericsson, E. (2005). Influence of street characteristics, driver category and car performance on urban driving patterns, Transportation Research Part D, 10(3), 213-229.

Cascetta, E., Punzo, V. and Sorvillo, R. (2010). Impact on Vehicle Speeds and Pollutant Emissions of a Fully Automated Section Speed Control Scheme on the Naples Urban Motorway (Paper presented at the 89th Annual Meeting of the Transportation Research Board; Washington, DC, USA).

El-Shawarby, I., Ahn, K., Rakha, H. (2005). Comparative field evaluation of vehicle 227 cruise speed and acceleration level impacts on hot stabilized emissions. Transport. 228 Res. D, 10, 13–30.

Erke, A., Sagberg, F. and Hagman, R. (2007). Effects of route guidance variable message signs (VMS) on driver behaviour. Transportation Research Part F, 10 (6), 447–457.

Frey, C., Unal, A. and Chen, J. (2002). Recommended strategy for on-board emission data analysis and collection for the new generation model. Prepared by North Carolina University for the office of Transport and Air Quality, US EPA.

Greenwood, I., Dunn, R. and Raine, R. (2007). Estimating the Effects of Traffic Congestion on Fuel Consumption and Vehicle Emissions Based on Acceleration Noise. J. Transp. Eng., 133, 96–104.

Haug, A., Zachariassen, A. and van Liempd, D. (2011). The costs of poor data quality. Journal of Ind. Enginerring and Mgt., 4(2), 168-193.

Int Panis, L., Broekx, S. and Liu, R. (2006). Modelling instantaneous traffic emission and the influence of traffic speed limits. Sci. Total Environ., 371, 270–285.

Levy, J.I., Hammitt, J.K. and Spengler, J.D. (2000). Estimating the Mortality Impacts of Particulate Matter: What Can Be Learned from Between-Study Variability? Environ. Health Perspect., 108 (2), 109-117.

Li, M., Boriboonsomsin, K., Wu, G., Zhang, W.B. and Barth, M. (2009). Traffic energy and emission reductions at signalized intersections: a study of the benefits of advanced driver information. International Journal of ITS Research, 7(1), 49-58.

Mayeres, I. (2000). The efficiency effects of transport policies in the presence of externalities and distortionary taxes', Journal of Transport Economics and Policy, 34(2), 233–660.

Mock, P. (2011). Evaluation of parameter-based vehicle emissions targets in the EU. How regulatory design can help meet the 2020 CO_2 target. White paper number 10. Fuel economy and GHG standard design series.

Nesamani, K.S., Chu, L., McNally, M.G. and Jayakrishnan, R. (2007). Estimation of vehicular emissions by capturing traffic variations. Atmospheric Environment, 41(13), 2996-3008.

Nesamani, S.K., Subramanian, P.K. (2006). Impact of Real-World Driving Characteristics on Vehicular Emissions. JSME International Journal Series B, 49(1),19-26.

Samet, J.M., Dominici, F., Zeger, S.L., Schwartz, J. and Dockery, D.W. (2000). National Morbidity, Mortality, and Air Pollution Study. Part I: Methods and Methodologic Issues. Research Report. Health Effects Institute, 94. 96p.

Schwartz, J. (2000). Harvesting and Long Term Exposure Effects in the Relation Between Air Pollution and Mortality. Am. J. Epidemiol., 151 (5), 440-448.

Soole, D.W., Watson, B.C. and Fleiter, J.J. (2013). Effects of Average Speed Enforcement on Speed Compliance and Crashes: A Review of the Literature. Accid. Anal. Prev., 54, 46–56.

Vicente Franco, V., Kousoulidou, M., Muntean, M., Ntziachristos, L., Hausberger, S. and Dilara, P. (2013). Road vehicle emission factors development: A review. Atmospheric Environment, 70, 84 -97.

Watkiss, P. and Downing, T.E. (2008). The Social Cost of Carbon: Valuation Estimates and Their Use in UK Policy. The Integrated Assess. Journ., 8(1).

Zhang, L. and Levinson, D. (2008). Determinants of route choice and value of traveler information; A field experiment. Transportation Research Record, Journal of TRB, 2086, 81-92.

Zhong, S., Zhou, L., Ma, S. and Jia, N. (2012). Effects of different factors on drivers' guidance compliance behaviors under road condition information shown on VMS. Transportation Research Part A, 46 (9), 1490-1505.