Inspection and Maintenance of the Vehicle Fleet in El Salvador

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Summary

Automotive vehicle emissions are a major source of air pollution in El Salvador, and in general in all of the cities of Central America. Gas and particulate emission levels from the fleet of vehicles in El Salvador are very high, when compared with international standards defining acceptable levels. These levels are high because the fleet of vehicles consists predominately of very old vehicles with deficient maintenance. The consequences of this situation are varied and serious: frequent respiratory problems among the populace, high levels of fuel consumption, excessive repair costs, high indices of accidents and on-the-road breakdowns, and greenhouse gas emissions (GHG).

Income levels of most vehicle owners in developing countries such as El Salvador do not allow them to acquire other, newer vehicles. This is a serious limitation for reduction of current emission levels. However, experiences in other nations have shown that a considerable margin of reduction is within reach of these countries, if they apply Inspection and Maintenance Programs (IMP). An evaluation of the IMP in El Salvador, whose results are presented in this article, shows that for an inspection cost of US$25 or less, the net benefits are quite considerable and increase year after year. The benefits considered in the calculations are those arising from savings in diesel fuel and gasoline, as well as those coming from the sale of atmospheric carbon reduction services.

In addition to the benefits quantified, the IMP generates incalculable positive effects on the health and quality of life of the population, as well as additional savings in vehicle maintenance costs and health services. And finally, something that is worth emphasizing, this type of program provokes significant reductions in greenhouse gas emissions.

1. Introduction

One of the major agents of pollution found currently in the so-called developing countries is vehicle disrepair. The lack of vehicle maintenance, their age, and second-hand vehicle imports (perhaps already retired from the vehicle fleet of the country of origin), taken together with the poor quality of the fuel sold, all represent a serious problem for the environment, population health, and local economies.

The exceedingly high rates of emissions, the resulting respiratory problems among the populace, high fuel consumption levels, continuous expenditures on repairs, and high probabilities of both accidents and breakdowns on the road provide clear evidence of this situation.

Although it is true that it is less expensive to have a vehicle in good repair, it is also true that the low levels of income do not allow the purchase of the type of automobile, which would prevent, or at least ease, these problems. Nevertheless, not all of the problems are due to the age of the vehicles. In a large number of cases, the disrepair of the vehicles is due more to a lack of awareness than a lack of knowledge of the rules for correct engine operation and fuel usage.

Thus, the need arises for a type of public control that would not only reduce or prevent the problems noted but would also attempt to inform and raise the levels of awareness of vehicle owners on the damage to their own pocketbook, the public treasury, and the health of their fellow citizens caused by driving an automobile in disrepair. Thus, there is a need to implement an Inspection and Maintenance Program (IMP) for automotive vehicles in El Salvador.

2. *Initial Considerations*

Complete combustion of a hydrocarbon produces only water and carbon dioxide (CO_2), nevertheless, these fuels almost never burn completely and this produces a majority of the atmospheric contaminants. In Central America, more than 50% of the gasoline-powered vehicles and 80% of the diesel-powered ones do not operate within internationally accepted standards (Toledo, 1996). Furthermore, it is acknowledged that a vehicle without emission controls in a developing country pollutes 10 times more than one that is controlled.

There is a tendency to believe that the vehicles that operate with diesel fuel pollute more than those that operate with gasoline. However, the reverse is true. Diesel engines are more energy efficient[1] than gasoline engines (i.e., for engines of equivalent horsepower) the diesel produces less contaminants and does not produce significant emissions from evaporation (Toledo, 1996)). In other words, if we compare well-tuned engines of similar technologies, the black smoke from the diesel engine contaminates less than the invisible smoke from the gasoline engine. However, this does not work the same way in developing countries, since the lack of maintenance means that the diesel engines in public transportation and heavy-duty service rarely operate adequately. Thus, in practice, diesel causes more severe environmental problems.

The study cited analyzed 20,000 diesel and gasoline vehicles from Central America. It showed that a tune-up could reduce carbon monoxide (CO), hydrocarbon (HC), and soot emissions between 40% and 60%. The same study analyzed 4,000 urban buses with un-tuned diesel engines and showed that 70% could pass the emissions tests if they tuned-up their engine or repaired the injection pump, while the rest required a complete overhaul (Toledo, 1996).

1 - In view of the fact that the diesel combustion process is very efficient, the fuel is converted almost completely into carbon dioxide (CO_2) and water. Thus, the levels of carbon monoxide (CO) and hydrocarbon (HC) emission are lower than those of gasoline engines. Notwithstanding, the emissions of nitrogen oxides (NO_x) and micro-particles less than 10 microns in diameter (PM10) from diesel engines represent an environmental contamination issue, as well as that of noise pollution and bad odors (Shell, 1992). Appendix 1 provides an accounting of the repercussions of environmental contaminants on health.

According to the author, an IMP has to go through the following stages:

- Conversion to lead-free gasoline.

- Obligation to control emissions by using catalytic converters.

- Two types of operational controls: periodic and selective. The periodic controls should be carried out in shops or verification centers authorized by the government; selective controls can be carried out on the road by private enterprise with police support.

In El Salvador, the first of the three recommendations mentioned is already a reality; the second is the project to be evaluated here (although the use of catalytic converters does not appear as an obligation); and the third step constitutes part of the program implementation strategy.

3. Costs and Benefits Expected from an IMP

A program of this type offers two main benefits: a) the potential sale of atmospheric carbon reductions due to reduced fuel usage[2], and b) a reduction in respiratory diseases.

Furthermore, other benefits are foreseen, which are:

1. Fewer traffic accidents. This will also reduce:
   a. Medical expenses, injuries, etc.
   b. Time on the road.
   c. Repair costs.

2. Reduction in traffic congestion costs.

3. Improvement in breathing air quality and urban appearance.

4. Reduction in fuel and maintenance costs.

On the other hand, project implementation also has its costs. Among these we find:

1. The cost of enforcing the emissions control program (i.e., ensuring the credibility of vehicle inspections).

2. The cost of system coordination, inspection period, authorized inspection stations, control schedule and random checks *ex post*.

3. The cost of designing an incentive system so that the vehicle-owning public collaborates with the project.

4. The investment in time and money for vehicle inspection on the part of the vehicle owner.

2 - An emissions control program achieves better engine combustion, which reduces contamination (which was caused by incomplete combustion); however, CO_2 emissions are increased. The foregoing effect is magnified even further if the use of a catalytic converter becomes obligatory. Thus, potential savings in CO_2 emissions can be defined as the reduction in fuel consumption due to engine tune-ups.

5. The Vehicle Fleet in El Salvador in Recent Decades

The largest percentage (44%) of the automobiles circulating in El Salvador through 1999 was produced during the 80's. An additional 27% was produced in the 70's, while another 6% was produced before 1970. In contrast, only 23% was produced during the 90's. These data speak clearly of the age of the country's vehicle fleet. (See Figure 1.)

These data allow us to establish a pair of indicators:

1. The number of vehicles over 10 years old in the vehicle fleet in a specific year.

2. The number of vehicles produced in a specific year in the vehicle fleet that same year (in other words, the number of "new" automobiles).

Figure 1. Composition of the vehicular fleet in El Salvador according to the decade of manufacture

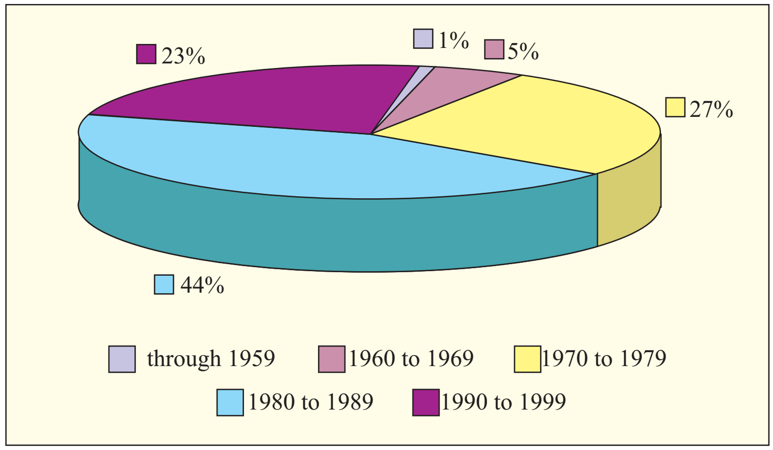
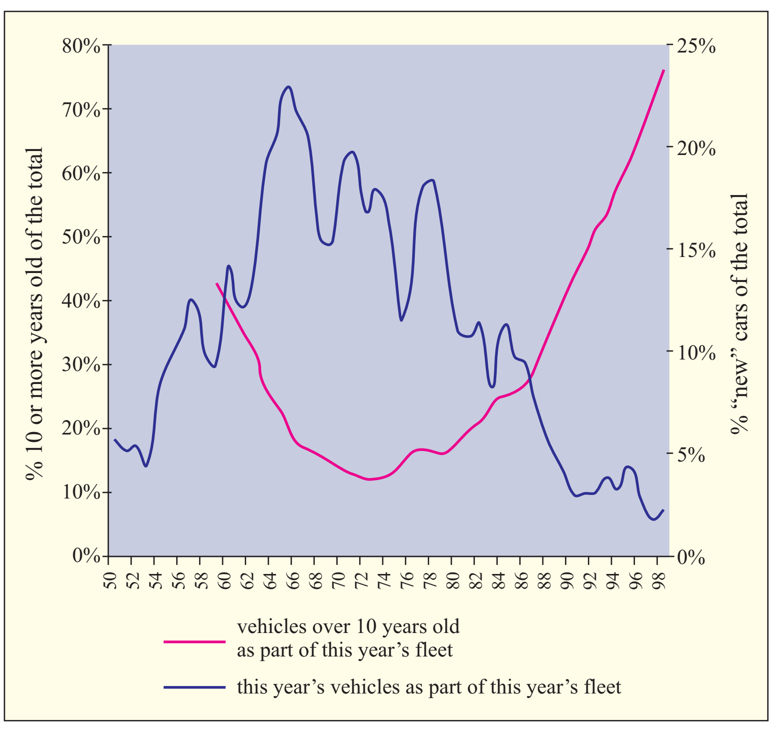


Figure 2 presents the curves corresponding to data series for both indicators for the period 1958-1999. As can be seen, the curve for Indicator 1 (number of vehicles over 10 years old) is concave downwards, with a "J" form. This curve has three clear segments: 1) descending through 1972, the year with the lowest percentage of vehicles over 10 years old with regard to the vehicle fleet in that year: 12.1%; 2) from 1973 through 1986, the percentage increases, on the average one percentage point per year; 3) growth rate stabilizes at 3.8 percentage points per year.

Figure 2. Two indicators of the age of the vehicular fleet in El Salvador, 1958-1999



In the curve for Indicator 2 (the number of "new" cars), two segments are visible: one that is predominantly upwards and which reaches its peak in 1965 (with a value of 22.8%); and the other is predominantly downward. It remains clear that the proportion of "new" cars has been decreasing significantly, which is in agreement with the increase in older vehicles shown in the other curve.[3]

With information on production years for Salvadoran vehicles, it was possible to estimate an indicator that

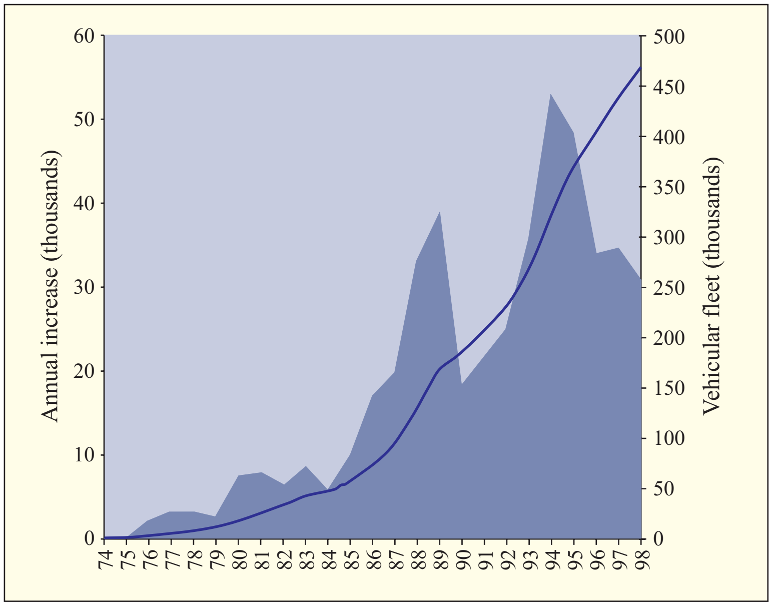
3 - The two indicators mentioned should be interpreted taking into account the fact that they have been drawn from the composition of the vehicle fleet according to their production years.

constitutes an approximation of the size of the vehicle fleet. We will call it Indicator 3. For this estimation, the premise was that the number of vehicles that make up the vehicular fleet in any given year is a product of the number of vehicles manufactured that year plus the vehicles manufactured in prior years. This calculation of the vehicle fleet incorporates a premise that is not always true – that vehicles arrive in El Salvador during the year of their manufacture. It is obvious that this premise is not fulfilled in the case of the second-hand vehicles, whose production year is always less than that of importation. In spite of this limitation on the calculation, the indicator can provide an approximate idea of the variations in the size of the vehicle fleet.

Additionally, an indicator was developed for the number of automobiles registered in country, based on the data for vehicular registration. We will call this Indicator 4.

Figure 3 provides the curves that establish the values for indicators 3 and 4, for each one of the years between 1975 and 1998. The shaded area corresponds to Indicator 4 (i.e., the flow of vehicles registered each year). The line corresponds to Indicator 3, and represents the vehicle fleet calculated for each year, as was explained above, based on the year-of-manufacture data.

Figure 3. El Salvador: Trends in the size of the vehicular fleet and its yearly increase (1974-1998)



Analysis of the data from Indicators 1, 2, 3, and 4 (from Figures 2 and 3) provides the following results:

- Regarding age of the vehicles: 77% of the fleet is over 10 years old.
- With regard to fleet growth: averaged 28% growth per year, from 1974 to 1999.

On the percentage of used vehicles that enter each year: reached 71% between 1995 and 1999.

5. Increase in Contamination Due to the Vehicular Fleet

According to an executive report from the United Nations Development Programme (UNDP) on air quality in Central America, the most important source of contamination in Central American cities is the automobile fleet. All of the vehicles in the region are imported. Used vehicles predominate, amassing more than 80% of the total between 1995 and 1998. Furthermore, the vehicle fleet in the region is so old that the average age of automobiles is over 14 years. The capacity for contamination by such an aged fleet is even greater since a majority of the automobiles in Central America lack emission control devices, such as catalytic converters. It is also worth noting that diesel vehicles are growing in number, more than 30% of the total circulating fleet, most of which are for public transportation and cargo: taxis, buses, and trucks. All of these data imply that the situation in El Salvador, with regard to automotive-caused air pollution, is representative of what is happening throughout the region.

In the aforementioned study (UNDP, 1999), the atmospheric contamination data from 45 monitoring stations was analyzed, eight of which were located in San Salvador.[4] Of the contaminants studied, nitrous oxide (N_2O) – a particulate matter in suspension sized greater than 10 microns (PST) and particulate matter sized less than 10 microns (PM10) – exceeded quality standards for urban centers in 1997 and 1998. For example, in 1997, San Salvador had the highest PST datum for all of Central America: 639mg/m^3 , in 1998 this value was 278mg/m^3. In 1990, the World Health Organization (WHO) established a standard of 75mg/m^3. Meanwhile, the values in San Salvador for N_2O were 80.4mg/m^3 in 1997 and 62.3mg/m^3 in 1998. These were, respectively, the second highest and highest values among the Central American capitals. The standard is 40mg/m^3, pursuant to the WHO norms for 1997.

There are several problems causing increased contamination from vehicular GHG emissions. These include the following:

1. A shortage of vehicle maintenance.
2. Subsidized fuel.
3. Imports of used vehicles in disrepair.
4. Deterioration and insufficient growth of the road network.
5. Traffic congestion problems.
6. Increasing vehicle *per capita* ratio and population density.

Fortunately, El Salvador does not suffer from considerable thermal inversion problems, which magnify the atmospheric contamination in those zones where inversions occur.[5]

In this context, an IMP application appears the solution for the deteriorated state of the vehicular fleet, while the problem of fuel subsidies requires urgent evaluation on the part of the responsible governmental agencies. The measures to prevent used and deteriorated vehicle imports are on the road to legislative approval. With regard to the deficient state of the highways, Table 1 provides a breakdown of the situation.

Table 1. El Salvador: State of the highways and number of vehicles in circulation, 1993 and 1999

Year	Total length in km	Number of vehicles in circulation	% of roads in good repair	% of roads in acceptable repair	% of roads in disrepair
1993	9,650	267,652	18	22	60
1999	11,200	501,932	38	N/A	N/A

N/A: Not available

Source: Hernandez, 1998. The information for 1999 was provided by Ing. Carlos Velasquez from the Office of the Vice Minister for Transportation.

4 - The information comes from the FUSADES Laboratory monitoring network, which is under the auspices of SwissContact.

5 - The geographic location of San Salvador and the topography of the zone are favorable to air dispersion, so that phenomena of thermal inversions are unknown (Castillo, 1995), although, according to SwissContact's records, between April and May 1998, a thermal inversion was present in San Salvador.

With regard to the problems of congestion, it is important to note that while the vehicular fleet is increasing by 10% per year, the country's road network grows by approximately 1% to 2% per year. Notwithstanding, it is important to remember that a great deal of roadwork does not translate into a longer network, but does improve circulation, among these are overpasses, street connectors, and street widening.

The increase in the ratio of the number of vehicles to the number of inhabitants is measured by the number of automobiles per one thousand inhabitants. In 1995, this indicator was 65, by 1999, it had reached 78, and there are projections that it will reach 100 by 2004.

6. *Methodology for Evaluating the IMP*

According to documents from ProEco-SwissContact (1997[a] and 1997[b]), taking a vehicle to an inspection and maintenance session can easily reduce the contamination between 30% and 40% while reducing the consumption of diesel or gasoline between 5% and 10%.[6]

In order to evaluate the IMP program, a conservative premise was used, consistent with a 10% reduction in contamination and a 5% drop in fuel consumption. The following step in the evaluation requires factors that relate fuel-use units with contamination units. These factors were calculated by the Energy Technology Institute of the Federal University of Zurich (ETI-FUZ) and correspond to vehicles measured in an FTP75[7] cycle, according to limits valid for 1993.[8]

Table 2 provides the factors used to calculate contamination due to CO, HC, nitrogen oxides (NOx), particulate matter, and CO_2 from fuel usage.

Table 2 shows that the emissions from the diesel vehicles in perfect shape are comparable to the gasoline-powered ones with a catalytic converter. The other important fact is the significant reduction in emissions with the use of a catalytic converter. The column where the factors increased by 10% due to the lack of maintenance shows a reduction in CO_2 emissions, which is contrary to that of the rest of the contaminants.[9]

A very important aspect that has a notable effect on the results is the premise that the use of catalytic converters be considered over time, since the converters produce an exchange: reduced contamination, but at the same time greater CO_2 emissions. The use of catalytic converters is not proposed in the Salvadoran case as a requisite of the IMP, their use will depend on the incorporation of new and used vehicles that are so equipped.

6 - According to Castro and Cordero (1998), the calculations in Costa Rica indicate that the inspection, control, and engine tune-up program generates a savings of 10% to 20% in fuel and a 30% reduction in vehicle emissions.

7 - The FTP75 (Federal Test Procedure at 75ºF) is a testing procedure that simulates in a laboratory a typical urban driving cycle for an automobile. This procedure is employed for emissions certification on new vehicles *ex*-plant. It was developed by the U.S. Environmental Protection Agency (EPA).

8 - The factors are obtained from vehicles in perfect condition and these change with changes in technology, however, they are considered representative of a true basis for El Salvador's vehicular fleet.

9 - The CO_2 factor in the 10% column is obtained by subtracting the increase in CO from the original datum for CO_2. As combustion improves, fewer contaminants are generated, but more CO_2.

Table 2. Emissions per vehicle: Metric tons of emissions per ton of fuel consumption

Emissions	**Perfectly tuned engine**	**Needs maintenance***
CO in diesel	0.01	0.011
CO in gasoline without cat. converter	0.45	0.495
CO in gasoline with catalytic converter	0.0175	0.01925
HC diesel	0.008	0.0088
HC in gasoline without cat. converter	0.055	0.0605
HC in gasoline with catalytic converter	0.002	0.0022
NOx diesel	0.045	0.0495
NOx in gasoline without cat. converter	0.025	0.0275
NOx in gasoline with cat. converter	0.00375	0.004125
Particulate matter in diesel	0.004	0.0044
Particulate mat. gasoline wo. cat. conv.	0	0
Particulate mat. gasoline w. cat. conv.	0	0
CO_2 diesel	3.13	3.129
CO_2 in gasoline without cat. converter	2.3	2.255
CO_2 in gasoline with cat. converter	3.137	3.13525

The emissions figure for "Needs maintenance" was arrived at by adding 10% to the emissions of a perfectly tuned engine.
Source: ETI-FUZ

7. Quantification of the Costs and Benefits of the IMP[10]

7.1 Benefits from the IMP

One of the benefits obtained if the vehicles are well maintained is fuel savings. Table 3 provides a breakdown of this benefit.

The data on savings are greater in the case of gasoline for price reasons, since the savings in metric tons of fuel is slightly larger in the case of diesel. The benefits were calculated over a 20-year period and are presented in five-year increments.

Table 3. Benefits in thousands of dollars from fuel savings (Per mt)

FUEL	**2001**	**2005**	**2010**	**2015**	**2020**
Savings in diesel consumption	6,507	9,389	14,848	23,481	37,135
Savings in gasoline consumption	10,932	15,948	25,567	40,990	65,715

Source: Author's calculations based on Table 2 and Table 2.1 of Annex 2.

10 - Appendix 2 provides an explanation of the methodology and premises used to quantify the benefits and costs of the IMP. An analysis is also made with regards to sensitivity of the results and on the use of the catalytic converter over time.

Another benefit is an eventual marketing of the carbon reductions. Table 4 provides these results.

Table 4. CO_2 emissions avoided (In thousands of mt)

	2001	2005	2010	2015	2020
Sum of CO_2 and CO emissions avoided	135	197	317	510	822
Conversion to thousands of mt of carbon	42	62	99	159	257

Source: Author's calculations based on Table 2 and Table 2.1 of Annex 2.

The sum of the benefits derived from reduced fuel consumption and the eventual sale of carbon reduction services provides the total benefits attributable to the IMP. These benefits (see Table 5) increase over time and are due primordially to fuel savings.

Table 5. Total benefits in thousands of dollars

Benefits	2001	2005	2010	2015	2020
From fuel savings	17,439	25,337	40,415	64,471	102,849
From carbon marketing	420	615	991	1595	2568
Total benefits	**17,860**	**25,952**	**41,406**	**66,066**	**105,417**

Source: Data from Tables 3 and 4.

The benefit generated by the sale of atmospheric carbon emission reduction services on the international market may take place once this market gets underway within the framework of the Clean Development Mechanism (CDM) established under the Kyoto Protocol. Although this benefit is small in comparison to the fuel savings, the revenues from the sale of carbon reductions grow over time. Furthermore, this type of initiative for emission reduction can act as a bellwether that the country is committed to world efforts to impede climate change and its severe effects. Furthermore, it also contributes to improving the credibility of the country's other initiatives in this area.

A benefit that is not directly quantified but that could be the most relevant one in a program such as IMP is the enhanced health of the population resulting from reduced pollution.

Table 6 provides an accounting of the contaminant emission reductions that would occur if the IMP were put into practice.

Table 6. Contaminant emission reductions (Thousands of mt)

Contaminant	2001	2005	2010	2015	2020
CO	23,398	28,365	33,917	35,847	27,765
HC	3,329	4,142	5,209	6,057	6,033
No_x	4,431	6,132	9,166	13,630	20,150
PM10	0.278	0.401	0.634	1.003	1.587
CO_2	111,149	168,551	283,092	474,536	794,013

Source: Author's calculations based on Table 2 and Table 2.1 of Annex 2.

By applying "dose-response" functions that express the effect of a change in the measure of contamination on a health outcome (such as the number of sick individuals, the number of office visits to doctors, the probability of falling sick, or the probability of premature death) it may be possible to estimate the additional benefits from the IMP. These would be derived from the cost reductions that a society would reap from a reduction in illnesses among the population and by the reduction of all the additional damage brought on by the diseases themselves.

Two procedures can be used to estimate the benefits to society from reduced contamination including:

a. Relate fuel consumption to an indicator of kilometers traveled and then relate this to the incidence of respiratory diseases.

b. Adopt the parameters from studies that relate pollution indicators to respiratory diseases.

It is possible to apply the first of the procedures cited by using the indicators found in Small and Kazimi (1995), which indicate health expenditures per mile for private automobiles of US$0.03 and US$0.527 for trucks.

To apply the second procedure, we can use a paper prepared by Sanchez and Morel (1995), wherein they determine elasticity of 0.4 for office visits with respiratory complaints regarding PM10 levels. With that datum as a referent, the reduction in office visits for respiratory complaints would be approximately 5.5% per year.

7.2 IMP costs

The costs involved in a program such as IMP include infrastructure installation and that of the necessary equipment for the inspections, resources used to audit the system and keep it operating, as well as the costs associated with vehicle inspections and repairs.

Table 7 deals only with the cost of taking the vehicle in for inspection

Table 7. IMP costs according to different scenarios for pricing inspection (Thousands of dollars)

Inspection pricing (US$)	2001	2005	2010	2015	2020
5	2,893	3,858	5,558	8,044	11,684
15	8,680	11,575	16,674	24,132	35,052
25	14,466	19,291	27,790	40,220	58,420
40	23,146	30,866	44,464	64,352	93,472

Source: Author's calculations based on Table 2 and Table 2.1 of Annex 2

Since the premise is that the vehicular fleet will grow over time, program costs will also increase.

7.3 Net benefits from the program

Tables 5 and 7 provide information for calculating the net benefits from the IMP, which appear in Table 8. The IMP would provide net positive benefits at three of the four prices used. At a cost of US$40 per inspection, the net benefits would only appear after the first 11 years of the project had transpired. The net benefits calculated could be conservative and inexact because the health benefits that derive from pollution reductions and the eventual benefits from reduced maintenance costs must still be considered.

Table 8. Net benefits from the IMP according to different scenarios for pricing inspection (Thousands of dollars)

Inspection pricing (US$)	2001	2005	2010	2015	2020
5	14,966	22,094	35,848	58,022	93,733
15	9,180	14,377	24,732	41,934	70,365
25	3,393	6,661	13,616	25,846	46,997
40	-5,287	-4,914	-3,058	1,714	11,945

Source: Data from Tables 5 and 7.

8. Conclusion and Recommendations

Given the dominant characteristics of the vehicular fleet in El Salvador, particularly the age and lack of maintenance, and the problems of environmental contamination, a program such as an IMP is necessary. This type of program generates different benefits. The paper estimates only those benefits arising from reduced fuel consumption and CO_2 generation. The costs are defined on the basis of different scenarios of inspection pricing. Given these benefits and costs, the program would be expedient, as long as the inspection costs stay below US$40 during the first 10 years.

Program evaluation was carried out from a social point of view, even though the author acknowledges that not all of the relevant costs and benefits were considered. Thus, it would be appropriate to continue working on an estimation of the costs and benefits excluded and assume different IMP evaluation perspectives. It might be interesting to evaluate the IMP from the point of view of the automobile owner or the firms that would offer inspection services.

It would be appropriate to make an evaluation from the point of view of the owner, because it would transmit the information necessary to show that payment for technical inspection services is not an expense but an investment with a series of associated benefits. This information would aid in promoting the project.

Again from the point of view of the owner, the benefits of the project are: the reductions in fuel consumption and maintenance – the benefits from reduced carbon emissions were not considered because they are not a private benefit. Among the costs, it is important to distinguish those for taking the car to the inspection – both money and time – and the additional one that arises if the vehicle does not pass inspection and requires some kind of tune-up. To estimate these costs, it would be necessary to gather the data on how many vehicles do not pass inspection and the costs for different types of repair work.

To obtain more specific and reliable estimates of the costs and benefits from the private perspective, it would be appropriate to carry out a panel study where a sample of vehicles is selected, which is then subdivided into two sub-samples: one would consist of vehicles that had gone through the inspection process; and the other with vehicles that had not done so. With this information it would be possible to carry out a regression analysis to obtain the relation between kilometers per gallon in the whole sample of vehicles and the fact of having gone through the inspection process and having made the recommended repairs, the age of the vehicles, make, model, type of fuel, and other relevant variables. Thus, it would be possible to evaluate the benefit in terms of better fuel performance gained from having passed the technical inspection and this benefit could be compared with the inspection costs.

Appendix 1.

Contaminants related to the vehicular fleet and their health effects

Contaminant	Results from	Health effects
CO (carbon monoxide)	Incomplete combustion	Very dangerous in poorly ventilated areas, colorless, odorless, and non-irritating. Reduces the absorption of oxygen by the red blood cells, affects perception and thought processes, reduces reflexes and can cause unconsciousness. Affects fetal growth in pregnant women. Together with other contaminants, it promotes respiratory and circulatory problems.
HC (hydrocarbons)	Incomplete combustion or evaporation. Bad odors from exhaust gases. When combined with NOx they produce ozone and form smog.	Itchy eyes, fatigue, and a tendency to cough. Can have carcinogenic or teratogenic effects. HC from vehicle engines can cause pulmonary diseases.
Photochemical smog (oxidants)	Concentrated HC and NOx in the atmosphere interact with solar radiation to produce a photochemical reaction known as oxidants, one of which is ozone, O_3.	Obscures visibility, irritates the eyes and the respiratory system, causes cancer.
Pb (lead)	Additive to increase the octane rating in gasoline.	Affects the circulatory, reproductive, kidney, and nervous systems of the body. Reduces learning abilities in children and may cause hyperactivity. May cause neurological damage.
Particulate matter PM10: Particulate matter with a diameter smaller than 10 microns, which floats in the air. Particulate matter PST: Particulate matter with a diameter greater than 10 microns, which floats in the air.	PM10 is produced by an oxygen deficiency in combustion. PST includes dust from areas without plant cover, unpaved roads, and industrial sources and services that burn high-sulfur fuels and substances that are not soluble in n-pentane. It also comes from vehicles burning leaded gasoline.	Health effects: bronchitis affects the respiration and increases susceptibility to asthma and the common cold. Damages are increased when they combine in the atmosphere with sulfur dioxide. May cause respiratory diseases (affecting children and the elderly more) and lung cancer. The lead present in PST causes neurological problems, which may lead to a reduction in IQ, among other damages. PM10 and PST particulate matter are considered the most serious problem in air quality throughout Central America.
NO_x (Nitrogen oxides NO,	Secondary products of combustion. The higher the combustion temperature the greater the formation of Nox.	They irritate the eyes, nose, throat, cause coughing, headaches, and damage the lungs.
NO_2, NO_3) SO_2 (Sulfur dioxide)	From the sulfur content in diesel fuel.	Colorless gas with a pungent odor, when dissolved in water it produces H_2SO_3. It causes corrosion and acid rain. Causes throat rash and irritation of the respiratory system.

Appendix 2.

The Analytical Method Used

This appendix describes the analysis utilized, clarifies the premises used, and presents a sensitivity analysis of the net benefits from the program. Finally, there are some considerations on the use of catalytic converters.

In order to evaluate the benefits of the IMP we need projections of what the emissions would be without an emissions control program and their effects on carbon generation, the use of fuels, and the incidence of respiratory diseases. This is known as the no-project situation or scenario.

The no-project scenario is compared to the project scenario, which would reflect the lowest carbon generation, lowered fuel usage, and fewer respiratory diseases. The difference between both scenarios is given in physical units, metric tons (mt) of carbon and fuel saved, or the number of respiratory diseases avoided. For these to be accounted for as benefits we must monetize these units; thus, we would use the prices per mt of carbon, per mt of fuel, and the prices of the doctor's visits for respiratory complaints. This article only considers the benefits from the savings in reduced atmospheric carbon emissions and for reduced fuel usage. The benefits accruing from a reduced incidence of diseases are not monetized but there is a physical reduction in contaminating agents.

The premises[11] used to carry out the project evaluation are presented in Table 2.1.

Table 2.1. Premises used for program evaluation

Improvement in diesel and gasoline consumption from 2001 to 2020	5%
Reduction in contamination	10%
Rate of growth of the diesel-powered vehicle fleet	2%
Rate of growth of the gasoline-powered vehicle fleet	8%
Proportion using catalytic converter in 2000	20%
Increase in catalytic converter usage per year	3.5%
Rate of growth in diesel consumption	9.6%
Rate of growth in gasoline consumption	9.9%
Assumed dollar price per mt of diesel	281
Assumed dollar price per mt of gasoline	503
Assumed dollar price per mt of carbon	10
Conversion of gallons to mt of diesel	0.0033
Conversion of gallons to mt of gasoline	0.00284
Conversion factor for carbon dioxide to carbon	3.67

The first two premises constitute the point of departure for program evaluation; the next two are taken from the historical growth of the vehicular fleet.

11 - With regard to the premises, three aspects stand out: a) an attempt was made to use conservative assumptions, b) there is a loss of precision with the use of unchanging assumptions over time, when – according to projections on the growth of the vehicle fleet – the problems of congestions "*ceteris paribus*" would modify the rate of growth in fuel consumption, and c) technology is not taken into consideration, which may be fuel sparing. This last effect would modify the rate of growth in fuel consumption, as well as the changes in fuel efficiency, increasing the kilometer per gallon ratio as well as an eventual fuel substitution.

The premises related to the use of catalytic converters are derived from the fact that in 2000, only 20% of the gasoline-powered vehicles had catalytic converters, and this proportion was increasing by approximately 3.5% per year. With an increase in this participation and the growth in the gasoline-powered fleet, there is certainty that the number of vehicles with catalytic converters will increase over time, while the number of vehicles without a catalytic converter will follow a parabolic trajectory, increasing over time to reach a maximum, and then beginning to decline. This proportion will eventually reach zero when all automobiles have catalytic converters. According to our premises here, this would not occur until 2023.

The premises on the growth in fuel consumption are taken from the annual information from 1985 through 1999 (See Table 2.2.). The assumptions on fuel prices are US$0.9143 per gallon of diesel and US$1.429 per gallon of gasoline. These prices appear in the Table on assumptions applied as prices per ton. Finally, an eventual carbon price of US$10 per mt is used. The last three assumptions are not actually assumptions but rather pre-established conversion factors.

The sensitivity analysis:

The critical premises in this evaluation are:

1. The reduction in contamination due to improved vehicle maintenance.
2. The use of fuels over time and savings through improved vehicle maintenance.
3. The use of the catalytic converters over time.

Table 2.2. Fuel use growth rates during the period from 1985 to 1999

Fuel	Average annual rate growth (percent)	Average annual increase (mt)
Diesel	9.6	21,850
Hi-Test Gasoline	8.2*	7,300*
Regular Gasoline	13.1	11,970
Gasoline	9.9	19,270

(*) If only the period from 1991 to 1999 is considered, the average increase is 17,061 metric tons per year and the average annual growth is 21.7%.

Source: Ministry of the Economy.

Assumptions 1 and 2 are endogenous to the implementation of the IMP – the more successful the program, the more pollution is reduced and the greater the fuel savings . Assumption 3 is exogenous and will depend on the incorporation of vehicles with catalytic converters over time. These assumptions may interact, for example, the greater the use of catalytic converters, less atmospheric contamination would be expected, and furthermore, the greater the incorporation of “new” vehicles into the fleet that meet environmental standards, there would be a simultaneous use of catalytic converters, fuel savings, and reduced pollutants.[12]

The scenarios arise from modifications of the first two premises, and to summarize, variations of the assumptions will take two directions: one where the variations favor project implementation and the other where the variations discourage project implementation.

The changes in the assumptions in favor of the project define the “High” scenario and the changes against the project define the “Low” scenario. These changes are compared with the results already obtained, which are called the “Basic” scenario.

12 - Obviously, it is a very slow process over time, given the incorporation of “clean” new vehicles is insufficient to substitute the “dirty” old vehicles.

The High scenario is reached with the following changes:

a. Pollution reduction reaches 20%.
b. Fuel savings reach 10% and the growth rate in fuel usage remains stable.

The Low scenario is developed from the following changes:

a. A pollution reduction of only 5% is achieved.
b. Fuel savings are only 2% and the growth rate in fuel usage remains stable.

It is important to note that the scenarios refer to the expected development of the project. Other actions may be implemented which improve fuel use and reduce contamination, but are not attributable to the IMP project (e.g., technological improvement in automobile design, changes in the relative prices for new and used vehicles, changes in fuel types, fuel use taxes, obligatory catalytic converter use, careful driving programs, etc). What must remain clear is that even though other actions may be taking place, which affect fuel consumption savings and contaminant emissions, what is expected is that the results provided by the scenarios are solely attributable to the IMP and not to the interference of other types of programs.

Results of the scenarios

Given the form in which the scenarios are defined, there are no cost variations, only program benefits. Thus in the High scenario, there is an increase in the benefits insofar as the fuel savings are greater, along with CO_2 savings and there is also an increase in contaminants avoided. The opposite occurs in the Low scenario.

Tables 2.3. and 2.4. summarize the net program benefits according to the pre-established scenarios. The data are presented only for inspection prices of US$5 and US$15.

Table 2.3. Net benefits US$ if inspection costs are US$5

Years	Scenarios		
	Low	Basic	High
2001	4,251	14,966	32,826
2005	6,523	22,094	48,046
2010	11,004	35,848	77,254
2015	18,382	58,022	124,088
2020	30,483	93,733	199,150

Table 2.4. Net benefits US$ if inspection costs are US$15

Years	Scenarios		
	Low	Basic	High
2001	-1,536	9,180	27,039
2005	-1,194	14,377	40,329
2010	-112	24,732	66,138
2015	2,294	41,934	108,000
2020	7,115	70,365	175,782

With regard to the Basic scenario, there is an increasing trend in net benefits,[13] since the costs are greater when inspection costs are increased. The greater the cost of inspection, the smaller the net benefits. If the inspection price is US$15, the net benefits are negative during the first 10 years of the project, according to the Low scenario conditions.

The other project benefit is fewer contaminant emissions. The tables for each scenario are presented below.

Table 2.5. High scenario: Contaminants avoided (Thousands of mt)

Contaminant	2001	2005	2010	2015	2020
CO	46,796	56,730	67,834	71,694	55,530
HC	6,657	8,283	10,417	12,113	12,066
NO_x	8,863	12,264	18,331	27,261	40,299
PM10	0.556	0.802	1,269	2,006	3,173
CO2	222,299	337,102	566,183	949,071	1,588,026

Table 2.6. Low scenario: Contaminants avoided (Thousands of mt)

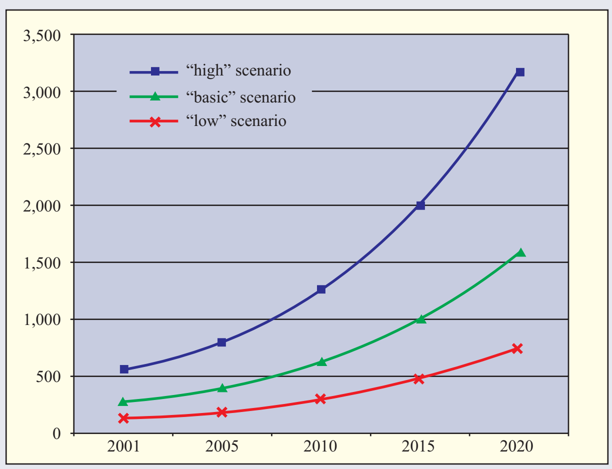
Contaminant	2001	2005	2010	2015	2020
CO	10,919	13,237	15,828	16,729	12,957
HC	1,553	1,933	2,431	2,826	2,815
NO_x	2,068	2,862	4,277	6,361	9,403
PM10	0.130	0.187	0.296	0.468	0.740
CO_2	42,900	65,529	110,975	187,424	315,754

The results clearly validate the lower pollution levels with the High scenario.

Since PM10 is one of the contaminants most closely associated with respiratory diseases, the figure presents the evolution of emission reductions for PM10, according to the different scenarios .

Using the elasticity obtained in Sánchez-Morel, in the "High" scenario we can conclude that doctor's visits for respiratory problems will decline by 10% per year, in the "Low" scenario, this figure would be only 2.7%.

Figure 2.1. Scenarios of PM10 emissions avoided (thousands of metric tons)



13 - The explanation for this trend is that the growth rate in weighted fuel use is greater than the growth in the vehicle fleet, which may be due to the greater number of automobile trips, longer average trips, and by an increase in highway congestion.

The calculations shown in this appendix allowed us to calculate the dollar benefits that would be derived from putting an IMP into practice, due to the fuel savings and carbon emission reductions. The calculations were made for the years 2001, 2005, 2010, 2015, and 2020. First, total benefits were estimated, then IMP costs were calculated, supposing different amounts for inspection costs, and then the net benefits that resulted from subtracting costs from total benefits arrived at previously.

Observations on the use of the catalytic converter over time

As the use of the catalytic converter increases, CO_2 emissions grow, but those of the other contaminants fall. Thus, changes in the growth of catalytic converter use would alter the results obtained.

The following summarizes the direction in which the outcomes would be affected, referring to two situations: the first implies an increase in the growth rate of catalytic converter usage (other assumptions remaining constant) and the second foresees a one to one increase in the growth rate of catalytic converter use and the rate of fuel-use improvement.

First situation

If catalytic converter use increases while the rest of the assumptions in the "Basic" scenario remain constant, the amount of CO_2 produced increases, but the difference between the amount of emissions without the project and with the project increases; notwithstanding, benefits are increased, if these carbon savings are potentially marketable. By increasing the participation of catalytic converter equipped gasoline-powered vehicles, even though CO_2 emissions increase, the difference between the CO_2 emissions in the situation without the project and the situation with the project, increases over time, thus improving carbon savings. Obviously, the amount of the possible savings ends when all of the vehicles have catalytic converters.[14] The opposite situation occurs when the emissions of CO decline, similar to the savings in CO due to project implementation. This is the general situation for the rest of the contaminants.

The foregoing situation can be generalized as follows: all of the assumptions of the "Basic" scenario are unchanged, but we increase the use of catalytic converters. Indeed, these do not constitute a part of the IMP project. The emissions of all of the contaminants except CO_2 decline, so that the difference between the amount of the emissions without the project and with the project would also decline. Thus, we also increase project benefits in the realm of health, by having less contamination, and the potential benefit from carbon reduction sales would also be increased.

Second situation

If we increase the use of catalytic converters and at the same time we increase the efficiency in fuel use as a result of the IMP (for example, increases of one percentage point in each growth rate) the amount of CO_2 emissions tends to decline when the project is carried out. This would further increase the CO_2 emissions avoided thus increasing project benefits as well.

14 - The gasoline used in automobiles without a catalytic converter reduces its relative participation in overall gasoline consumption, because it has less CO_2 emissions with regard to the total CO_2 generated, and thus the difference in CO_2 emitted by implementing the project or not becomes continuously smaller until it eventually disappears.

References

BCastillo, Isaac (1995). Energía y Medio Ambiente El Caso de El Salvador. Mimeógrafo. Document prepared for the Comisión Ejecutiva Hidroeléctrica del Río Lempa (CEL).

Castro, René and Sarah Cordero (1998). Evaluación del Impacto Ambiental y Sostenibilidad del Desarrollo. 1ª edición, San José: EUNED.

Energy Technology Institute of the Federal University of Zurich (ETI-FUZ). Laboratorio de Motores de Combustión Interna y Tecnología de Combustión. http://www.lvv.ethz.ch.

Hernandez de Larios, Silvia (1998). Transporte urbano y contaminación del aire en la región metropolitana de San Salvador. Working Document of Project: "Prevención y Mitigación de la Contaminación Industrial y Municipal en el Área del Gran San Salvador" financed by USAID.

Ministry of Environment and Natural Resources (1999-2000). Licitación publica nacional e internacional Contratación de servicios de instalación, administración y operación de plantas de revisión técnica vehicular, la cual incluye la revisión de emisiones contaminantes de gases, partículas y ruidos. MARN-09/99 y MARN 03/99.

Orellana, Eliseo (1998). Perfil epidemiológico y medio ambiente en la Región Metropolitana de San Salvador. Working Document of Project: "Prevención y Mitigación de la Contaminación Industrial y Municipal en el Área del Gran San Salvador" financed by USAID.

ProEco-SwissContact (1997). Control de Emisiones de Gases en Motores a Gasolina.

ProEco-SwissContact (1997). Control de Emisiones de Gases en Motores a Diesel.

Shell (1992). El automovilismo y el medio ambiente. Shell Briefing Service, Number 2.

Small, Kenneth and Camila Kazimi (1995). On the Cost of Air Pollution from Motor Vehicles. In Journal Of Transport Economics and Policy. Volume 29 (Nº 1). January 1995.

Sánchez, José Miguel and J. Morel (1995). Una estimación de los beneficios en salud de reducir la contaminación en Santiago. Economía del Medio Ambiente en América Latina. Juan Ignacio Varas Editor. Ediciones Universidad Católica de Chile.

Sancho, Francisco and E. Vega (1998). Base Metodológica para Incorporar Costos Ambientales en Tarifas de Servicios Públicos. Document of the Ministry of Environment and Energy (MINAE) of Costa Rica, realized in April 1998.

Toledo, José (1996). Control de la contaminación del aire. Guatemala: Pro Eco.

UNDP (1999). Informe Ejecutivo de la Calidad del Aire en Centro América.