Jordan Journal of Civil Engineering, Volume **5**, No. **2**, **2011**

Emission Rate of Gases Emitted from Private Gasoline Vehicles in Irbid - Jordan

Talal M. Al-Momani [1] and Amjad D. Al-Nasser [2]

[1] Department of Earth and Environmental Sciences, Faculty of Science, Yarmouk University. E-Mail: talamom@hotmail.com
[2] Department of Statistics, Faculty of Science, Yarmouk University. E-Mail: amjadn@yu.edu.jo

ABSTRACT

In this paper, we analyze the emissions caused by private gasoline vehicles based on a random sample of 950 vehicles. Different types of pollutants; carbon monoxide (CO), carbon dioxide (CO_2) and hydrocarbon (HC) were analyzed based on the Jordanian emission standards with special reference to three different vehicles' manufacturing countries; namely: Korea, Japan and Germany. The analysis results indicated that Korean made vehicles gave better results than Japanese and German made ones on superiority to pass the tests of vehicles' emission. The results indicated that at a significance value of 0.05 there was a statistical relationship between Japanese vehicles and model year, engine capacity, vehicle fuel supply system and periodic maintenance. Also, for German vehicles there was a statistical relationship between manufacturing year, fuel type and fuel supply system. However, Korean vehicles showed a statistical relationship only with the fuel supply system. Overall, all vehicles should have an injection system in order to reduce exhausts' emissions, and the vehicles should be as new as possible. It should also be recommended not to import vehicles with carburetor fuel supply system.

KEYWORDS: Environment, Air pollution, Exhaust emissions, Private gasoline vehicles, Statistical relationship, ANOVA analysis, Chi-square test, Jordan emission standards.

INTRODUCTION

The transport sector is responsible for considerable pollutants, putting directly and indirectly pressure on many environmental receptors such as humans, buildings, atmosphere and ecosystems (Mierlo et al., 2004). Air pollution in cities is mainly due to vehicular emissions. Transportation systems are increasing everywhere and the improvements in technology are insufficient to counteract this growth. Vehicle emissions constitute a serious environmental concern, particularly in highly populated cities. These emissions are characterized with the presence of various pollutants (i.e., carbon monoxide (CO), carbon dioxide (CO_2) and hydrocarbon (HC)), which, at high concentrations, can cause adverse health effects (Ghose et al., 2004; Fadel and Hashisho, 2000). The primary health effect of CO is to reduce the oxygen carrying capacity of the blood. In ambient concentrations, CO can affect the functions of the brain, lungs, heart and the ability to exercise, all of which are sensitive to blood oxygen content. Exposure to high CO levels is also associated with low birth weights in infants. HC includes many toxic compounds that cause cancer and other adverse health effects (WHO, 2003). The motor vehicle exhaust is the most predominant source of air pollution in urban centers all

Accepted for Publication on 15/4/2011.

over the world. Road transport constitutes a major source of air pollution, and its share is expected to rise in the future because of the rising global demand for private mobility. Age and technological change determine the internal dynamics of motor vehicle populations and influence the environmental impact of road transport in various ways (Sharma and Khare, 2001; Zachariadis et al., 2001).

Motor vehicles are a major source of emissions contributing to air pollution on local to global scales. New vehicle emission standards have become more stringent, regulating carbon, CO, CO_2, HC, nitrogen oxides (NO_x) and Particulate Matter (PM) emissions (Mazzoleni et al., 2004). It is estimated that in Mexico City, 75% of HC come from mobile sources (Rivores et al., 2002).

Several recent studies in different regions in Jordan analyzed vehicular exhaust emissions (VEE). In Irbid directorate, in the northern part of Jordan, Al-Momani (2005), Al-Nasser and Al-Momani (2006) studied the statistical modeling of air pollution caused by exhaust gases from gasoline vehicles. In Amman and Al-Zarqa, in the middle part of Jordan, Assi and Al-Sawair (2007) and Abu-Allaban et al. (2007) worked on studying and assessing the levels of exhaust emissions from different types of gasoline driven vehicles.

In a related work in India, Ghose et al. (2004) studied the assessment of the impact of vehicular emissions on urban air quality and its management. Also, Rivores et al. (2002), in Mexico city, studied the relationship of vehicle inspection and maintenance to air pollution. Different environmental aspects concerning alternative fuels, drive trains and travel behavior are considered in many research works (see, Mierlo et al., 2004; Nilsson and Kuller, 2000). An international urban air pollution model for the transportation system was presented by Lyons et al. (2003). However, Zachariadis et al. (2001) studied the effect of age and technological change on motor vehicle emissions. Moreover, different statistical methodologies of vehicle emissions from inspection/maintenance (I/M) testing data and for estimating speed correction factors with confidence intervals for mobile source emission models were discussed in Washburn et al. (2001) and Nilsson and Kuller (2000). Amman, Irbid and Al-Zarqa are the most populated cities in Jordan. Irbid has the first rank regarding the population density (620.1 persons per km^2) compared to Amman (280.4 persons per km^2) and Al-Zarqa (170.2 persons per km^2). In addition, Irbid has the second rank according to the population size (974800 persons) compared to Amman (2125400 persons) and Al-Zarqa (810500 persons). The population represents 17.8%, 38.8% and 14.8% for Irbid, Amman and Al-Zarqa, respectively (Department of Statistics, 2006).

The major aim of this study is studying the effect of transportation and vehicle characteristics, with special reference to manufacturing country of different types of private gasoline vehicles, on emissions and air pollution in Irbid city based on measurements of CO, CO_2 and HC for gasoline vehicles at the idle state.

The remainder of this paper is devoted to present the methods used for data collection and the vehicles' characteristics included in the study. The diversity of vehicles based on the manufacturing country and the classification of vehicles according to national emission limits are discussed. Concluding remarks are presented and recommendations are suggested.

Data Collection and Vehicle Characteristics

In Irbid, there are three stations using new technologies for vehicle maintenance which are certified by the Department of Motor Vehicles in Irbid. Among these certified stations, we selected randomly two stations. The first station is (Visa Techno-test gas analyzer model, Visa-4012, manufactured by Techno-test company, Italy) which is available at Techno-star Test Center, located in the west of the industrial zone in Irbid. The second station is (Sun gas analyzer model, Sun-SMP 4000, manufactured by Sun electric company, UK) available at Al-Azam Auto Care Center, located in the east of the industrial zone in Irbid.

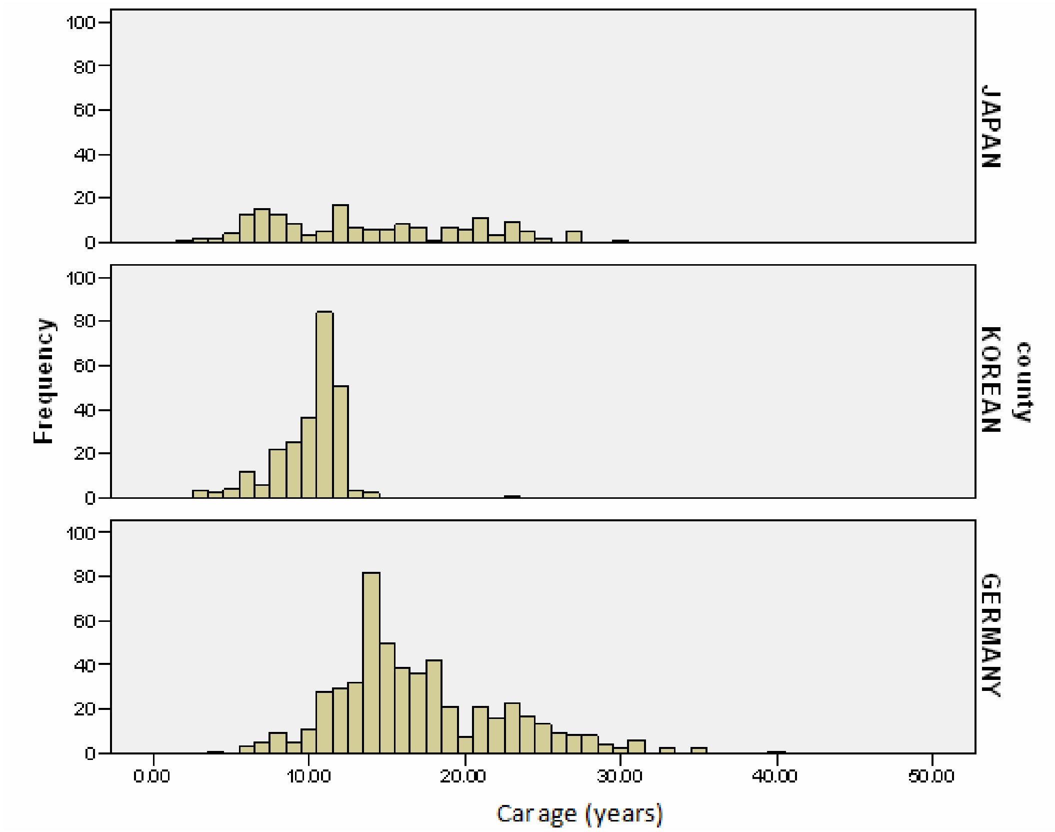

Figure 1: Distribution of vehicle ages [age = (2007 – model year)]

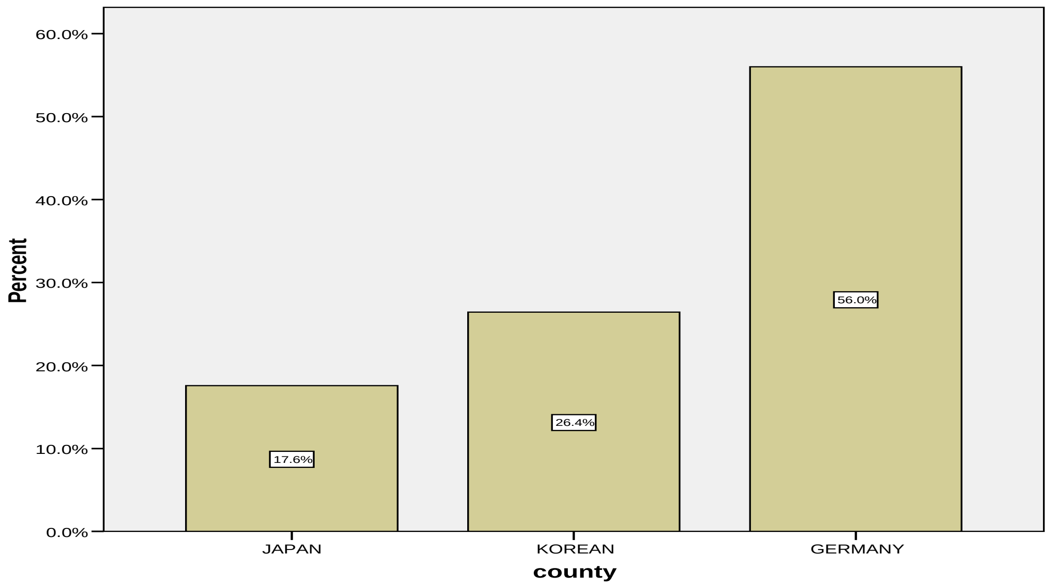

Figure 2: Vehicles' distribution based on manufacturing countries

Figure 3: Diversity of Korean vehicles

Data were collected almost within 24 weeks, during May 2006 – October 2006. In each week, we collected data within three days, including Saturdays and two other different days. Inside the stations, the vehicles were systematically selected (every two vehicles), excluding the vehicles that had serious technical problems (according to the technicians' opinion).

The information about each selected vehicle was recorded on a special prepared sheet. This sheet consisted of two parts; the first part consisting of general information concerning vehicle manufacturing country (Korea, Japan and Germany) and vehicle characteristics. The second part record the emission levels and the test results for each pollutant.

For each vehicle, the exhaust gases' emissions were measured based on the user guide of the computerized exhaust gas analyzer. The probe of the analyzer was put inside the vehicle’s tail-pipe at the idle speed, then after operating the vehicle for a short period of time, steady readings for (CO, CO_2 and HC) were taken .

Then, any vehicle was considered to pass the emission test if it conformed to the official standard emission limits in Jordan including (CO Max. 5%), (CO_2 Min. 10%) and (HC Max. 600ppm) at idle speed (Department of Drivers and Vehicles Licensing, 2007).

Within the study period, we collected information about 1000 private vehicles, 50 of which were excluded; therefore we ended up with a sample of 950 vehicles. This sample was assumed to be a representative sample of all private vehicles in Irbid. The skewed nature of vehicle emissions also had important implications for drawing a representative sample of vehicles from a population for testing (Wenzel et al., 2000; Al-Nasser and Al-Momani, 2006).

We believe that the vehicle characteristics affect the emission process. Some vehicle models are simply designed and manufactured better than others. Some vehicle models and engine families are observed to have very low average emissions, while others exhibit very high rates of emission control failure (Wenzel et al., 2000). Also, the model year is a function of the normal degradation of emission control of properly functioning vehicles, resulting in moderate emission increase and malfunction or outright failure of emission control on some vehicles, possibly leading to very large increases in emissions, particularly CO and HC. Figure 1 represents the age [Age = (2007 – Model year)] of the vehicles considered in this study.

The results indicated that almost all of the Korean vehicles were new; while there was a diversity between old and new of Japanese and German vehicles. However, the vehicle emissions varied by many factors or vehicle characteristics other than the vehicle age, such as: manufacturing country, engine size and fuel supply system. A representative sample of vehicles would account for all of these factors. Table 1 describes the vehicle characteristics considered in this study.

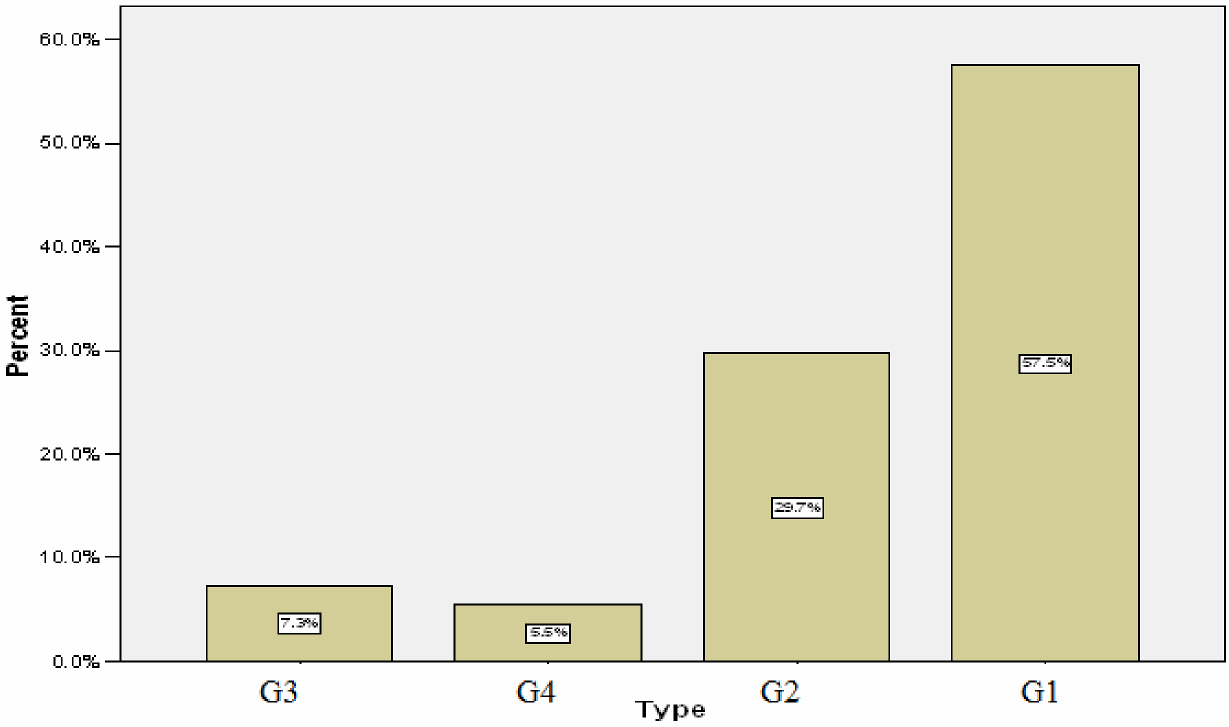

Figure 4: Diversity of German vehicles

Moreover, the degree to which owners maintain (periodic maintenance) their vehicles by providing tune-ups and servicing according to manufacturer schedules can affect the likelihood of engine or emission control system failure and therefore tailpipe emissions.

Diversity of Vehicles Based on Manufacturing Country

Real-world emissions are sensitive to vehicle technology independent of vehicle age. For our sample, the vehicles' distribution based on different manufacturing countries is presented in Figure 2. The results indicated that most of the vehicles tested were manufactured in Germany (56%), while Korean vehicles represented (26.4%) and Japanese vehicles represented only (17.6%). Therefore, the same country may produce different vehicles with different quality levels in connection to different vehicle emission control improvements.

The results (Figures 3-5) indicate that Japanese made vehicles have a wider diversity than Korean or German vehicles. There are three brands of Korean vehicles (K1, K2 and K3), four brands of German vehicles (G1, G2, G3 and G4) and eight brands of Japanese vehicles (J1, J2, …, J8).

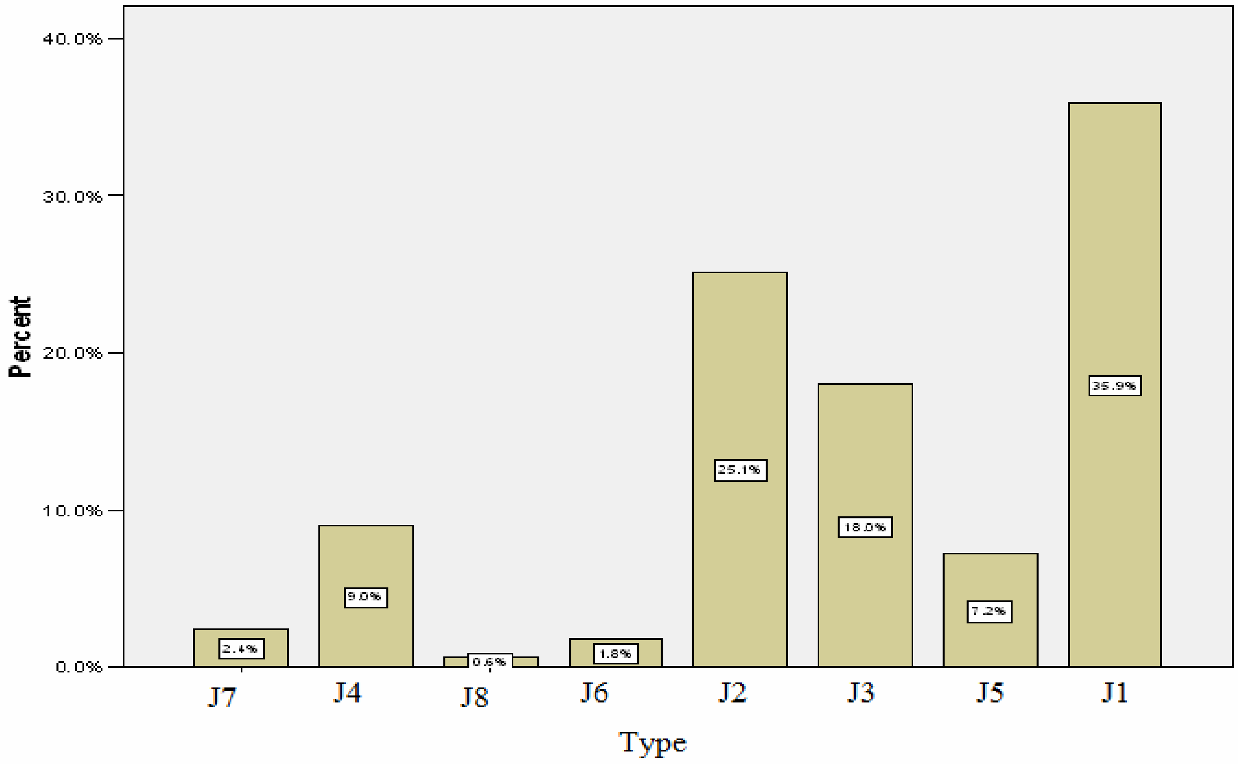

Figure 5: Diversity of Japanese vehicles

Categorization of Vehicle Emissions with Reference to Specific Manufacturing

The average values of different pollutants; CO, HC and CO_2 are presented in Figures 6-8 for specific manufacturing in comparison with the official standard limits in Jordan. The results indicated that German and Korean vehicles passed (on average) all the tests according to Jordanian standards. However, some of the Japanese vehicles' brands (J1, J7 and J8) failed to pass (on average) the CO and HC standards. Hereafter, to see whether the average emission values of the tested private Japanese, German and Korean automobiles differed significantly, we performed one way ANOVA. The ANOVA results are presented in Table 2. The test results in Table 2 were significant F(2,949) = 5.671 with a p-value of 0.004 for CO_2 and F(2,949) = 5.304 with a p-value of 0.005 for CO. Follow-up test "Least Significant Test" (LSD) was used to evaluate the pairwise differences among the average emissions. The results are given in Table 3 .

The follow-up test results indicated that there were significant differences in the emissions (CO_2) average between Korean vehicles (M= 11.291, SD = 2.33), which had higher CO_2 values, and Japanese vehicles (M= 10.55, SD = 2.49). Also, there were statistical differences in the average of CO_2 between Korean vehicles and German vehicles (M= 10.82, SD = 2.24). The same statistical inference was drawn for the CO emissions with a superiority in the average results for Korean vehicles on other ones(see Table 4).

The modern Korean vehicles had an advantage over the other vehicles in reducing different pollutants. The main factor affecting these results was the vehicle age. All Korean vehicles were new, while the other vehicles had different vehicle ages.

Table 1: Description of vehicle characteristics

Characteristics	Description	Categories
Manufacturing Country	Korean vehicles	Daewoo, Kia, Hyundai
	German vehicles	Opel, Mercedes, BMW, Golf
	Japanese vehicles	Toyota, Mitsubishi, Nissan, Honda, Suzuki, Mazda, Datsun, Isuzu
Manufacturing Year (MY)	Old vehicles	1965 - 1990
	New vehicles	1991 - 2000
	Modern vehicles	After 2000
Fuel Supply System	Different fuel supply systems	Injection
		Carburetor
Engine Size	Small	Less than 1500 cc
	Medium	1500 - 2500 cc
	Large	More than 2500 cc
Fuel Type	Gasoline	Normal
		Super
		Unleaded
Periodic Maintenance	Different periods	1, 2, 3, 4, 5, 6 Months or Never

Table 2: One-way ANOVA results

		Sum of Squares	df	Mean Square	F	Sig.
CO_2	Between Groups	60.817	2	30.409	5.671	0.004
	Within Groups	5077.529	947	5.362		
	Total	5138.346	949			
HC	Between Groups	692552.678	2	346276.339	1.347	0.260
	Within Groups	243432776.165	947	257056.786		
	Total	244125328.843	949			
CO	Between Groups	82.265	2	41.133	5.304	0.005
	Within Groups	7343.399	947	7.754		
	Total	7425.665	949			

Vehicles' Classification Based on Jordan Emission Standards

It seems that Korean vehicles highly conformed to the national standards of vehicle emissions, as can be noted from Table 5, for all emissions. The percentages of Korean vehicles that failed to pass the test were (17.5%, 26.7% and 14.3%) less than those of German vehicles (20.1%, 30.3% and 21.1%) or Japanese vehicles (27.5%, 35.3% and 26.3%) for (CO, CO_2 and HC) emissions, respectively. Also, it was clear that the German vehicles were better than the Japanese ones.

Taking different factors into consideration, the results almost go in the same trend. The results in Appendix A (Table A.1 - Table A.5) confirm our conjectures.

According to the model year, Table A.1, the results can be summarized as follows:

a. **Old vehicles;** 1965-1989: there are few Korean vehicles manufactured in this period which passed the emission test. Therefore, it is fairer to compare the results between German and Japanese vehicles. The results indicated that the percentage of failure of Japanese vehicles was more than that of German vehicles in the same period (model year). This means that old German vehicles work better than Japanese ones according to the Jordanian standards.

b. **Moderate vehicles;** 1990-2000: the trend of the test results was very clear for all emissions. German vehicles had the best results and the highest percentage in passing the emission test compared to Korean vehiles, and the worst were the Japanese vehicles.

c. **Models after 2000;** modern vehicles: the Korean vehicles totally failed compared to the results of the other vehicles. For Japanese and German vehicles, these results were not clear, because the sample size for each model was less than 5. This means that we need more investigations with the modern vehicles to draw the right conclusions.

Table 3: LSD multiple comparisons test

Dependent Variable	(I) country	(J) country	Mean Difference (I-J)	Std. Error	Sig.
			Lower Bound	Upper Bound	Lower Bound
CO_2	JAPAN	KOREA	-.7345(*)	.2312	.002
		GERMANY	-.2717	.2054	.186
	KOREA	JAPAN	.7345(*)	.2312	.002
		GERMANY	.4628(*)	.1773	.009
	GERMANY	JAPAN	.2717	.2054	.186
		KOREA	-.4628(*)	.1773	.009
CO	JAPAN	KOREA	.83440(*)	.27808	.003
		GERMANY	.27044	.24700	.274
	KOREA	JAPAN	-.83440(*)	.27808	.003
		GERMANY	-.56396(*)	.21324	.008
	GERMANY	JAPAN	-.27044	.24700	.274
		KOREA	.56396(*)	.21324	.008

* The mean difference is significant at the .05 level.

Vehicle emissions can vary greatly with engine capacity. We classified engine capacity into three categories, see Table 5. However, there were still emission differences within the same engine capacity category based on the manufacturing country. The results of these differences are shown in Table A.2 and can be summarized as follows:

a. **Small engine size:** the results for (CO, CO_2 and HC) emissions indicated that only (18.2%, 26.8% and 14.1%) of Korean vehicles failed and only (17.1%, 27.8% and 19%) of German vehicles failed. Small engines from these countries are almost homogenous according to national emission limits for (CO and CO_2) emissions. However, Japanese vehicles (33.7%, 43.5% and 32.6%) failed to gain a good position.

b. **Medium engine size:** it seems that Korean vehicles (15.1%, 26.4% and 15.1%) have better results than the other vehicles (German or Japanese). However, Japanese vehicles were as good as German ones.
c. **Heavy engines:** only Japanese and German vehicles were comparable, since there were no Korean vehicles with a large engine size included in our sample. The results indicated that German vehicles are superior to Japanese vehicles in passing the emission test for CO and CO_2 but not for HC.

Table 4: Descriptive statistics of emission levels

Country		CO_2	HC	CO
JAPAN	N	167	167	167
	Mean	10.556	539.24	3.1411
	Std. Deviation	2.4934	475.268	3.05658
KOREA	N	251	251	251
	Mean	11.291	457.13	2.3067
	Std. Deviation	2.3391	607.291	2.69611
GERMANY	N	532	532	532
	Mean	10.828	498.31	2.8707
	Std. Deviation	2.2456	462.809	2.73612

Fuel type can have a substantial impact on vehicle tailpipe and evaporative emissions. By choosing the best type of fuel, we can reformulate a gasoline standard as an emission-control strategy. Table A.3 shows a description of the effect of fuel type on emissions. The results in this table are:

a. Most vehicles in Jordan area during our study used normal fuel. The test results of the different vehicles made with normal fuel have the same general comment, that is; Korean vehicles are superior to German and Japanese ones. Also, German vehicles are superior to Japanese vehicles for all pollutants.
b. For super fuel type, there is some improvement with German vehicles in passing CO and CO_2 emission test over Korean vehicles, but not with HC. Japanese vehicles come in the last rank according to the test results.
c. Unleaded fuel: we cannot adopt an effect of unleaded fuel in decreasing the emissions. All vehicles with unleaded fuel passed the test.

Different vehicles have different fuel supply systems. However, most of the modern vehicles start to trash away the carburetors and substitute it by an injection supply system. Table A.4 compares the results among different manufacturing countries based on the fuel supply systems. The results are:

a. **Injection:** it seems that injection improves the quality of Japanese made vehicles; the only characteristic putting Japanese vehicles in a good position according to passing/failing results compared with the other vehicle types. This conclusion is also true with German vehicles. Injection systems integrate the superiority of Japanese and German vehicles in reducing the emission amounts over the Korean vehicles.
b. **Carburetors:** here, there is an anti conclusion of injection. The results support that Japanese and German vehicles with carburetor fuel system should not be imported to Jordan.

Vehicle inspection and maintenance is very important. The degree to which owners maintain their vehicles can affect the likelihood of engine or emission control system failure and therefore tailpipe emissions. Table A.5 represents a good comparison between vehicles in Jordan area according to the number of care and maintenance times. The results can be summarized as follows:

Table 5: Distribution of conformance/non-conformance of vehicle emission test to the Jordanian standards

Major Pollutants			Manufacturing Country		
			JAPAN	KOREA	GERMANY
CO	Fail	Count	46	44	107
		%	27.5%	17.5%	20.1%
	Pass	Count	121	207	425
		%	72.5%	82.5%	79.9%
CO_2	Fail	Count	59	67	161
		%	35.3%	26.7%	30.3%
	Pass	Count	108	184	371
		%	64.7%	73.3%	69.7%
HC	Fail	Count	44	36	112
		%	26.3%	14.3%	21.1%
	Pass	Count	123	215	420
		%	73.7%	85.7%	78.9%

Table 6: Chi-square tests – CO

Manufacturing Country	Vehicle Characteristics	Chi-Square Value	d.f.	P-Value	Contingency Coefficient
Japan	MY	2.972	2	0.226	0.133
	Engine Capacity(*)	7.293	2	0.026	0.209
	Fuel Type	1.060	2	0.589	0.080
	Fuel Supply System (I/C)(*)	8.941	1	0.003	0.231
	Maintenance	3.001	4	0.558	0.134
Korea	MY	1.984	2	0.371	0.089
	Engine Capacity	0.276	1	0.600	0.033
	Fuel Type	2.490	2	0.288	0.099
	Fuel Supply System (I/C)	2.175	1	0.140	0.093
	Maintenance	5.785	4	0.216	0.150
Germany	MY(*)	24.465	2	0.000	0.210
	Engine Capacity	1.801	2	0.406	0.058
	Fuel Type(*)	14.860	2	0.001	0.165
	Fuel Supply System (I/C)(*)	50.831	1	0.000	0.295
	Maintenance	3.746	4	0.441	0.084

(*) = Significant at 0.05.

a. For a monthly maintainance: there are few owners who frequently care about their vehicles. However, with such small sample, the results indicated that the owners of Korean vehicles should care about the HC level. The test results gave superiority for Korean vehicles over the other types, but not with HC emission.

b. For a maintainance every two months or more: it can be noted that as the number of maintenance times decreases, Japanese and German vehicles start to fail in the emission tests. However, Korean vehicles have better results than both of them.

Table 7: Chi-square tests – CO_2

Manufacturing Country	Vehicle Characteristics	Chi-Square Value	d.f.	P-Value	Contingency Coefficient
Japan	MY(*)	8.413	2	0.015	0.224
	Engine Capacity(*)	8.291	2	0.016	0.223
	Fuel Type	1.656	2	0.437	0.100
	Fuel Supply System (I/C)(*)	8.973	1	0.003	0.232
	Maintenance	4.554	4	0.336	0.165
Korea	MY	0.820	2	0.664	0.057
	Engine Capacity	0.003	1	0.959	0.003
	Fuel Type	2.708	2	0.258	0.103
	Fuel Supply System (I/C)	2.677	1	0.102	0.103
	Maintenance	2.699	4	0.609	0.103
Germany	MY(*)	21.895	2	0.000	0.199
	Engine Capacity	4.317	2	0.115	0.090
	Fuel Type(*)	28.949	2	0.000	0.227
	Fuel Supply System (I/C)(*)	31.572	1	0.000	0.237
	Maintenance	8.478	4	0.076	0.125

(*) = Significant at 0.05.

Table 8: Chi-square tests – HC

Manufacturing Country	Vehicle Characteristics	Chi-Square Value	d.f.	P-Value	Contingency Coefficient
Japan	MY	3.628	2	0.163	0.147
	Engine Capacity	4.700	2	0.095	0.168
	Fuel Type	3.552	2	0.169	0.146
	Fuel Supply System (I/C)(*)	9.861	1	0.002	0.243
	Maintenance(*)	11.222	4	0.024	0.259
Korea	MY	0.298	2	0.861	0.034
	Engine Capacity	0.031	1	0.860	0.011
	Fuel Type	5.261	2	0.072	0.143
	Fuel Supply System (I/C)(*)	7.269	1	0.007	0.168
	Maintenance	8.933	4	0.063	0.185
Germany	MY(*)	17.608	2	0.000	0.179
	Engine Capacity	5.794	2	0.055	0.104
	Fuel Type(*)	16.869	2	0.000	0.175
	Fuel Supply System (I/C)(*)	10.989	1	0.001	0.142
	Maintenance	7.348	4	0.119	0.117

(*) = Significant at 0.05.

Table 9: Vehicle characteristics as a factor of vehicle emissions

Vehicle Origin	**CO**	**CO_2**	**HC**
Japan	Engine Capacity Fuel System	Model Year Engine Capacity Fuel System	Fuel System Maintenance
Korea	None	None	Fuel System
Germany	Model Year Fuel Type Fuel System	Model Year Fuel Type Fuel System	Model Year Fuel Type Fuel System

Table 10: A description of a vehicle with controlled emissions

Vehicle Origin	Vehicle characteristics
Japan	New → Small → Injection → 3M maintenance
Korea	New → Injection
Germany	New → (Super or Unleaded) → Injection

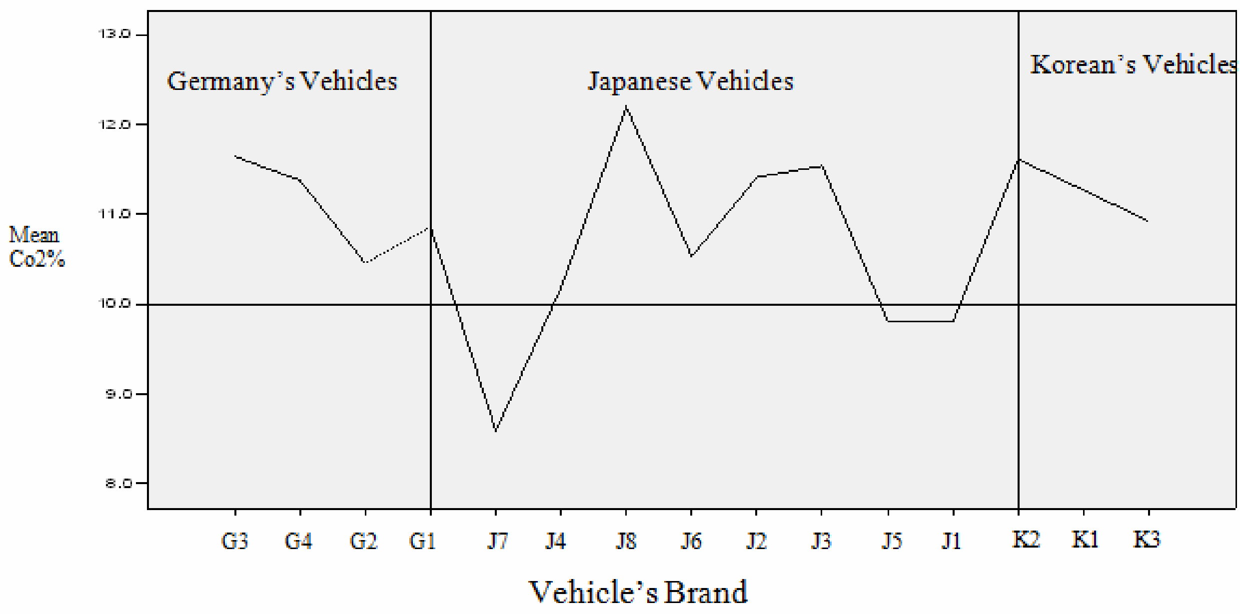

Figure 6: Average CO_2 emission levels with reference to Jordanian standards

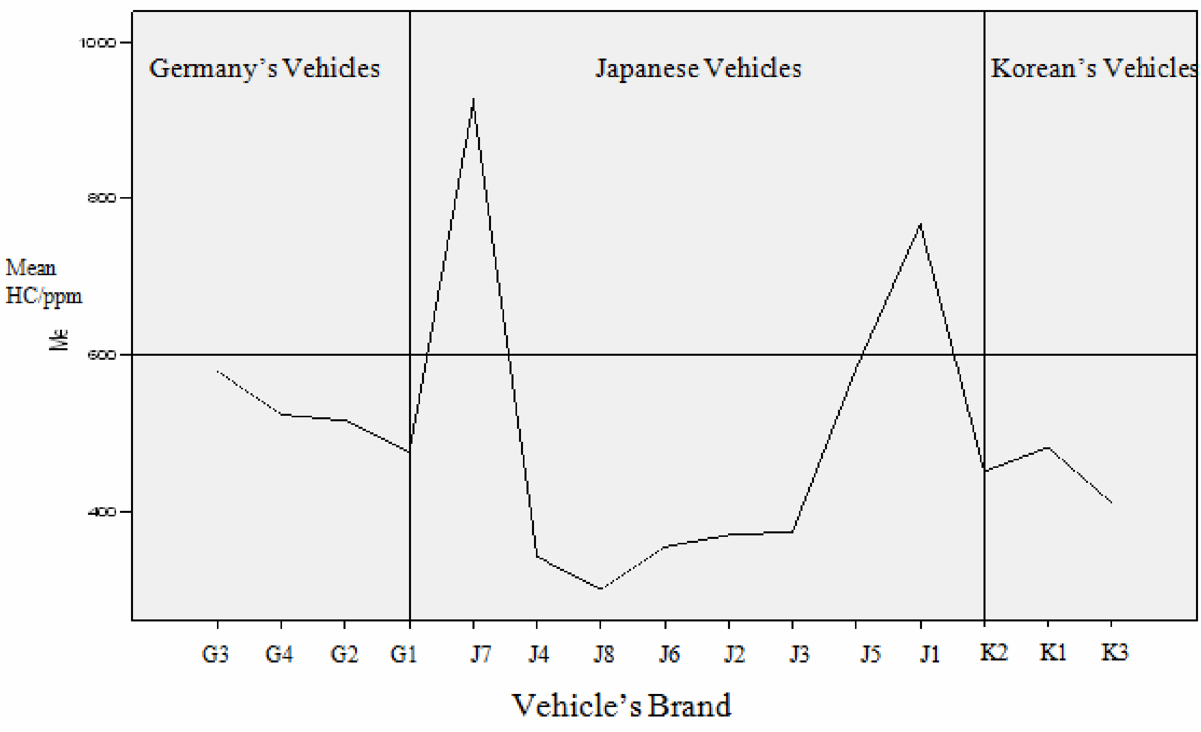

Figure 7: Average HC emission levels with reference to Jordanian standards

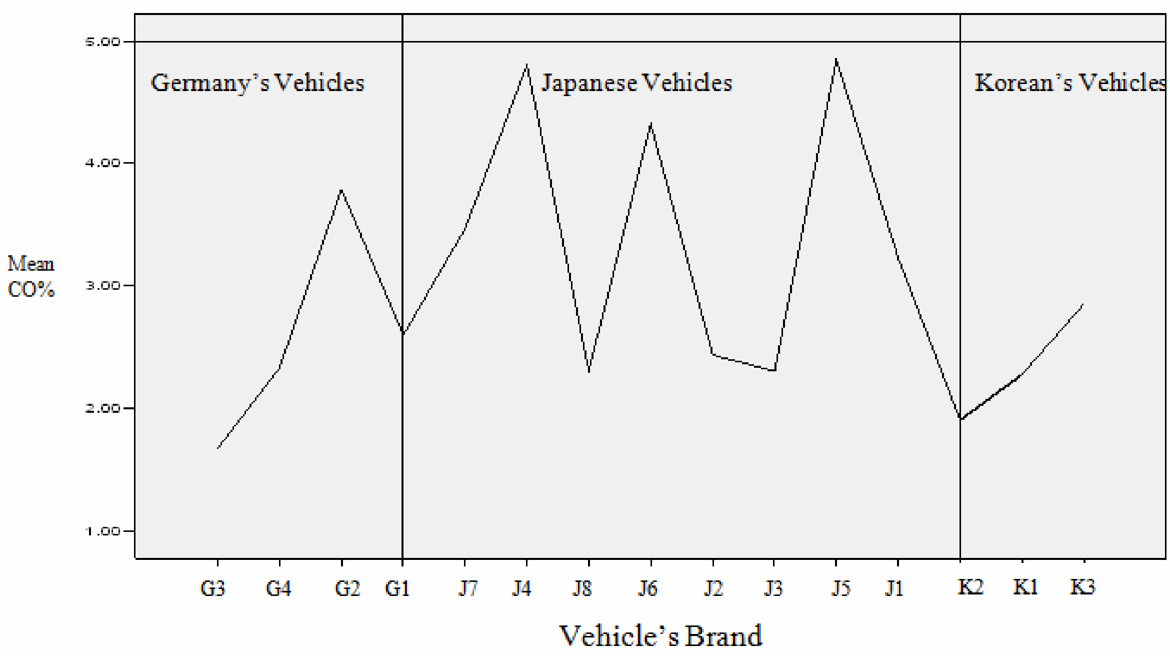

Figure 8: Average CO emission levels with reference to Jordanian standards

c. Never: the results for vehicles without maintenance support Korean vehicles over Japanese and German ones. Such results encouraged us to draw a conclusion that German and Japanese vehicles must have a cyclic maintenance period to keep their quality on the top, while periodic maintenance makes Korean vehicles always get better.

CONCLUSIONS AND RECOMMENDATIONS

The results obtained from this study agreed with those of Washburn et al. (2001) indicating that vehicles manufactured by different manufacturers produce different percentages of vehicle emissions. This reflects the engine technology and emission control system used by these manufacturers. Accordingly, there is a significant relationship between car manufacturer and emission rates.

The overall conclusion is that Korean vehicles have less emissions than Japanese or German vehicles, and German vehicles gave better results than Japanese vehicles regarding the preference of injection fuel supply system vehicles. Moreover, we performed Chi-square test to test the hypothesis: Is there a statistical relationship between vehicle characteristics and the manufacturing country for different pollutants? The results are given in (Table 6 – Table 8).

The results indicate that, at a significance level value of 0.05, there is a statistical relationship between Japanese vehicles and model year, engine capacity, vehicle fuel supply system and periodic maintenance. For German vehicles, there is a relationship with manufacturing year, fuel type and fuel supply system. However, Korean vehicles have a statistical relationship with fuel supply system. Table 9 summarizes the results.

These results indicate that whenever we purchase a new vehicle it should have an injection fuel supply system, no matter what the manufacturing country is. More attention should be given with a Japanese vehicle to engine size and maintenance period. Small engine "less than 1500cc", with a periodic maintenance of once "at least every three months" is a rule with Japanese vehicles in order to reduce pollutants from emissions. However, the most aspect which should be considered with a German vehicle is the fuel type (super or unleaded).

The results support that only new vehicles should be used by Jordanian citizens and that the vehicles with carburetor fuel supply system should not be imported to Jordan in order to reduce and control vehicle emissions.

Acknowledgments

We wish to thank the editor of JJCE and the referees for their insightful comments and suggestions which greatly improved the presentation of this paper.

REFERENCES

Abu-Allaban, M., Al-Jedaih, M., Al-Malabeh, A. and Suleiman, A. 2007. Emission Rates of Gaseous Pollutants from Motor Vehicles. *Jordan Journal of Chemistry,* 2 (2): 199-209.

Al-Momani, T. M. A. 2005. Air Pollution Caused by Exhaust Gases from Gasoline Vehicles in Irbid Directorate. *Abhath Al-Yarmouk-Basic Sciences and Engineering,* 14 (2): 269-288.

Al-Nasser, A. D. and Al-Momani, T. M. A. 2006. Statistical Modeling of Exhaust Gas Emissions – Irbid Directorate. *Abhath Al-Yarmouk-Basic Sciences and Engineering,* 15 (1): 155-172.

Assi, R. and Al-Sawair, J. 2007. Vehicular Exhaust Emissions in Amman. Royal Scientific Society. Amman, Jordan.

Department of Drivers and Vehicles Licensing. 2007. Traffic Law Number (47-2007) for Different Exhaust Gases Emitted from Gasoline Vehicles, Amman, Jordan.

Department of Statistics (DOS). 2006. Statistical Year

Book. Amman, Jordan.

Department of Statistics (DOS). 2007. Statistical Year Book. Amman, Jordan.

Fadel, M. and Hashisho, Z. 2000. Vehicular Emissions and Air Quality Assessment in Roadway Tunnels: the Salim Salam Tunnel. *Transportation Research – Part D,* 5: 355-372.

Ghose, Paul R. and Banerjee, S. K. 2004. Assessment of the Impacts of Vehicular Emissions on Urban Air Quality and Its Management in Indian Context: the Case of Kalkota (Calcutta). *Environmental Science and Policy,* 7: 345-351.

Lyons, T. J., Kenworthy, J. R., Moy, C. and Santos, F. D. 2003. An International Urban Air Pollution Model for the Transportation Sector. *Transportation Research – Part D,* 8: 159-167.

Mazzoleni, C., Moosmuller, H., Kuhns, H. D., Keislar, R. E., Barber, P. W., Nikolic, D., Nussbaum, N.J. and Watson, J. G. 2004. Correlation between Automotive CO, HC, NO and PM Emission Factors from On-road Remote Sensing: Implications for Inspection and Maintenance Programs. *Transportation Research – Part D,* 9: 477-496.

Mierlo, J. V., Timmermans, J. M., Maggetto, G., Bossche, P. V., Meyer, S., Hecq, W., Govaets, L. and Verlaak, J. 2004. Environmental Rating of Vehicles with Different Alternative Fuels and Drive Trains: A Comparison of Two Approaches. *Transportation Research – Part D,* 8: 387-399.

Nilsson, M. and Kuller, R.2000. Travel Behavior and Environmental Concern. *Transportation Research – Part D,* 5: 211-234.

Rivores, H. G., Cabrera, E. and Ovalle, P.2002. Vehicle Inspection and Maintenance and Air Pollution in Mexico City. *Transportation Research – Part D,* 7: 73-80.

Sharma, P. and Khare, M. 2001. Modeling of Vehicular Exhausts. *Transportation Research – Part D,* 6: 179-198.

Utts, J., Niemeier, D. and Riong, L. 2000. Statistical Methods for Estimating Speed Correction Factors with Confidence Intervals for Mobile Source Emission Models. *Transportation Research – Part D,* 5: 1.3-120.

Washburn, S., Seet, J. and Mannering, F. 2001. Statistical Modeling of Vehicle Emissions from Inspection/Maintenance Testing Data: An Exploratory Analysis. *Transportation Research – Part D,* 6: 21-36.

Wenzel, S. and Slott, R. 2000. Some Issues in the Statistical Analysis of Vehicle Emissions. *Journal of Transportation and Statistics,* 3 (2): 1-14.

World Health Organization (WHO). 2003. *Environmental Health Information.* Geneva.

Zachariadis, T., Ntziachristos, L. and Samaras, Z. 2001. The Effect of Age and Technological Change on Motor Vehicle Emissions. *Transportation Research – Part D,* 8: 221-227.