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TOPIC 3
SAFETY ANALYSIS
AND POLICY (SIG)

VEHICLE INSPECTION/MAINTENANCE SYSTEM IMPROVEMENTS FOR SAFETY AND ENVIRONMENTAL CONSIDERATIONS

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Abstract

The vehicle age distribution and time from the last inspection are important considerations when evaluating the effects of exhaust emissions. A survey of CO and HC emissions from a sample of 600 cars was carried out in order to assess the influence of a range of factors on emission levels. The survey was conducted under two conditions: idle and load engine modes (the last was 3000 rpm).

INTRODUCTION

Modern society comprises a wide range of human activities, many of which produce large quantities of air pollutants. Road traffic is one of the main sources of such pollutants, especially CO, HC (carbon monoxides and hydrocarbons). It has been illustrated that vehicle pollution is one of the important considerations of the population in assessing quality of life (Hakkert and Pistiner, 1989). Road transport share in emissions of these gases varies in different parts of the world. Despite the use of recent innovations and up-to-date technologies in vehicle engine production, as well as the wide implementation of 3-way catalyst converters, the total amount of these pollutants has not been reduced significantly. Moreover, in some areas, an increase of CO, HC pollutants have been observed. The first reason causing this detrimental effect is the continued increase of motorization (the vehicle number per 1000 inhabitants), especially in those countries where the saturation level of motorization has not yet been reached. Another reason is an increase in the annual mileage which occurs practically all over the world and reflects the growth of human life level (Watkins, 1991).

Generally, the emission quantity from petrol-engined vehicles is larger than from diesel vehicles. This is caused as by the difference in combustion processes, as the greater share of petrol engined vehicles in the fleets, which is why the study deals with air emissions from petrol vehicles. It appears that in Israel, in spite of a relatively low level of motorization, the aforementioned pollution problem is proceeding on a considerable scale. The following data illustrate the current situation: the share of pollutants from road traffic for CO is more than 90%; HC- close to 100% (Asif Faiz, 1993).

Road traffic represents a complicated system. In order to improve the functioning of such a system concerning the vehicle emission problem, greater efforts in every possible direction should be made. The subject of the given study is the influence of vehicle related factors on the emission levels. These factors are vehicle age distribution in national fleet and the Inspection/Maintenance System efficiency for vehicles in use. As a consequence, at the first stage of the study the international comparisons of the Israeli vehicle fleet (concerning vehicle age distribution) with USA, United Kingdom and Dutch fleets were carried out. Furthermore, a survey of CO and HC emissions from a sample of 600 cars was conducted in order to assess the influence of noted factors on emission level.

VEHICLE FLEET ANALYSIS

At this stage, let us examine the vehicle distribution in the fleet according to age. All the data relate to the period of 1990-1991 (Figure 1). In Figure 1, the vehicle age distributions for the fleets of the USA, United Kingdom, Holland and Israel are presented. Characteristics of the same distributions appear in Table 1 (Anilovich and Hakkert, 1993).

The characteristics show that there is a significant share of old vehicles in the Israel fleet in contrast to United States and the two European countries, and this despite lower mean age than in the United States fleet.

The prominent share of old vehicles in the Israeli fleet is illustrated by a high median value as well as significant percentage of vehicles older than 9 years in the vehicle distribution. When contrasted with the British fleet, the difference is most eloquent, and it is demonstrated in mean value. The displayed indices of the vehicle fleet's age distribution indirectly characterize the level of needed expenditure for keeping the fleet's "average" vehicle in proper technical condition. As can be seen, the vehicle age situation in Israel differs from the same in the countries compared. Thus, it is appropriate to ascertain the connection between vehicle age and vehicle emission level. It has been revealed in the study of Gallagher and Livo (1991) that vehicle age and maintenance can have an impressive effect on CO emissions. Hence, it seems fair to assume that there is a certain correlation between vehicle age and some characteristic of I/M system on one hand, and the vehicle emission level on the other. In order to evaluate this correlation for the conditions of Israel, a survey of CO and HC emissions from the car sample was conducted.

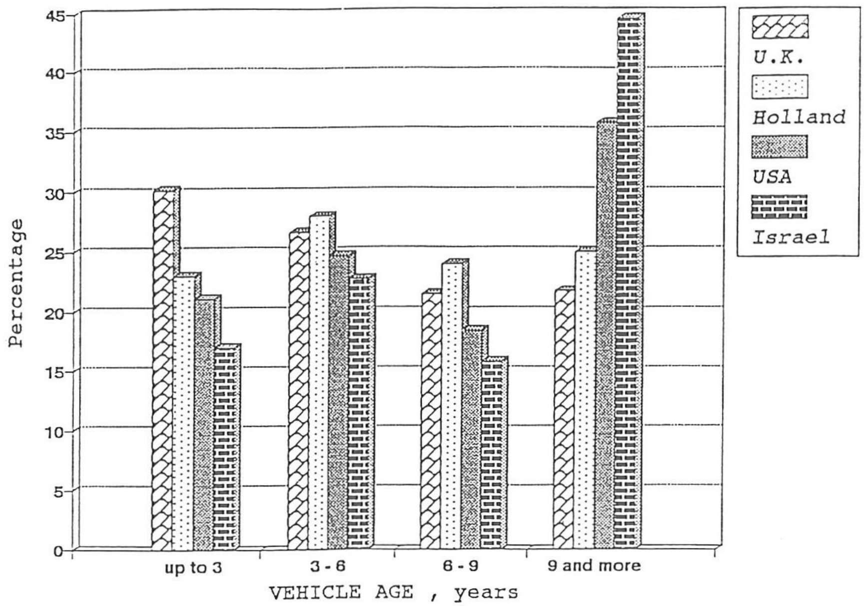


Figure 1 **Vehicle distribution in fleets according to vehicle age**

Table 1 **The mean and median values of fleet's age and percentage of vehicles older than 9 years (all types)**

Country	Mean Value years	Median Value years	% of Vehicles Older than 9 years
USA	7.8	6.5	35.8
UK	5.8	5.3	21.7
Holland	6.3	5.8	25.0
Israel	7.2	8.0	44.5

PASSENGER CAR EMISSION SAMPLING

General

The survey conducted attended to the passenger car sample of 625 vehicles. The testing procedure was included into the Ministry of Transport's roadside checking enforcement. The adopted course of action assumed that the vehicles are to be stopped in random order by a police officer, and checked in a specified way. Emissions' testing included CO and HC measurements, which were conducted in two modes. The first was the idle engine mode, the second—the "fast" idle mode, which implies a rotary speed of 3000 rpm. In addition to these measurements, individual vehicle data were recorded.

Method of measurements

All the measurements were conducted by a vehicle Gas Analyzer. Its operation principle is based on using an infrared beam, sensitive to the values of CO and HC concentrations. An important part of the testing process was to attest that the heat conditions of the engine correspond to manufacturer requirements. The CO and HC measurements in both of the aforementioned two modes were carried out twice. The following data of tested vehicles were recorded:

- date of the current testing;
- vehicle registration number;
- year of production;
- car model and modification;
- engine capacity;
- date and place of last annual test.

ANALYSIS OF SURVEY RESULTS

Sample representativeness

Age distribution and engine capacity distribution of cars in the sample were analyzed at the first stage. This evaluation was to be compared with the respective distributions in the Israeli fleet as a whole (Figure 2).

As can be seen from Figure 2, there is no significant difference between age distribution in the sample and the whole fleet, except for two points to be mentioned:

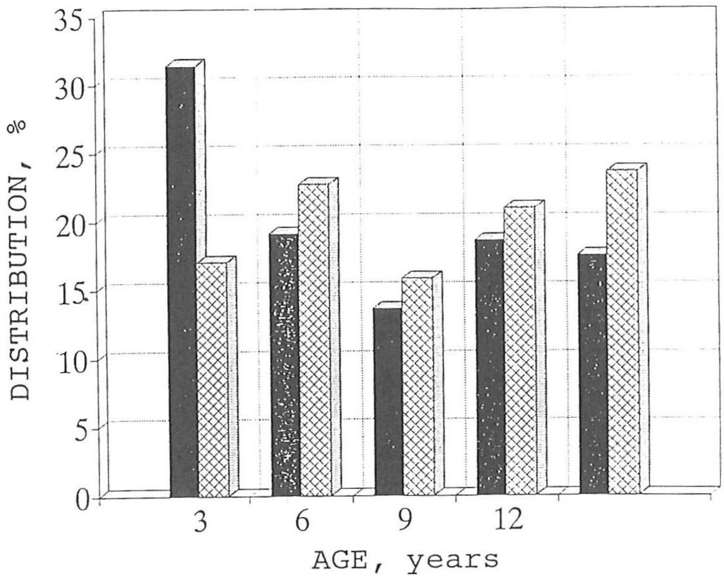
- the share of new vehicles (0-3 years) is greater, than the respective value in the fleet
- the share of the oldest vehicles (more than 12 years) is correspondingly less

As to the engine capacity distribution in the sample versus the respective distribution in the whole fleet (Figure 2b), there is only a subtle difference between them. Summarizing these comparisons, one can assess that the given sample is representative of the Israeli vehicle fleet in terms of vehicle age and engine capacity distributions.

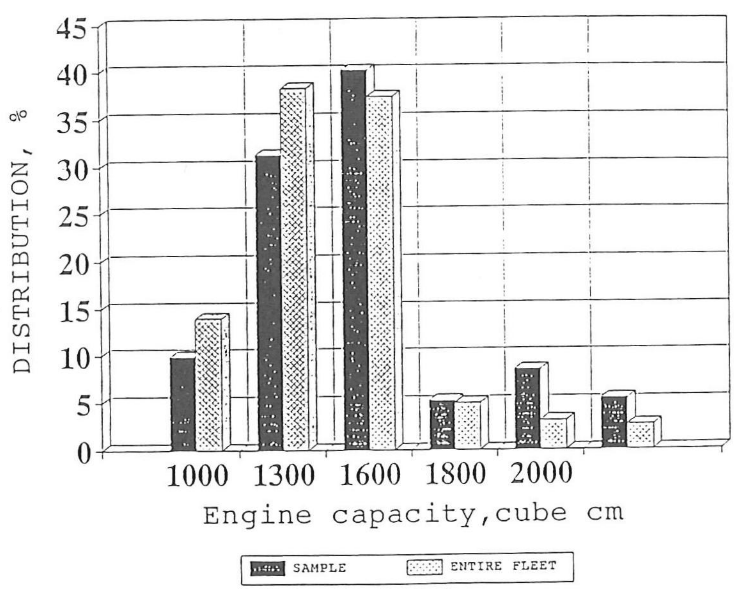
Preliminary analysis

CO emission data measured for the idle engine mode versus vehicle age and time since the last test are presented in Figures 3 and 4 respectively. For the three remaining cases (CO%-fast idle mode and HC, ppm—idle and fast idle modes) the dependencies are similar to those presented in Figures 3 and 4.

As can be seen from Figures 3 and 4, there is a definite correlation between the mean values of CO emission and vehicle age, while no influence of time since last test on CO emission values has been noticed. To bring these findings forward, linear regression analysis was conducted subject to the two mentioned factors (the vehicle age and the time since last test). The main results of the analysis are given in the Tables 2 and 3.



a)



b)

Figure 2 **Vehicle distribution in the sample and in the Israeli fleet, according to**
a) vehicle age
b) engine capacity

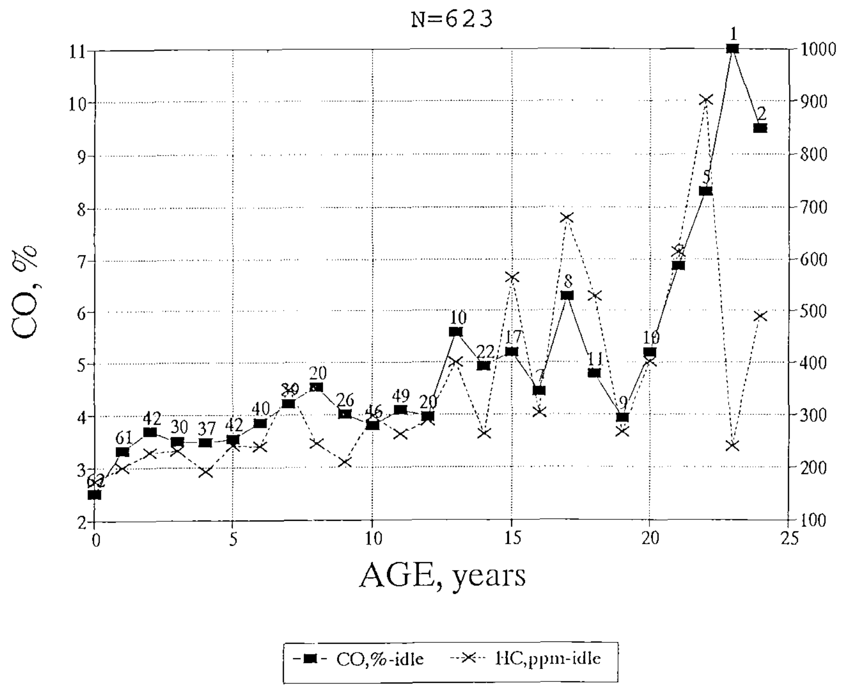


Figure 3 The mean values of emissions versus vehicle age (numbers represent observation quantity for each age)

Table 2 Results of linear regression analysis (the vehicle age influence)

Characteristics of equation	Regression	Characteristics	Values	
$Y_i^* = A_i + B_{1i} {}^* X_{1i}$; N=625**	CO, % idle	CO, % fast idle	HC, ppm idle	HC, ppm fast idle
Correlation coefficient - R_1^2	0.0659	0.0113	0.0754	0.0429
Coefficient - A_i	2.92	2.71	163	138
Coefficient - B_{1i}	0.139	0.125	15.5	9.9

* i = 1,2,3,4 for CO idle, CO fast idle, HC idle, HC fast idle.
** sample size is 625 observations for each of the four measurements.
X_{1i} a variable of the vehicle age, years.

Table 3 Results of linear regression analysis (influence of the time since last test)

Characteristics of equation	Regression	Characteristics	Values	
$Z_i^* = C_i + D_{1i} {}^* X_{1i}$; N=607**	CO, % idle	CO, % fast idle	HC, ppm idle	HC, ppm fast idle
Correlation coefficient - R_1^2	0.000065	0.002682	0.000096	0.000005
Coefficient - A_i	3.9	3.6	280	210
Coefficient - B_{1i}	0.0059	-0.0327	-0.7413	-0.1422

* i = 1,2,3,4 for CO idle, CO fast idle, HC idle, HC fast idle.
** sample size is 607 observations for each of the four measurements.
X_{1i} a variable of the time since last test, month.

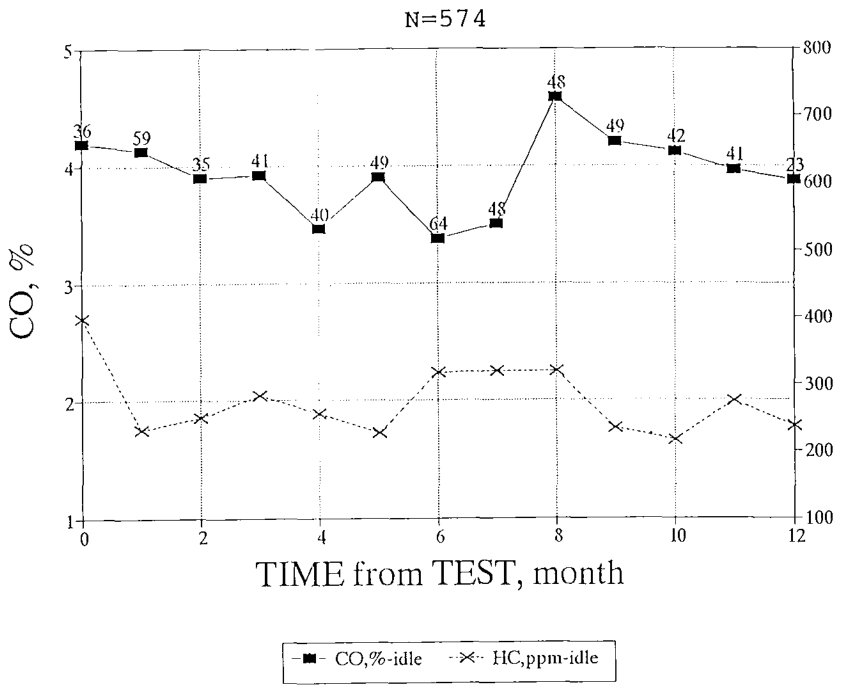


Figure 4 The mean values of emissions versus time since the last test

The data of Table 2 indicate a weak correlation existing between CO and HC emission levels and vehicle age (the coefficient of correlation—R^2 changes from 0.0113 to 0.0754). On the other hand, in all the cases the correlation was positive (coefficient $B_i > 0$). From Table 3, it cannot be identified that the time since last test influences the vehicle emission level (the coefficient of correlation does not exceed 0.00268 and the coefficients Di are negative in three out of four cases).

The results of the preliminary analysis show that only vehicle age influences vehicle emission level; however the degree of this influence is rather weak. On the other hand from the data of Table 2, one can assume that, there are some distinctions between various groups of vehicle age. This suggests analysis of vehicle emission distribution (CO and HC) for each age group separately.

Emission distribution analysis according to vehicle age group

In the light of previous findings it is suggested to divide the tested sample of vehicles to five age groups in the following way:

Group Number	Range of Age, years	Number of Observations
1	0—3	196
2	4—6	119
3	7—9	85
4	10—12	116
5	more than 12	109

The CO and HC distributions for first age group, as an example, and for both aforementioned engine modes are shown in Figure 5 (the graphs for remaining groups are omitted). In addition the main characteristics of all the distributions are presented in Table 4.

Table 4 Emission distribution characteristics for each group

Group	Mean Value				Standard Deviation			
Number	CO, idle	CO, f.idle	HC, idle	HC, f.idle	CO, idle	CO, f.idle	HC, idle	HC, f.idle
1	3.15	2.22	204	147	2.84	2.14	221	185
2	3.61	3.50	213	195	2.85	2.59	209	264
3	4.19	3.70	279	210	2.91	2.62	318	347
4	3.93	3.89	283	224	2.98	2.70	254	221
5	5.43	4.60	455	320	3.69	3.05	531	376
entire sample	3.90	3.38	274	209	3.14	2.71	326	278

As can be seen from Table 4, both emission values tend to grow as the age group. This statement is valid for CO and HC measurements in both modes. Furthermore the percentage of vehicles which could fail in the idle engine mode is presented in Table 5. The two criteria defining failure are considered:

- CO values exceed 4.5%;
- CO values exceed 4.5% or HC values exceed 1000 ppm.

Table 5 Percentages of failed vehicles for different age groups according to Israeli standard requirement and additional criteria considered*

Group Number	Vehicle Percentage emits more than 4.5% of the CO	Vehicle Percentage emits more than 4.5% of the CO or more than 1000 ppm of the HC
1	26.2	26.2
2	30.2	30.2
3	45.8	48.2
4	33.3	33.3
5	53.8	54.7
entire sample	35.9	36.3

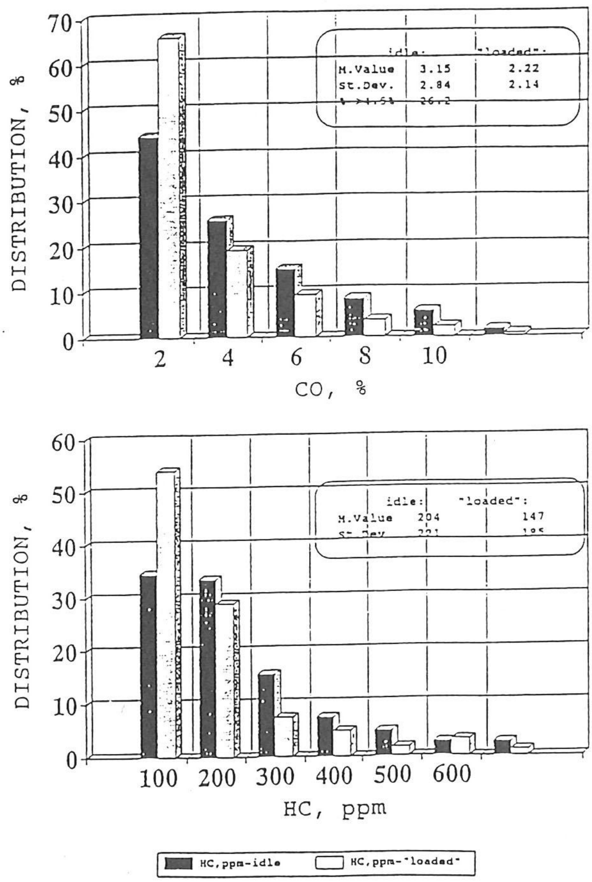
* the analysis was carried out for the idle engine mode only

This leads to the following findings:

- The most suitable function which describes the emission distributions is an exponential function (an additional justification of this statement is the value of the coefficient of variation which is close to 1).
- Except for the two cases (HC standard deviation values for the groups 2, 3), the overwhelming majority of result represents higher values of emissions in the idle engine mode in contrast to the fast idle mode. This fact complies with the data of other research (see for example Armstrong et al., 1987). It is important to note that the current requirement of the Israel Ministry of Transport for vehicles passing annual tests in idle engine mode is the percentage CO emission which should not exceed 4.5%.
- As can be seen from Table 5, more than one third of the vehicle sample would be identified as failed vehicles. No substantial differences for each age group were obtained when the

additional HC emission criterion was considered. This may be caused by the presence of a positive correlation between CO and HC emission levels (that is why there is no reason to add such a criterion to the vehicle emission test).

- The meaningful result is the percentage increase of vehicles failed attributed to vehicle age (apart from group 4 in which the percentage of vehicles failed less than in group 3). This result proves the definite correlation between CO and HC emission levels and vehicle age.



a)

b)

Figure 5 **Emission distributions for age group from 0 to 3 years:**
a) CO%;
b) HC, ppm

Vehicle emission analysis in respect to the time since last test and engine capacity

The linear regression analysis comprises the time since last test and vehicle engine capacity as the separate factors influencing the CO and HC emissions was conducted additionally for each vehicle age group. The analysis issues are presented in Table 6.

Table 6 Results of linear regression analysis (the factors are time since last test and engine capacity)

Group Number	Characteristics of Linear Regression	Values of Correlation Coefficient (R^2) and Coefficient of Regression	
	$Y_i=A_i+B_i*X_i$	Time since last test	Engine capacity
1	Corr coefficient: R_i^2	0.0290	0.0275
	Coefficient: B_i	0.1025	-0.0012
2	R_i^2	0.0036	0.0027
	B_i	-0.0403	-0.0004
3	R_i^2	0.0145	0.0496
	B_i	0.0783	0.0019
4	R_i^2	0.0116	0.0030
	B_i	-0.0805	0.0004
5	R_i^2	0.0016	0.0015
	B_i	-0.0409	0.0002

The data of Table 6 confirm that there is no correlation between emission levels on one hand and time since last test and engine capacity on the other hand. Agreeing this finding with the values of Table 5, one can point out that there is no proper maintenance of vehicle engine, no sufficient preparation to annual test being conducted, and finally, that the quality of vehicle emission checking at the test stations is not high enough.

CONCLUSIONS

The main conclusions of the study conducted are as follows:

1. There is an explicit correlation between CO, HC emission levels and vehicle age. This is mainly expressed by a growth of the mean value and standard deviation of the vehicle emissions as well as by an increase of vehicle failure percentage as the vehicle age group.
2. Taking into consideration the emission standard requirement in Israel (CO emission should not exceed 4.5%), the measurements of sample illustrate a poor situation that is worsened as vehicle age (the percentage of vehicles failed exceeds 50% for age group over 12 years). One of the likely causes of this is connected with a large share of old vehicles in the fleet.
3. There is no difference in the quantity of vehicles failed when an additional HC-criterion has been merged to a standard CO-criterion. This fact can be explained by the existence of a direct correlation between CO and HC emission levels in vehicles tested. For this reason, it cannot be proposed to add HC-criterion to the current testing procedure in order to make it more efficient.
4. The analysis shows that there is no proper maintenance of the vehicle engines and the annual test performance must be improved in respect to the vehicle emission control.
5. The analysis issues represent a foundation for elaboration of the Inspection/Maintenance program which will use the differentiated approach for various age groups of vehicles.

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