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An Investigation into A Socio-Economic Fit Between Vehicular Emissions and Economic Activities: A Case Study of Commercial Vehicles

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ABSTRACT

Vehicular emission is one of the challenges in managing environmental pollution. The present study is designed to find a socio-economic fit between economic activities and the resultant emissions associated with automobiles. To proceed, it focuses on estimating seven different types of vehicular emissions; carbon monoxide, carbon dioxide, nitrogen oxide, particulate matter 2.5 and 10, volatile organic compounds, and the total suspended particulate matter. This exercise is based on data from a sample of 1200 respondents from the district of Peshawar. Results demonstrate that socio-economic factors and vehicle-specific characteristics significantly affect the excessive vehicular emission in the study area. It has been found that the socio-economic variables like age of respondent, education of respondents, and family size of the respondent, earning members in respondent's family, monthly income of the respondents, total household expenditures, and wealth are factors significantly affecting commercial automobiles' emissions. Moreover, it was found that the cost incurred on the maintenance of the vehicle by the owner/driver is within the income range of the respondent. Based on the results, it is recommended that the identification and countering of challenges being raised by the emissions from commercial automobiles is very important for both the environment and the economy. This can only be done by a comprehensive cost-benefit analysis among different but conflicting priorities. As a top priority, the Khyber Pakhtunkhwa Government Driving School may be revamped to impart more efficient and effective training on road awareness and the resultant emissions from automobiles. Similarly, the Khyber Pakhtunkhwa Vehicle Emissions Testing Station (VETS) should be upgraded with the latest as well as smart machinery and equipment, especially the mobile testing stations that operate in shifts to cover the round-the-clock monitoring. Also, the emission fitness certificate shall be made conditional for the annual tax token renewals. The replacement of old and outdated engines with modern Euro–VI engines shall be incentivized so that the drivers are encouraged for the shift, ultimately benefiting both the environment and the drivers economically.

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1. Introduction

Currently, economies throughout the world face challenges of sustainable economic growth and environmental degradation. Several factors, including unsustainable economic growth, population growth, increase in the vehicle fleet, per capita affluence, and increase in advanced technological appliances, etc., continuously degrade the environment. However, most researchers argue that environmental Degradation is because of industrialization, which is considered to be the main driver of growth (Cherniwchan, 2012).

Pakistan is one of the most polluted countries globally due to industrial and vehicular emissions and crop burning (Sota, 2021). The increased urban population in the country induced motorization (public and private), leading to an increase in air pollution through toxic exhaust gasses. Particulate matter PM 2.5 in Pakistan was recorded at 37 $\mu g/m^3$ in 2016. With the current rate of particulate matter, the citizens of Pakistan are losing life by 2.7 years approximately. Similarly, according to the latest report of WHO, Lahore city is the most polluted district with approximately 11 million population in the country. The particulate matter PM 2.5 in 2016 was recorded at 64 $\mu g/m^3$ in district Lahore causing a decrease in the average life expectancy of the citizens by approximately 5.3 years; moreover, if the concentration of particulate matter is sustained at the current level in the district, it would decrease the average lives of a citizen by 5.8 years. In Peshawar, the particulate matter was 34 $\mu g/m^3$ causing a decrease in the life of citizens by 1.9 years (Sota, 2021). Like other developing countries, Pakistan has experienced tremendous growth in the population in the last two decades. The population growth caused increased urbanization and an increase in the development of industries and the number of vehicles, creating an increased demand for energy consumption (Purohit, Munir, & Rafaj, 2013).

According to the Pakistan Environmental Protection Agency, the level of pollutants in major cities of Pakistan has surpassed the accepted level. It has been recorded that almost in all major cities, the level of pollutants in the air is approximately seven-fold to that specified by the World Health Organization (WHO). The major causes of air pollution in Pakistan include an increased number of vehicles in urban localities, unplanned industrial activities, inefficient energy sources, environmental protection policy non-compliance, the increasing number of outdated and poorly maintained auto-mobiles, and lack of air quality control measures (Javed, 2015). The air pollutants and quality data in Pakistan have been challenged by socio-economic researchers and scientists (Niaz, Jiti, & Zhang, 2015). However, the major sources of air pollutants include SO_2, NO_2, and particulate matter (PM2.5 and PM10). Moreover, previous literature attempts to calculate the air pollutants in major cities of the country, including Karachi, Lahore, Islamabad, Peshawar, Rawalpindi, and Quetta. Moreover, Pakistan initiated an investigation of air pollutants collaborating with the Japan International Cooperation Agency in 2000. The ambient air was assessed in Lahore, Islamabad, and Rawalpindi, and air quality samples were collected in selected cities using mobile stations. The results revealed that the particulate matter (PM10) was exceeding the WHO standard limit by 50 $\mu g/m^3$ (24-hour average) and 20 $\mu g/m^3$ (annual average). The mean suspended particulate matter (SPM) for three cities was 2000 $\mu g/m^3$ and the average particulate matter PM10 was 700 $\mu g/m^3$ (JICA/EPA, 2000).

However, the concentration of sulfur dioxide (SO_2), Nitrogen Oxide (NO_2), and carbon dioxide (CO_2) were found according to the WHO guideline limit. Hourly average data has been presented in Table 1 below. SUPARCO conducted another study. It is believed that the major source of air pollution in urban areas is transportation; the transportation sector uses approximately 47.4 percent of petroleum products in the country, inefficient fuel and poorly maintained vehicles have been considered the major source of air pollutants in the urban areas. The total number of registered vehicles in the country in 1994 was 3.5 million. However, the total number increased to 5.2 million in 2005 which exacerbated the problem of increased automobile emissions. Thus, vehicular emission is considered the main source of total emissions. The National Emission Inventory of Pakistan estimated vehicular emissions in 1998. However, the emissions inventory is not quantified accurately for several reasons, including road quality, weather conditions, fuel efficiency, age and maintenance of the vehicle, average speed, etc. The estimated inventory of vehicular emissions revealed that the total emissions produced by vehicles in the country were approximately account for 35,362 tons of particulate matter, about 324 or 473 tons of nitrogen oxide, and around 12,871 tons of sulfur dioxide in 1998 (Hussain et al., 2020). It is considered that human activities mainly cause damage to the environment. Providing several examples of human activities augments the statement, including increased automobile fleet, road congestion, technological and industrial achievements, power plants, and use of fossil fuels domestically, etc. These activities achieve daily life goals and produce byproducts in the form of toxic emissions - which affect almost every citizen in the area (Clémençon, 1997).

Commercial automobiles are used to meet the daily needs of citizens like; shopping and traveling, access to educational institutions and workplaces, etc. Furthermore, these automobiles are a source of employment for several hundred citizens in the locality. However, outdated and poorly maintained commercial automobiles cause severe air pollution through excessive toxic emissions. The pollutants from those automobiles interact with humans through touch, breathing, and food, thus causing serious threats to human life, including cancer, severe respiratory disease, skin, brain, heart diseases, genetic mutation, etc., resulting in poor health of citizens and, hence, poor labor supply and low productivity (Moldovan et al., 2002). The objective of this study is to explore the nature and causes of excessive emissions from automobiles and its relationship with the socio-economic status of drivers/owners in the study area.

2. Literature Review

Allegrini and Costabile (2002) argued that the increase in the Degradation of environmental quality in cities is because of an increase in population, an increase in economic activities, and increase in the number of private and commercial automobiles. This is consistent with El-Fadel and Bou-Zeid (1999), who highlighted the increase in automobile fleet in the cities and its positive correlation with the rise in environmental Degradation. Atash (2007) stated that the increase in automobile fleet, outdated and poorly maintained vehicles on the road, increase in industrial activities, increase in population, road congestion, unplanned urbanization, lack of emission control policies, etc., are the most important factors of air quality degradation in developing countries. Similarly, Bindra and Hokoma (2004) argued that one of the most influential air pollution factors in cities is increased automobiles in urban areas and fossil fuels.

Boxall, Adamowicz, Swait, Williams, and Louviere (1996) studied environmental quality changes arising from recreational hunting and forest management. The study found that the chosen method is more appropriate than the contingent valuation technique. Goyal, Van Der Leij, and Moraga-González (2006) argued that land transport is the main cause of air pollution in metropolitan cities. The authors further argued that approximately 70 percent of carbon monoxide, 10 percent of sulfur dioxide, 30 percent of nitrogen dioxide, 50 percent of hydrocarbons, and 30 percent of particulate matter; come from land transport in major cities of the developing countries. These pollutants have several effects on human life, the environment, climate, economic activities, agricultural production, etc. Furthermore, these studies specifically stated that an increase in air-borne disease, cancer, genetic mutation, damage to the ecosystem, and landscape, and economic effects in major cities is because of an increase in vehicular emissions. Faiz, Weaver, and Walsh (1996) stated the economic cost of air pollution in major cities from automobile emissions; affects almost all aspects of economic activities, including; the deterioration of historic buildings and places. Hence, a decrease in tourism, loss of landscape, and agricultural production resulted in food shortage and malnutrition, affecting the labor market and increasing health expenditures.

Mayer (1999) argued that air pollution is mainly a by-product of human activities to achieve sustainable development and growth objectives. These sources of air pollution would be categorized as trade liberalization, fuel combustion for domestic use, industrial production, automobiles and power plants, etc. However, the author emphasized that the increase in the local and commercial auto-mobile fleet in recent years has contributed more than other sources of air pollution. Similarly, Fenger (1999) argued that approximately three thousand air pollutants are recognized to date, in most of the pollutants come from the combustion of fuels. Moreover, approximately 500 different pollutants are emitted from automobiles' combustion engines, affecting human health and economic activities (Kumar et al., 2011).

Economic activities are considered the most important feature of cities; however, these economic activities also create negative externalities. These negative externalities affect the air quality in cities, thus increasing the risk of exposure to toxic emissions and creating health problems. (Atash, 2007) argued that unregulated economic activities in developing countries are the main cause of the increase in air pollution. Similarly, Bekir and Surhid (1997) argued that the increase in automobiles in cities is positively associated with economic growth; particularly, the per capita income in cities is more than in rural areas. The increase in vehicle fleets in cities contributes to increasing vehicular emissions. D'Amato (2002) argued that air pollutants from automobile emissions affect the surrounding atmosphere in several ways; including, a temperature rise, affect plant growth and yield, affect the quantity of pollen produced, etc. Automobile emission is considered the biggest source of greenhouse gases. Although it is not solely responsible for greenhouse gases, vehicular emissions affect the global climate and air quality through wind speed, ventilation, precipitation, mixing depth, dry deposition, and the production of chemicals, etc. (Hell, Mutegi, & Fandohan, 2010).

Faiz et al. (1996) argued that the environmental and health damage in metropolitan cities is directly proportional to the increased consumption of fossil fuels and the number of automobile fleets, population growth, and traffic congestion. Faiz et al. (1996) argued that the increase in health issues in urban areas is directly associated with the increase in vehicle fleets and emissions from those vehicles. Schafer, Kypreos, Gomez, Jacoby, and Dietrich (1999) empirically forecasted the world vehicles fleet per 1000 persons to be 1.8, and when private cars and trucks are included, it is 2.3 vehicles per 1000 persons. Hence, the author suggested that the number of vehicles worldwide is sharply increasing, increasing at a greater rate in developing countries. Automobile emissions have remained the key issue for policymakers and researchers; when linked with various types of diseases. Bell, Davis, Gouveia, Borja-Aburto, and Cifuentes (2006) argued that with the increase in the vehicle fleet and toxic vehicular emissions, there had been an increase in skin diseases and respiratory system diseases. Similarly Ghose, Paul, and Banerjee (2004) have stated that air pollution caused by automobile emissions is closely associated with various diseases, including; respiratory diseases like bronchitis and asthma, cardiovascular diseases, the interaction of emissions with DNA skin diseases, and eye disease, etc. Furthermore, the authors suggested that because of the increase in vehicular emissions in urban areas, there is a need to investigate the effects of that emission on human health, especially on children's health. There has been a strong correlation between emissions concentration in the air and the poor health of the citizens in urban areas.

Ramani, Jaikumar, Khreis, Rouleau, and Charman (2019) argued that the concentration of toxic gases, including; CO_2, NO_2, and SO_2 in the air of urban areas, had caused an increase in respiratory, cardiovascular, and other diseases. However, it is difficult to investigate the separate effects of those toxic gases on human health because, generally, citizens are exposed to a mix of those gases.

3. Methods and Materials

3.1. Data and Data Sources

This study used primary data collected through open and closed-ended questionnaires and interviews with drivers on roads and government officials at offices and on roads. Similarly, the data about the emission levels of each class of vehicles was also collected during road checking in collaboration with the Vehicle Emission Testing Station (VETS), Khyber Pakhtunkhwa Transport, and Mass Transit Department Peshawar. However, other required data was collected from concerned departments or institutions.

3.2. Sampling Method and Sample Size

The number of commercial automobiles that have taken route permits in different categories from Khyber Pakhtunkhwa Transport and Mass Transit department is 282,911 divided into the three categories, i.e., Light Transport Vehicles (LTV)= 135282, Heavy Transport Vehicles (HTV) = 81266, and Public Service Vehicles (PSV) = 66,380.

Because the population is finite, the Yamane method of sample size calculation is used. Yamane's formula (1967) for sample size is given by:

$$\boldsymbol{n = N/[1 + N(e^2)} ------------------ \boldsymbol{Sample\ size}$$

Where, n is the sample size, N is population under study, & e is Margin of error

The sample size for each category is determined through the above formula with a 0.05 margin of error. The resultant sample sizes are; LTV = 399, HTV = 398, and PSV = 397. Therefore, a total of 1194 commercial automobiles of different categories were tested.

3.3. Analytical Technique

The first hypothesis of the research states that; the mechanical, technological, and socio-economic factors do not contribute to the excessive emissions from commercial automobiles. To test this hypothesis, suppose the owner/driver wants to spend a share of income on vehicle maintenance to reduce the greenhouse gasses from the vehicle. Hence, it is supposed that the more effort/expenditure dedicated to the maintenance of a vehicle decreases the emission; in other words, excessive emissions from a typical vehicle increase maintenance expenditure. The conventional consumer theory would be appropriate for formulating the empirical model and testing this hypothesis. A consumer maximizes their utility constrained to a fixed budget, or the consumer minimizes the budget to attain a fixed utility level. There are several methods developed and applied for estimating consumer demand, including; translog, suggested by Christensen and Luginbyhl (1975), Almost Ideal Demand System (AIDS) developed by Deaton & Muellbauer (1980); Rotterdam by Theil (1976). The relationship has been checked through an econometric regression where; the dependent variable is expenditure/cost-share incurred on maintaining the vehicle to control the greenhouse gas emission by pre-specified limits. The economic theory of the Almost Ideal Demand System (AIDS) developed by Deaton and Muellbauer (1980) has been used (because of the fact; it is more flexible as well as it provides various properties of demand system including homogeneity and symmetry) to check the effects of different factors on expenditure share of maintenance. Specifically; the model is based on expenditure function $c(u,)$which is given as follows;

$$\log[c(u,p)] = (1-u)\ln[a(p)]\ln[b(p)] \qquad (1)$$

Where c represents total cost, u and p represent utility and prices respectively, utility lies between 0 (subsistence) and 1 (bliss) so that the functional forms of a(p) and b(p) can be considered as the costs of subsistence and bliss, respectively. Deaton and Muellbauer (1980) further specified the functional form of ln a(p) and ln b(p) as follows;

$$\ln a(p) = a_0 + \sum_{i=1}^{n} a_i \ln(p_i) + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij} \ln(p_i)\ln(p_j) \quad (2)$$

$$\ln b(p) = \ln a(p) + \beta_0 \Pi_j p_j^{\beta_j} \quad (3)$$

where; $a_i, \beta_j, and\ \gamma_{ij}$Represent parameters are to be estimated. Substituting equations 2 and 3 in the cost function, ln [c (u, p)] becomes;

$$\ln c(u,p) = a_0 + \sum_{i=1}^{n} a_i \ln(p_i) + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij} \ln(p_i)\ln(p_j) + \beta_0 \Pi_j p_j^{\beta_j} \quad (4)$$

A generalized form of the AIDS model can be derived from equation (4) by applying Shephard's Lemma [∂c(u, p)/∂p] and then budget shares w_i. Hence, the logarithmic differentiation of equation [1] gives the budget share as a function of price and utility, which is given as follows;

$$w_i = a_i + \sum_{j=1}^{n}\gamma_{ij} \ln(p_j) + \beta_i ln\left(\frac{x}{p}\right) + \epsilon_i \quad (5)$$

Where;

$$\ln(p) = a_0 + \sum_{i=1}^{n} a_i \ln(p_i) + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij} \ln(p_i)\ln(p_j) \quad (6)$$

In the above system w_i is the budget share of vehicle maintenance, p_i is price of vehicle maintenance, X represents total expenditures on the vehicle, and P is the price index.

The study further augments equation (5) with other controlling variables such as vehicle type, engine type, fuel consumption, fuel type income earned/day/week/month, etc., and dummy variables indicating routine maintenance schedule.

$$w_i = a_i + \sum_{j=1}^{n}\gamma_{ij} \ln(p_j) + \beta_i ln\left(\frac{x}{p}\right) + \sum_{i,j}^{n}\delta_i S_j + \sum_{i,j}^{n}\theta_i D_j + \epsilon_i \quad (7)$$

Where S = vector of scheduled maintenance dummies, δ_i is vector of parameters, D is vector of other controlling variables, and θ_i is vector of parameters.

The hypothesis can be tested by checking the effect of an individual variable on the cost share of maintenance.

The present study assumes that the total maintenance cost on the commercial vehicle is out of the range of drivers/owners of commercial automobiles (hypothesis 02). Similarly, hypothesis 03 states that the socio-economic indicators such as income, age, education, etc of drivers/owners do not contribute to controlling excessive vehicular emissions. These hypotheses can be checked in several ways; the simplest way of testing these hypotheses is to apply some statistical tests, mean equality, or Analysis of Variance (ANOVA). However, the results obtained from these may be distorting or misleading because the owner/driver's responses may not be accurate for several reasons, including; avoiding any penalty, carbon tax, etc. Hence, the present study has tested the hypothesis with simple statistical tools and has rephrased the hypotheses. The owner/driver does not value the quality of the environment for a healthy and better life. These hypotheses have been tested, and if the owner/driver values the quality of the environment, then it may be inferred that the maintenance cost of the vehicle, as well as the importance of environmentally friendly modes of transportation, is in the range and matters respectively for owner/driver of a commercial vehicle. There are several non-market evaluation methods for estimating the demand for a non-marketable good/service. Employing this method for testing the hypothesis has determined the ability of individual owners/drivers for maintenance and estimated the total economic cost/value of air pollution in the study area in the context of commercial vehicle owners/drivers. Following this approach, testing this hypothesis comes from the non-market valuation methods. Most of the previous research used the Contingent valuation method (CVM). Hence, it is assumed that CVM is an appropriate economic theory for estimating the environmental value in the study area.

Contingent Valuation Method (CVM) is widely used for goods and services that are not commonly traded in the market; for instance, health quality, healthy environment, water quality, etc. The demand and supply of commonly traded goods are determined through market price. However, non-market goods and services have no explicit price; therefore, it is challenging for researchers and economists to determine such goods' demand. The concepts of willingness to pay (WTP) and Willingness to Accept (WTA) are indirect prices for non-market goods and services. Following the studies of U. Mustafa, Ahmad, and Haq (2014) and S. A. Mustafa, Kamaruddin, Othman, and Mokhtar (2009) suppose the following utility function where a typical owner/driver maximizes the utility derived from two types of goods/services; marketable and non-marketable subject to a constrained income;

$$u(X, m) \tag{8}$$

The owner/driver derives the utility from (X), marketable goods and services, and (m) the environmental quality enhanced after commercial vehicle maintenance. The expenditure function for attaining the said utility level is given as follows;

$$e(u, p, m) \tag{9}$$

Where; u is utility level and P is set of marketable goods and services prices

Equation 8 is the lowest sum of the monetary value of attaining the said level of utility. However, the function is cumulative in (*p*) and (*u*) while diminishing in (*m*); for finding the optimal solution for the owner/driver, it is pertinent to achieve optimization from the expenditure minimization problem;

$$\min(pX + pm) \tag{10}$$

Subject to

$$U = u(X, m) \tag{11}$$

In equation 10, the marketable goods/services are treated as numeraire; and the price of marketable goods and services equals 1. The Lagrangian multiplier can achieve the expenditure minimization problem to estimate the Hicksian demand for analogous goods/services. The Hicksian demand is given as follows;

$$h_i = h_i(u^*, pm) \tag{12}$$

H_i is the Hicksian demand for good/service *i,* a function of fixed utility level, price, and enhanced environmental quality from vehicle maintenance. By putting the Hicksian demand function into the minimum expenditure equation; it calculates the least expenditure function; given as follows;

$$e^* = e(u^*, p, m) \tag{13}$$

Where; e is the minimum expenditure required by owner/driver to achieve a fixed level of utility u^*, on the other hand, and e^* is the least expenditure, a function of fixed utility level, prices, and enhanced environmental quality after the vehicle's maintenance. Deriving equation 13 concerning price calculates the compensated demand for goods/services under consideration;

$$\frac{\partial e}{\partial p} = h_i(p_m, u^*) \quad (14)$$

However, the Willingness to Pay (WTP) is the integration of change in the quality of the environment from m to m* after the vehicle is maintained to exhaust fewer emissions in the environment. Hence, the Willingness to Pay (WTP) is given as follows;

$$WTP = -\int_{m}^{m^*} \frac{\partial e(m,u^*)}{\partial m} .(dm) \quad (15)$$

Willingness to Pay (WTP) is the monetary amount an owner/driver of a commercial vehicle would give to appreciate any enhancement in the quality of the environment for a better life after the maintenance of the vehicle. Hence, the willingness to pay for an improved quality of the environment is given as follows;

$$WTP = e(p,u,m) - e(p,u,m^*) \quad (16)$$

Where m is the existing environment quality and $m^*$is the improved environment quality after vehicle maintenance, the changes in expenditure would probably result in two situations; a) corresponding surplus and b) excess rewarding. The econometric model can be specified by considering all other variables, including wealth, level of education, per day/week/monthly income from a commercial vehicle, household size, etc. hence, and the econometric model is given as follows;

$$WTP_i = \beta_0 + \beta_1 O/D_i + \beta_2 D_i + \beta_3 AE_i + \beta_4 BD_i + \epsilon_i \quad (17)$$

Where; WTP denotes Willingness to Pay for i^{th} owner/driver, O/D is owner/driver features (including; income from a commercial vehicle, wealth, education, household size, etc.), D is owner/driver demographic characteristic (urban or rural), AE is Adverse effects awareness of owner/driver from vehicular emission in the environment, and BD is any air-born disease owner/driver faced with environmental pollution.

In the present research, the WTP has been treated as a binomial variable that takes only two values; 1 if the owner/driver is willing to pay for the maintenance of a commercial vehicle and 0 if the driver/owner is not willing to pay. Hence, the appropriate econometric technique would be Probit or Logit regression for estimating the unknown parameters.

Hypothesis H_{04} states that the current emission level from district Peshawar's commercial vehicles is within the existing regulatory regime. To test this hypothesis, the required emission level from commercial automobiles is estimated and then cross-checked with the pre-specified international standards. The previous body of literature described several methods and techniques for estimating the emission level from vehicles. These methods and techniques include; the Average Speed Model (ASM) and Instantaneous Emission Model (IEM). The average Speed model states that the vehicle's emission can be estimated only by considering the driving patterns of drivers, and driving patterns are only described by the mean speed of the vehicle. However, this model has a few limitations; the approach does not consider the various cycles, vehicle specifications, and driving behaviors. Chassis Dynamometer is used for testing different road conditions and variable speeds to record the exhaust emissions from vehicles, including carbon monoxide (CO), carbon dioxide (CO_2), Nitric Oxide (NO_x), and Hydrocarbons (HC) (Ajtay, Weilenmann, & Soltic, 2005).

On the other hand, the Instantaneous Emission model (IEM) was introduced to overcome the shortcomings of the average speed model. The model records the emissions from the vehicle continuously on the chassis hydrometer test on the specific time interval of 1 second. Emission value is recorded on average for each pair of acceleration and speed. Hence, the emission function specified in the Instantaneous Emission Model (IEM) is a dimensional matrix of recorded speed and product of acceleration and speed. However, the model has limitations, as it records high emission levels from high acceleration [29]. In the last two decades, several models have been developed to estimate the emissions from transportation in environmental economics. However, the Average Speed Model (ASM) is widely used in European and US transport departments to estimate the level of emissions caused by vehicles. Two widely used programs for estimating the emissions in grams per kilometer are Transport Research Laboratory (TRL) and Computer Program to Estimate Emissions from Road Transport (COPART). Most studies in developing countries frequently used these two programs to estimate the emission level in regions, states, or nationwide. These computer packages estimate the emission g/kg and estimate the components of emissions, including; CO, NOx, HC, CO_2, and particulate matter (PM). These both estimate the emission in grams per kilometer of traveling, which is a function of the vehicle's speed [69, 70]. Following [72], the function of the Transport Research Laboratory (TRL)is given as follows;

$$EF_i, m, n = k + ax + bx^2 + bx^3 + \frac{d}{x} + \frac{e}{x^2} + \frac{f}{x^3} \quad (18)$$

Where, d, e, f, represent parameters assigned to an engine size, *m* and *n is* Technology of engine, *x is* mean speed in kilometers per hour, EF_i, m, n is value of emission in g/km traveled, I is given vehicle type, n is Size of Engine, and m is the Age of Engine.

Similarly, a functional form for a computer program to estimate Emissions from Road Transport (COPART) exists to estimate vehicular emissions. The emissions are classified into three different types: 1) Evaporative (E_{EVAP}), hot (E_{hot}), and cold (E_{cold}). Evaporative emissions occur from carbonator, gas tank, or during fuel injection. This form of emission is considered minor because it is only confined to gasoline engines. However, the cold and hot emissions mainly occur in diesel-powered engines. Cold emission is when the engine starts at ambient temperature and hot emissions are exhausted into the atmosphere while the engine is hot and running. Following the study of [102-103], the equations are given.

$$Total\ Emission = Cold\ Emission + Hot\ Emission + Evaporative\ Emission$$

The formula for Hot emission during the hot engine operations; is given as follows.

$$E_{hot;i,j,k} = N_j \times M_{j,k} \times e_{hot;i,j,k} ----------------(hot\ emission)$$

Where, $E_{hot;\,i,j,k}$ is pollutant emission of vehicle *i* in grams for a specific year, J is the Type of Vehicle, *K* represents Road, N_j *and* $M_{j,k}$ is number of vehicles of type *j* in a specific year and distance (mileage) by per vehicle *j* in kilometers on road type *k*.

Similarly, the formula for cold emission is given as under;

$$E_{cold;i,j} = b_{i,j} \times N_j \times M_j \times e_{hot;i,j} \times \left(\frac{e_{cold}}{e_{hot}}\right)_{i,j} ----------(cold\ emission)$$

Where; $E_{cold;\,i,j}$ is Pollutant *i by* vehicle type *j* for a specific year, $b_{i,j}$ is Fraction of any distance/mileage traveled with a cold engine, N_j and M_j is the number of vehicles of type *j* and total distance traveled in kilometers by type *j* vehicle respectively, $e_{hot;\,i,j}$ is mean fleet emission factor of i^{th}-pollutants by vehicle type *j* on road *k* when it is operating under the hot condition of the engine, and $\left(\frac{e_{cold}}{e_{hot}}\right)_{i,j}$ is the ratio of i^{th}-pollutant hot and cold emissions of vehicle type *j*.

4. Results and Discussion

4.1. Descriptive Statistics

The vehicular emission estimated in previous literature are Nitrogen Oxide (NO_2), Particulate Matter 2.5 and 10 ($PM_{2.5}$ and PM_{10}), Total Suspended Particulate Matter (TSP), Volatile Organic Compounds (VOC), Corban monoxide (CO), and Carbon Dioxide (CO_2). The data has been estimated on these pollutants with the help of COPERT 5.4 software. The sample size of the present study is 1200 observations. The data on emissions from commercial automobiles have been estimated for each commercial vehicle included in this study (see Appendix 02). The descriptive statistics of vehicular emissions are presented in Table 1.

Table 1
Descriptive Statistics of Estimated Vehicular Emissions

	Carbon monoxide	Carbon Dioxide	Nitrogen Oxide	Particulate Matter 10	Particulate Matter 2.5	Total Suspended Particulate Matter	Volatile Organic Compounds
Mean	281.47	48971.42	35.85	14.77	11.83	12.29	51.91
Median	36.33	11866.1	3.09	3.06	1.77	1.67	3.74
Maximum	11847.19	3657469	3013.86	1154.48	937.63	1401.75	2542.14
Minimum	0	285.54	0	0.05	0.03	0.02	0
Std. Dev.	1088.42	216982.5	178.81	67.61	55.11	65.08	211.62
Sum	337762	58765706	43023.71	17724.24	14190.72	14743.07	62288.89
Observations	1200	1200	1200	1200	1200	1200	1200

Source: Author's estimation from survey data 2021.

On average, each vehicle among the sample size emits approximately 281.47 kilograms of carbon monoxide; however, the vehicles included in the sample emit approximately 337762 kg of carbon monoxide yearly. In the study area, vehicles included in the survey emit approximately 48971 kg of carbon dioxide on average in a year.

Furthermore, the total carbon dioxide emission by 1200 different vehicles accounts for approximately 58765706 kg in a year. The vehicles included in the sample emit approximately 35.85 kg of nitrogen oxide on average in a year. However, the total nitrogen oxide by 1200 vehicles in the study area accounts for approximately 43023 kg in a year. On average, vehicles included in the survey emit approximately 14.77 kg of Particulate Matter 10 (PM_{10}) in a year. On the other hand, Particulate matter from 1200 vehicles included in the survey emits approximately 17724.24 kg in a year. In the survey data, each vehicle emits Particulate matter 2.5 ($PM_{2.5}$) on average 11.83 kg in a year. Total Particulate matter 2.5 ($PM_{2.5}$) from 1200 vehicles included in the survey accounts for approximately 14190 kg in a year. Total suspended particulate matter emitted by a vehicle on average in the survey sample accounts for approximately 12.29kg in a year. However, all included vehicles in the survey sample emitted approximately 14743kg of total suspended matter. Volatile organic compounds account for approximately 51.91 kg on average by each vehicle in a year, and the same is emitted from 1200 vehicles which approximately accounts for 62289 kg in a year.

Table 2 shows the detailed descriptive statistics of vehicular emissions and socio-economic variables. Age of the respondent, monthly income, family size, household total monthly expenditure, marital status, education, family income, endowed wealth, and urban/rural residency are taken as socio-economic variables; however, for encountering vehicle characteristics, engine capacity, average distance covered by a vehicle per liter of fuel, expenditure incurred on maintenance of the vehicle in local currency. Furthermore, the total amount that a driver/owner is willing to pay to control the toxic emissions from vehicles in the study area. The respondents are approximately 32 years old, however, the maximum recorded age is 65 years old, and the minimum is 20 years old. Education is considered one of the most important socio-economic variables that significantly affect individuals' decision-making. On average, the respondent's education is approximately six years of schooling. However, the minimum education recorded in the sample survey is illiterate (0 years of schooling), and the maximum recorded education is postgraduate (18 years of schooling). Urban and rural residency is another significant socio-economic variable.

Table 2
Descriptive Statistics

			Bootstrap 95% Confidence Interval	
		Statistic	**Lower**	**Upper**
	N	1200	1200	1200
	Minimum	0.003		
	Maximum	11847.19		
	Sum	337762		
	Mean	281.4684	281.46	281.4683
CO	Std. Deviation	1088.416	1088.4	1088.415
	N	1200	1200	1200
	Minimum	0.001		
	Maximum	3013.855		
	Sum	43023.71		
	Mean	35.85309	35.853	35.85309
NO_2	Std. Deviation	178.812	178.81	178.8128
	N	1200	1200	1200
	Minimum	0.029		
	Maximum	937.633		
	Sum	14190.72		
	Mean	11.8256	11.825	11.8256
PM2.5	Std. Deviation	55.11296	55.112	55.11296
	N	1200	1200	1200
	Minimum	0.051		
	Maximum	1154.477		
	Sum	17724.24		
	Mean	14.7702	14.7702	14.7702
PM10	Std. Deviation	67.60705	67.607	67.60705
	N	1200	1200	1200
	Minimum	0.003		
	Maximum	2542.144		
	Sum	62288.9		
	Mean	51.90741	51.907	51.90741
VOC	Std. Deviation	211.6194	211.61	211.619
	N	1200	1200	1200
	Minimum	285.544		
	Maximum	3657469		
	Sum	58765706		
	Mean	48971.42	48971.4	48971.42
CO_2	Std. Deviation	216982.5	216982	216982.4
	N	1200	1200	1200
	Minimum	0.015		
	Maximum	1401.75		
	Sum	14743.08		
	Mean	12.2859	12.285	12.2859
PMTSP	Std. Deviation	65.0815	65.0815	65.0815

A dummy variable has been used in this study. Those respondents who are inhabitants of urban locality take values 1 and 0 otherwise. 469 respondents out of 1200 are residents of the urban locality, accounting for approximately 39% of the total sample size. Marital status is also considered a significant socio-economic variable influencing the decision-making of households. This variable is categorical; however, almost all the respondents are either married or single in the present study. Hence, the variable is treated as a binary variable that takes value one if the respondent is married and 0; otherwise, a total of 82% (984 out of 1200) of respondents are married in the total sample size. The family size of the respondents influences the household's constrained budget, thus affecting the individual's decision-making.

Table 3
Descriptive Statistics

		Statistic	Bootstrap 95% Confidence Interval Lower	Upper
	N	1200	1200	1200
	Minimum	20		
	Maximum	65		
	Sum	38686		
	Mean	32.24	32.24	32.24
Age	Std. Deviation	8.204	8.204	8.204
	N	1200	1200	1200
	Minimum	0		
	Maximum	18		
	Sum	7475		
	Mean	6.23	6.23	6.23
Education	Std. Deviation	5.158	5.158	5.158
	N	1200	1200	1200
	Minimum	0		
	Maximum	1		
	Sum	469		
	Mean	0.39	0.39	0.39
Urban/Rural	Std. Deviation	0.488	0.488	0.488
	N	1200	1200	1200
	Minimum	0		
	Maximum	1		
	Sum	984		
	Mean	0.82	0.82	0.82
Marital Status	Std. Deviation	0.384	0.384	0.384
	N	1200	1200	1200
	Minimum	1		
	Maximum	15		
	Sum	5552		
	Mean	4.63	4.63	4.63
Family Size	Std. Deviation	2.642	2.642	2.642
	N	1200	1200	1200
	Minimum	1		
	Maximum	7		
	Sum	1216		
Household Earning members	Mean	1.01	1.01	1.01
	Std. Deviation	0.212	0.212	0.212
	N	1200	1200	1200
	Minimum	10000		
	Maximum	100000		
	Sum	32142000		
	Mean	26785	26785	26785
Monthly income	Std. Deviation	31419.51	31419.5	31419.51
	N	1200	1200	1200
	Minimum	10000		
	Maximum	100000		
	Sum	32158000		
	Mean	26798.33	26798.3	26798.33
Total expenditure	Std. Deviation	31895.71	31895.7	31895.71
	N	1200	1200	1200
	Minimum	0		
	Maximum	80000000		
	Sum	2.01E+08		
	Mean	1673929	1673929	1673929
Endowed wealth	Std. Deviation	3713378	3713378	3713378
	N	1200	1200	1200
	Minimum	200		
	Maximum	2000		
	Sum	4840196		
	Mean	4033.5	4033.5	4033.5
Engine Capacity	Std. Deviation	2291.573	2291.57	2291.573
	N	1200	1200	1200
Expenditure on vehicle maintenance	Minimum	500		
	Maximum	200000		

	Sum	17419800		
	Mean	14516.5	14516.5	14516.5
	Std. Deviation	9054.584	9054.584	9054.584
	N	1200	1200	1200
	Minimum	0		
	Maximum	5000		
	Sum	27550		
Willingness to Pay amounts	Mean	22.96	22.96	22.96
	Std. Deviation	173.83	173.83	173.83
	N	1200	1200	1200
	Minimum	100		
	Maximum	6000		
	Sum	5116850		
Number of vehicle types in the Study Area	Mean	4264.04	4264.04	4264.04
	Std. Deviation	3089.517	3089.517	3089.517
	N	1200	1200	1200
	Minimum	2		
	Maximum	16		
The average distance covered by the vehicle per liter of fuel	Sum	7172		
	Mean	5.98	5.98	5.98
	Std. Deviation	3.589	3.589	3.589
	N	1200	1200	1200
	Minimum	15000		
	Maximum	1000000		
	Sum	32773000		
	Mean	27310.83	27310.83	27310.83
Family Income	Std. Deviation	33235.44	33235.44	33235.43

Source: Author's estimation from survey data 2021.

Family size is a count variable that takes only positive integers as values. The average family size of respondents is approximately 5 members. The minimum recorded family size is 1, on the other hand, on maximum it is 15 memebrs. Earning members in a household increases the purchasing power of the household. Hence, it is categorized as one of the most vital socio-economic variables. On average majority of the responses indicated that there is only one earning member; however, on maximum, it has been recorded that there are 7 members in a household who earn. Monthly income is the most important socio-economic variable that directly influences household decision-making. On average, every household earns approximately Rs. 26785 per month. However, different vehicle drivers/owners earn their monthly income based on their vehicles and the number of hours worked. The minimum monthly income recorded in the study survey accounts for approximately Rs. 10,000, and the maximum recorded monthly income is 100,000 PKR.

Expenditure by a household represents the consumption behavior of individuals—the present study recorded household expenditure every month in local currency units. On average, the respondents spend approximately 26798 Pakistani rupees in a month. However, the minimum recorded expenditures by a respondent account for 10,000 PKR, and the maximum expenditure by a respondent is 100,000 Pakistani rupees. An endowed wealth of an individual affects the decision-making of individuals and influences spending behavior. The minimum endowed wealth recorded in the survey data is 0, and the maximum is Rs. 80000000. Family income is captured as a socio-economic variable in this study, the minimum family income recorded in the survey data is 15,000 PKR, and the maximum is Rs. 1,000,000. However, the average family income in the sample data is approximately 27311. The study included variables to capture the effect of vehicle characteristics on emissions. Engine capacity is measured in cubic capacity, also known as "CC." the maximum engine capacity recorded in the survey is 12000 cc while the minimum is approximately 200cc. The vehicle fleet is one of the most important variables determining the emissions in the area. The vehicle fleet of the same type is recorded in the present survey. The maximum recorded fleet is 6000 vehicles; however, the minimum recorded vehicle fleet of the same type is 100. Fuel consumption is recorded as the average distance covered in kilometers per liter of fuel. On average, the vehicle covers approximately 6 km per liter of fuel. Expenditure on vehicle maintenance significantly affects the emissions from the vehicle. On average, the respondent spends approximately 14516 PKR on vehicle maintenance. The present survey recorded the willingness to pay for controlling excessive emissions from automobiles. The maximum amount a respondent is willing to pay for controlling excessive emissions from vehicles is Rs. 5000 per month; however, on average, every respondent is willing to pay approximately Rs. 23 per month.

Table 4
Probit model estimation with its marginal values 0

Variables	Probit Model Coef.	Std. Err.	Marginal Effects Coef.	Std. Err.
Monthly Income	0.325***	0.113	0.077***	0.026
Age	1.861***	0.806	0.441**	0.191
Education	1.886***	0.648	0.447***	0.153
Marital Status	0.657**	0.284	0.155**	0.067
Family Size	-1.898***	0.424	-0.449***	0.1
Wealth	0.048**	0.023	0.011**	0.005
Constant	-4.908***	1.293	--	--
Pseudo R2				0.323
Likelihood Ratio				-776.97
LR chi2(6)	51.93	Prob > chi2		0

Source: Author's estimation from survey data 2021, ***, and **, means significant at 1% and 5%, respectively.

Education is an important socio-economic variable that significantly affects the willingness to pay respondents for controlling the excessive emission from vehicles in the study area. One unit increase in the respondent's education increases the willingness to pay by approximately 0.45 units. Marital status increases the willingness to pay respondents for controlling excessive vehicular emissions in the study area. Marital status is a dummy variable that takes 1 if the respondent is married and 0 otherwise. When the respondent is married, it increases the respondent's willingness to pay by approximately 0.155 units. Family size negatively affects the respondent's willingness to pay for controlling excessive vehicular emissions. If there is an increase of one unit in family size, it will significantly decrease the respondent's willingness to pay by approximately 0.45 units. Endowed wealth is one of the most important socio-economic variables that normally affect respondents' decision-making. The increase of one unit in the endowed wealth of the respondent most likely increases the respondent's willingness to pay for the control of excessive vehicular emission in the study area by approximately 0.01 units.

5. Conclusion and Recommendations

The present study found that vehicle age, the average distance traveled per liter of fuel, engine capacity, average speed of the vehicle, average temperature, total distance traveled, and numbers of the same type in the locality significantly affect the level of emissions from commercial automobiles in Peshawar city. The present study found that on average, CO emissions from vehicles in the city are approximately 281 kg in a year. CO_2 emission from vehicles accounts for approximately 48971 kg per year. Similarly, the average emissions of NO_2, PM2.5, PM10, VOC, and PMTSP account for approximately 35.85, 11.82, 14.77, 51.90, and 12.28 kg per year, respectively. Moreover, the study also found that the age of the respondent, education of respondents in whole years, family size of the respondent, earning members in the respondent's family, monthly income of the respondents, total household expenditures of the respondents, and wealth of the respondents are significantly affecting the commercial automobiles' emissions in Peshawar city. Based on the findings of this study the following recommendations are made.

1. Emission from commercial automobiles is a problem that affects both the economy and the environment. Policymakers need to look into the cost and benefit analysis along with affordability while figuring out among competing priorities.

2. The role of government driving schools is very crucial for drivers' education regarding emissions and overall road sense. Presently the government driving school under Khyber Pakhtunkhwa Transport and Mass Department is in obsolete condition and needs a total revamping with the provision of different new model commercial vehicles for effective training of the commercial automobile drivers.
3. The Vehicular Emission Testing Station (VETS) may be further strengthened with the provision of updated emission testing machinery and mobile testing stations. Furthermore, their duty hours may be divided into shifts including the night shift as most of the heavy commercial vehicles enter the city during night time to transport goods to and from industries located inside and in the outskirts of the city.
4. A new policy may be looked into whereby commercial automobiles are obligated to obtain an emission fitness certificate from VETS before proceeding with the annual token tax renewal. An MOU between the Khyber Pakhtunkhwa Excise, Taxation, and Narcotics Control Department and the Khyber Pakhtunkhwa Transport and Mass Transit Department would be required to enforce this policy.

Author's Contribution:
Naveed Gul: Conceptualized the study, designed the Methodology, collected the data and analyzed it. Interpreted the results, and writing and editing of the paper.
Naila Nazir: Reviewed and approved the final manuscript.

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