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A BENEFIT-COST ANALYSIS OF MOBILE SOURCE EMISSION CONTROL OPTIONS UNDER THE AUTO FUEL CHARGE PROPOSAL FOR HUNGARY

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EXECUTIVE SUMMARY

As part of its efforts to reduce environmental damages associated with the transportation sector, the Government of Hungary (GOH) currently is considering programs designed to reduce mobile source pollution. The Auto Fuel Charge (AFC), consisting of an environmental product fee assessed on leaded fuel sales, has been proposed as a means of raising revenues that will be used to fund a number of programs designed to reduce environmental damages caused by motor vehicles. This report describes an economic analysis of the costs and benefits of emission reduction options specified in the AFC proposal, with the intent of assisting in the design of economically efficient programs.

As a percent of Hungary's national air pollution emissions, road traffic accounts for 38% of the carbon monoxide, 28% of hydrocarbons, 23% of the nitrogen oxides, and 91% of the lead emitted annually. The transportation sector in Hungary has emerged as a significant contributor to air pollution for a number of reasons, including a relatively old vehicle fleet, and a higher than average lead content in fuels when compared to Western Europe. In Budapest, a hub for national and international highway systems, ambient air quality concentrations exceed international standards for nitrous oxides, lead, soot, and, occasionally, carbon monoxide. Air pollution from road transport causes a number of environmental effects, of which the largest component of damages is attributed to human health risks. The range of annual damages to society caused by vehicle fleet air emissions is estimated at 4,440 to 34,800 M HUF for Budapest, and 8,800 to 69,600 M HUF for all of Hungary. While damages (benefits) estimates are highly uncertain, they provide useful benchmarks by which to judge the relative benefits of alternative policy options.

Hungary's existing air pollution strategy targets the control of emissions in new and used vehicles, a reduction in the lead and SO2 content of fuels, infrastructure and traffic management, and promoting the use of vehicles with catalytic converters. Under the AFC proposal, funds generated from the leaded fuels tax will be reinvested in a variety of expenditure programs to reduce environmental damages. As proposed, program options will be subsidized to varying degrees, with 30% of the revenues going to personal vehicle programs, 20% to public vehicles, 22% towards infrastructure improvements, and 28% to programs mitigating environmental impacts other than air pollution. Specific technical measures include retrofitting catalytic converters onto automobiles, engine replacements, retrofitting buses with turbochargers, and improving traffic flow in Budapest.

This study employs benefit-cost (BC) and cost-effectiveness (CE) techniques to evaluate program options, with a "toxicity weighted" approach used to make cost-effectiveness analysis more meaningful. To implement the toxicity weighting scheme, both US-based National Ambient Air Quality Standards (NAAQS) and Hungarian NAAQS were utilized for weighting the relevant pollutants in terms of likely toxicity to human health. Both of the resulting indices indicate lead is the most toxic pollutant, and carbon monoxide the least

toxic. In estimating benefits, the concept of "hazard units" is employed in developing a hazard weighted measure of emissions across pollutant and across components of the vehicle fleet. The results indicate that over 44% of the "hazard units" emitted from vehicles consist of hydrocarbons, and that buses and trucks create a share of hazard units disproportionately larger than the share of their total emissions. Hazard units are converted into a monetary measure of damages for comparison with program costs. A linear damage function is assumed to estimate the benefits of pollution reduction policies, implying that benefits (damages avoided) are directly proportional to the percent reduction achieved from the baseline hazard units emitted.

The results of the benefit-cost and cost-effectiveness analysis of the AFC proposal indicate that the top three program options, in terms of having the largest positive net present value (NPV) per vehicle, are related to the bus fleet. This is a function of the high level of baseline emissions and the relatively high level of emissions reductions attributable to the bus fleet options. The costs associated with buying and installing environmentally-improved diesel engines, adopting "green/clean" technology in bus replacement, or purchasing and installing pollution control equipment in existing busses are more than offset by the benefits resulting from the reductions in pollutants, as well as by the fuel savings from the more efficient "green" engines. These bus options would contribute to mitigating the consistent violations of the air quality standards for NO_X and soot for Budapest.

A ranking of the policy options from best to poorest performers is provided in the table below, where measures reflect the present value of benefits accruing in the form of avoided damages as a result of implementing the specified number of units (e.g., vehicles, pollution control devices), net of the implementation costs. In summary, the evaluation reveals the following:

- ***The three transportation programs assessed that will generate the greatest positive net social benefits for Hungary (benefits in excess of the costs) are bus fleet related.***

- ***The net benefits per vehicle of the next three highest ranking options generate positive net benefits, or, under the most conservative scenarios, roughly break even. These options include retrofitting catalytic converters into 2 and 4 stroke vehicles, and the incremental "environmental" investment for compressed natural gas buses.***

- ***The remaining options (e.g., 2-stroke engine replacement in autos, infrastructure improvements) perform with moderate to substantial negative net benefits when measured in terms of environmental impacts alone. However, in some cases, there are significant benefits other than those accounted for in this study that would accrue from these options.***

AFC PROGRAM RANKING BY ESTIMATED PRESENT VALUE OF NET SOCIAL BENEFITS
(PV Net Benefits per # Vehicles)

Benefit-Cost (1) Option	PV Net Benefits Low (M Ft)	PV Net Benefits Medium (M Ft)	PV Net Benefits High (M Ft)	Per Units (#)
High Net Benefit Options				
1a. Diesel bus engineers environmental cost(1)	505	1,000	3,937	100
1b. Diesel bus engines total investment costs(2)	449	944	3,877	100
2a. Diesel bus replacement environmental cost(1)	315	809	3,731	100
3. Bus turbochargers	62	132	545	100
Moderate Net Benefit Options				
4. 2-Stroke catalysts	(2)	20	155	1,000
5a. CNG Buses environmental cost(1)	(7)	(1)	3,694	100
6. 4-Stroke catalysts	(15)	(5)	56	1,000
Negative Net Benefit Options				
7. 2-Stroke engine replacement	(125)	(88)	131	1,000
5b. CNG buses total investment costs(2)	(567)	(58)	2,951	100
2b. Diesel bus replacement total investment costs(2)	(655)	(161)	2,764	100
8. Park'N'Ride	(656)	(613)	(586)	1,000
9. Roads and repaving (per KM)	(6,816)	(5,987)	(1,074)	170

(1) Environmental costs are incremental costs of the policy option attributable strictly to emissions reductions.

(2) Total investment costs are total cost of the policy option, incorporating costs associated with objectives other than air quality improvements (e.g., fuel savings, safety, comfort, etc.)

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1.0 INTRODUCTION

Air pollution (including concerns over global warming and acid rain), noise pollution, and urban congestion are among the adverse effects emanating from the transportation sector. Recognition of these effects is propelling efforts in many countries to implement programs designed to reduce motor vehicle pollution. The Government of Hungary (GOH) currently is considering a proposal, the Auto Fuel Charge (AFC), consisting of an environmental product fee assessed on leaded fuel sales. Revenues from the AFC, estimated at between $18 to $46 million per year depending on the legislative outcome, will fund a number of programs designed to reduce environmental damages caused by vehicles.

1.1 PURPOSE OF THE STUDY

Hungary's Ministry of Environment and Regional Planning (MERP) along with the U.S. Agency for International Development (U.S. AID) have sponsored this research to assess the environmental and economic effectiveness of the expenditure-side programs contained in the AFC proposal for mitigating emissions from mobile sources in Hungary. The goal of the study is to provide decision makers with an economic analysis of the costs and benefits of emission reduction options as specified in the AFC proposal in order to assist them in their decision-making process. These analyses are intended to help design specific programs so that they are economically efficient, and to evaluate whether some of the programs deserve greater levels of expenditure than others. Accordingly, this research provides a preliminary assessment of the potential magnitude of the benefits and cost-effectiveness of various program options under consideration by the GOH.

The research and analysis that has been completed draws on participation and information from many different organizations within Hungary as well as U.S. AID technical assistance. The study focuses exclusively on those options that mitigate air pollution impacts from mobile sources. While the adverse effects of urban congestion were taken into consideration, the empirical analysis is limited to the impacts of programmatic actions on traffic flows and consequent emissions performance levels. Other impacts, such as changes in the opportunity costs of time spent in travel, or options aimed at other adverse effects such as waste products (e.g., used oils, tires, etc.), were not included in this analysis.

1.2 OUTLINE OF THE REPORT

The report is organized as follows. Chapter 2 provides background information on mobile source air pollution in Hungary, including an overview of transportation-related air pollution and its economic damages in Hungary. Chapter 3 discusses fundamental issues in developing a comprehensive mobile source emission control policy, and the various AFC policy options

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are described. Chapter 4 delves into the methodology of benefit-cost analysis and cost-effectiveness techniques, and the data used to perform the analysis. An overview of the study's findings, results of the analysis for specific policy options, and recommendations are presented in Chapter 5. Finally, the implications of the study's findings for policy and future analytic work are outlined in Chapter 6. An appendix is included that provides output from the "HUNFLEET" spreadsheet model developed for and applied in the analyses.

2.0 MOBILE SOURCE AIR POLLUTION ISSUES IN HUNGARY

2.1 INTRODUCTION

Discussion of mobile source air pollution in Hungary focuses largely on Budapest for a number of reasons. Much of the available detailed information regarding vehicle fleets and performance, as well as air quality data, is provided for Budapest. Budapest's role as the hub in both national and international highway systems make its transportation problems transcend local and regional dimensions. In addition, the analysis is conducted in such a way that it can readily be extrapolated to other urban areas where the primary incidence of air pollution damages are incurred. Thus, the analysis is based on data profiles gathered for Budapest.

Section 2.2 describes Hungary's air pollution problem in terms of emission levels, ambient concentrations, and the exceeding of standards. Section 2.3 details the role of transport in the problem. And Section 2.4 looks at the magnitude of Hungary's problem as defined by damage estimates and other evidence.

2.2 EMISSION LEVELS, AMBIENT CONCENTRATIONS, AND EXCEEDING OF STANDARDS

Ambient air quality in Budapest is measured through a system containing 36 gas pollution gauging stations, 51 precipitation dust gauging stations, and 8 monitoring stations. Within the municipality of Budapest there are three different air quality zones including those with high priority (forests and green territories), Level I (predominantly urban areas), and Level II (industrial territories dispersed throughout the urban territories due to the surrounding growth of the city through time).

Ambient air quality concentrations in Budapest exceed international standards for nitrous oxides, lead, soot, and, occasionally, carbon monoxide, as shown in Table 2-1. Transportation is the dominant source of these air pollutants. Transport contributes to 57% of nitrogen oxides, 80% of lead, 81% of carbon monoxide, and 75% of hydrocarbons.

2.3 THE ROLE OF TRANSPORT IN HUNGARY'S AIR POLLUTION PROBLEM

National Level. While Hungary has relatively fewer vehicles per capita than Western European countries (150 versus 350 per 1,000 people), transportation has emerged as a significant contributor to air pollution for a number of reasons. The average age of Hungary's fleet of 1.9 million vehicles in 1990 was over 9 years old, as shown in the

Table 2-1
Air Pollutant Emissions, Air Quality, and Source Distribution in Budapest

Assessment & Source Contributor	CO	HC	NOx	Pb	SO2	formal-dehyde	Soot/ dust
Over Limit(1)	occasional	high	yes	yes	high	na(3)	yes
Transport (1987)	81%	75%	57%	80%	12%	na	na
Industry (1989)	14%	10%	34%	20%	38%	na	na
Residential (1990)	5%	15%	9%	na	50%	na	na
Total Emissions(2)	185	20	26.5	.15	24	-	-

Source: *Air Pollution in Budapest*, 1991, p. 2.

(1) Based on survey data assessing ambient air quality status relative to Budapest Air Quality Standards which substantially coincide with OECD, ISO and WHO standards.

(2) Emissions are provided in 10,000 tons per year.

(3) Data not available.

transportation profile provided in Table 2-2. Combined with more lenient vehicle emission standards for new vehicles, inspection programs requiring checkups only every two to three years that create substandard maintenance of vehicles, and a fleet of 2 stroke vehicles that constitutes 31% of the automobile population, the average emissions for Hungary's automobiles are relatively high. Furthermore, not only do the majority of Hungarian vehicles operate with leaded fuels, but the lead content of 0.3 grams per liter is twice that usually found in Western Europe (although, as of 1992, the lead content will be reduced to 0.15 grams per liter). In the case of diesel fuels, the sulphur content is 0.5 Wt.% compared to 0.3 Wt. % in the U.S.

Major pollutants of motor vehicles include carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HC) and other volatile organic compounds (VOCs), ozone (precursors: HC and NOx), lead (Pb), sulfur dioxide (SOx), particulate matter, and toxics (benzene, asbestos, aldehydes, and ketones). As shown in Table 2-3, in 1985, road traffic emissions' share of total national emissions reveals the central role of the transportation sector in contributing to air pollution.

Table 2–2
PROFILE OF HUNGARIAN TRANSPORTATION SECTOR

1990 Number	Cars	Buses	Motor Cycles	Trucks	Hvy Trks	Trailers	Total
Budapest	471,799	5,555	9,915	47,953	2,901	25,984	564,107
Urban Hungary	1,348,600	21,641	87,979	160,789	18,169	121,102	1,758,280
Total Hungary	1,944,553	26,121	168,817	224,048	38,397	204,725	2,606,661
Percent Private	98%	2%	96%	31%	2%	67%	88%
Percent Gas*	99%	40%	na	50%	0%	na	92%

Modal Distribution							
Budapest	84%	1%	2%	9%	1%	5%	100%
Urban Hungary	77%	1%	5%	9%	1%	7%	100%
Total Hungary	75%	1%	6%	9%	1%	8%	100%

Age Distribution of Private Cars	Pre 1970	1971–75	1976–80	1981–85	1986–90	Total	Avg Age
Budapest	3%	11%	21%	28%	37%	100%	8.21
Urban Hungary	4%	14%	23%	26%	33%	100%	8.88
Total Hungary	4%	14%	25%	26%	32%	100%	9.09
Percent 2 Stroke**	51%	30%	33%	34%	26%	31%	

* Gasoline versus diesel vehicles.

** Consists of Barkas, Trabants, and Wartburgs. 2 stroke production was suspended in 1989.

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Table 2-3
Estimated 1985 Annual Emissions of Road Transport

Pollutant	CO	HC	NOx	Lead	SO2
Emissions (Metric tons)	489,070	73,100	87,000	500	13,800
Percent Highway	32.1%	32.7%	74.4%	na	na
Percent Urban	67.9%	67.3%	25.6%	na	na
Road Traffic Pct. of National Emissions	37.9%	28%	22.5%	90.9%	na

Source: Meretei, 1989, p. 9.

Budapest

In Budapest, the percentage of 2 stroke autos is somewhat higher than the national average, at 36% of the car fleet. Two stroke cars account for 39% of total transportation emissions. The HC emission rates of 4 stroke vehicles are significantly better than those for 2 stroke vehicles. (However, while 4 strokes also perform a little better in CO emissions, they actually emit more grams of NOx per km than 2 strokes.)

There are 484 km of main roads and 4,228 km of all types of roads in Budapest. Traffic is estimated to operate at 110% of capacity (Mayor's Office). The high level of traffic makes it difficult to increase average urban speeds. Traffic congestion is severe at certain locations and times of day, leading to extensive idling and increasing vehicle emission rates per distance traveled. Improved traffic flow regimes can help address this problem. Over 500 traffic lights regulate Budapest's traffic with one Siemans traffic system connecting 200 crossings in the southeast-central section of the city. A new traffic light system connecting 80 lights is planned for the north part of Budapest with World Bank funding.

Budapest's role as a hub in the national and international highway systems compounds its air quality problems in terms of magnifying both its emissions burdens as well as in the difficulty in assigning cost responsibility for the infrastructure. Budapest's transportation funding is declining rapidly in real terms. In 1991, only 44% of Budapest's transportation budget was funded. In 1991, funding declined to 21% of the budget, or 1 billion forint.

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2.4 THE MAGNITUDE OF ENVIRONMENTAL DAMAGES CAUSED BY TRANSPORTATION RELATED AIR POLLUTION

To conduct a benefit-cost analysis, monetized estimates are needed of the level of damages caused by mobile source air pollution in Hungary. Benefits can then be proxied by estimates of the extent to which policies are expected to reduce damages.

Our investigation revealed that research efforts to determine the adverse impacts of air pollution in Budapest, as well as in Hungary as a whole, have recently been attempted. These studies, which provide the existing estimates of the environmental damages caused by transportation, fall into two categories -- primary research studies based on actual Hungarian experience, and secondary estimates extrapolated via benchmarks developed from the experience of other countries. For the benefit-cost analysis embodied in this report, we have relied primarily on primary research to the greatest possible extent.[1] However, because the reports and methodologies of these damage estimation research efforts were not available for our review within the timeframe of this project, the accuracy or reliability of the estimates is uncertain.

The categories of environmental damages caused by road transport air pollution that are relevant to this study are the adverse impacts of pollutants on:

1. Human health (e.g., pain and suffering, health care costs, lost productivity, mortality, etc.).

2. Flora (e.g., reduced yields of cultivated plants).

3. Soiling (e.g., loss of aesthetic values, increased cleaning costs, declines in property value, etc.); and

4. Buildings (e.g., costs of deterioration, protection).

The largest component of damages is attributed to human health risks.

Lower Bound Damage Estimate

According to estimates derived by KTI (for 1986), transport-caused damages amounted to 2850 M HUF for air pollution damages to: human health (1200 M HUF), flora (152 M

[1] Dr. Tibor Varkonyi's work appears to provide the basis for a number of different group's estimates of environmental damages based on research internal to Hungary rather than extrapolated from international experience.

HUF), soiling (248 M HUF) and buildings (1250 M HUF). Accounting for additional materials damages to buildings due to transport-related corrosion adds an additional 250 M HUF, yielding a total damage estimate from mobile source air emissions of 3100 M HUF (KTI, 1987; Fleischer, 1990).

The methods, data, and conceptual foundation of these damage estimates were not available for review, but discussions with participants in the original research indicate that health damages were based on the "cost of illness" (COI) approach that uses medical expenses, foregone earnings, and insurance payments to beneficiaries (in case of mortality) to value adverse impacts to health. As shown in the economics literature, the COI approach significantly understates the true value individuals placed on good health and longevity (i.e., the willingness to pay, WTP, to reduce the risk of illness or fatality).[2] In other words, the value of good health is greater than the cost of being ill. Accordingly, adjusting for this distinction, the health component of the KTI estimate is doubled to develop a revised estimate of 4300 M HUF (1986 price levels). Then, accounting for inflation from 1986 through 1991, the damage value reaches 8800 M HUF per year, Hungary-wide, in 1991 values).[3]

Because of limited emissions data, this benefit-cost study focusses on Budapest, where the air pollution damages are likely to predominate. In order to have a city-relevant damage figure, 50% of the state-wide damage estimate is attributed to Budapest (which is likely to be a conservative assumption for the share of national damages arising from emissions in Budapest). Thus, as a preliminary exercise, we adopt 4,400 M HUF (approximately $ 57 million) as the lower bound estimate of the annual level of damages caused to society due to vehicle fleet air emissions in Budapest.[4]

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[2] See Reichart, Cranor, Raucher and Zapponi (1991) for a discussion of valuing risk reductions to human health (see especially Chapter 7).

[3] This is based on 10% inflation for 1988 and 1989, and 30% for 1990 and 1991. No inflation adjustment is included for 1986 to 1987 (the results were first thought to be in 1987 prices rather than 1986 levels), therefore the current year estimate for 1991 may be understated.

[4] Although the current analysis is focussed on Budapest, the methodology can be extended to investigate the benefits and costs of mobile source emissions reduction policies in the rest of Hungary. And, if a disproportionate share of benefits accrue in Budapest, then some equity concerns may arise if the programs are funded by fuel charges levied on all Hungarians. In such a case, equity issues may be moderated if, for example, some AFC funds are directed towards worthy rural area infrastructure needs.

Moderate Damage Estimate

Some critiques of the KTI study that serves as the basis for our damage estimates claim that only one year's lost productivity is included in the damage estimates. Consequently, a moderate scenario was developed for the economic analysis of the benefits of avoiding transport-related air pollution damages in which the low scenario is adjusted to account for multiple (i.e., future) year impacts on human health. Absent verification regarding the omission of future year damages and the extent to which they would increase the damage estimates, we employ the value of 8,800 M HUF (i.e., a doubling of the lower bound damage value) to reflect a more moderate approximation of the damages caused by Budapest-originating road transport air pollution.

High Damage Estimate

In order to put the discussion of damage estimates as a result of transport-related air pollution in perspective, a comparison of the amount of damages as a percentage of gross domestic product (GDP) is provided here. For the lower bound damage estimate scenario developed above, Hungary-wide damages as a result of transport-related air pollution based on one year's loss is 8,800 million forint in 1991, with 4,400 million forint attributed to Budapest. This total for Hungary represents approximately 0.7% of GDP. For the moderate damage scenario, Hungary-wide damages due to transport-related air pollution are 17,600 million forint, or 8,800 forint for Budapest in 1991. The total for Hungary in the medium scenario represents approximately 1.4% of GDP.

If we examine benchmark international data to establish a perspective on transport-related air pollution damages as a percent of GDP, we find estimates ranging from 5 to 8%, which is considerably greater than the values portrayed above. For example, at the low end of this range, 5% of 1986 GDP would indicate damages on the order of 54,400 M HUF (1986 price levels), which in 1991 terms would be in excess of 100 billion HUF. Proponents of this type of benchmark approach in Hungary suggest that transport-related environmental damages are on this order.

In order to develop an upper bound damage value to use in this study, we adopt the GDP bench-marking approach, but apply it conservatively by netting out damages not strictly related to air pollution from road transport (i.e., netting out damages associated with noise, vibration, winter road salting, etc.). This implies a relevant upper-end damage estimate for Hungary of 34,000 M HUF (1986 values). When apportioned to Budapest emissions and updated to 1991 price levels, this results in "high" damage estimate of 34,800 M HUF per year for Budapest.

Conclusion

It is important to reiterate that the benefits (damages) estimates described above and used in this analysis are highly uncertain. Nonetheless, the use of these estimates in this preliminary assessment provides a useful benchmark, particularly as a wide range in damage levels are provided by the low, moderate and high estimates derived above. And, the benefit-cost assessment can easily be modified for sensitivity analyses if more robust or alternative damage measures are developed. Furthermore, even though the magnitude of the benefits estimated for any given policy option may be uncertain, the analytic approach will reveal the relative benefits of alternative policy options so that options can be effectively compared to one another.

3.0 HUNGARY'S TRANSPORTATION EMISSION CONTROL STRATEGY

3.1 INTRODUCTION

Strategies for air pollution abatement from the transportation sector range from stringent control over the number of vehicles and their use, to improvements in the efficiency of the overall transportation sector. Since the former type of approach has broader economic implications for the underlying infrastructure of a country, the strategies examined herein are limited to those that control emissions from vehicles and improve the transportation infrastructure.

A comprehensive strategy to combat transport-related air pollution can be framed in four key areas as follows:[1] 1) efficient and clean vehicles for both personal and public transportation; 2) clean fuels; 3) infrastructure and traffic management; and 4) a policy framework utilizing a variety of mechanisms to encourage the use of clean fuels and vehicles and to modify travel behavior.

Programs aimed at improving personal and public vehicles include increasing emissions standards for new vehicles, retrofitting pollution control technologies in used vehicles, and inspection and maintenance programs. Reducing the lead and sulphur content in gasoline and diesel is a primary target for improvement of a country's fuel stock, while reduction of aromatics and heavy oils in diesel and other octane boosting additives in gasoline as well as the substitution of clean fuels provide additional targets. Infrastructure and traffic management measures are aimed at improving traffic flows as well as optimizing the proportion of public versus personal vehicle use. Finally, a variety of policy measures can support any of the above objectives. Such policy measures may include adjustments in import tariffs to the advantage of clean vehicles, sales tax adjustments that alter relative prices and thereby create incentives for consumers in favor of clean fuels, and so forth.

In the remainder of this section we review Hungary's transport-related air pollution measures in the framework delineated above. A summary is provided of existing and planned transport-related programs in Hungary, as well as an overview of the proposed Automotive Fuel Charge (AFC) program.

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[1] The characterization of strategies is informed by The World Bank's working paper by Asif Faiz, et al, entitled Automotive Air Pollution: Issues and Options for Developing Countries, WPS 492, August 1990, page xii-xv.

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3.2 EXISTING MEASURES TO REDUCE TRANSPORT-RELATED POLLUTION

Hungary has already taken significant steps on the road to a comprehensive transportation air pollution strategy. Existing and planned measures are described below that reveal a balanced approach across the four key areas described above. Following are highlights of key aspects of existing and planned legislation, regulations and activities that will impact transportation-related air pollution in Hungary.

Clean Vehicles:

- **New Vehicles** -- Many new vehicles in Hungary are nominally subject to ECE emission control regulations, however, enforcement is low at this time. [2]

- **Used Vehicles** -- Commencing in January 1992, the emissions performance of all two stroke vehicles that provide transportation services (e.g., taxis) is required to meet the standards achieved by a two stroke car retrofitted with a catalytic converter.

- **Inspection and Maintenance Programs** -- Nominal inspection and maintenance program are in force with testing for excessive smoke and carbon monoxide required every 2 to 3 years.

- **Inspection and Maintenance Programs** -- An *annual* inspection and maintenance program will take effect in May, 1992 to control CO emissions performance, and in May 1993 to control HC emissions performance to comply with manufacturers standards.

Clean Fuels:

- **Leaded Gasoline** -- National standards for the maximum lead content in gasoline will decrease from 0.4 gr/l to 0.15 gr/l in 1992. The actual level of lead is currently 0.3 gr/l, therefore lead-content will decline by 50%.

- **Diesel** -- SO2 content will be reduced 20 to 25% in diesel fuels commencing mid 1992.

[2] For passenger cars ECE regulation R15-04 is in effect. For diesel trucks and buses ECE R 24 regulates smoke, however, the effectiveness of the measure is limited due to he installation of undersized engines. And finally, in January 1992, ECE regulations R-49-02 will limit HC, CO, and NOx emissions from diesel truck and bus engines.

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- **Fuel Plans** -- Plans are underway to provide sufficient leaded and unleaded fuels to satisfy the changes required by the AFC program. Stations now use 3 or 4 pumps to offer 86 octane leaded (including lubricants, for 2-stroke vehicles), 92 octane leaded and unleaded auto fuel, and 98 octane leaded. Plans are being formulated to replace 86 leaded with 95 octane unleaded, while continuing to offer 92 leaded and 98 leaded. Consequently, no new pumps and concomitant investment costs will be required. Since the fuel supply is limited, enough 95 octane unleaded fuel cannot be supplied for both the 2 and 4 stroke fleet. Therefore, 2 strokes will use 92 plus oil additives. The same price for unleaded and leaded fuels will be charged.[3]

Infrastructure and Traffic Management:

- **Network Planning** -- Hungary's Institute for Transport Sciences uses a comprehensive multi-criterion evaluation framework [4] for network planning that includes time costs, vehicle operating and maintenance costs, traffic safety, air pollution, noise pollution, infrastructure maintenance costs, land-use costs and accident costs. The relative importance placed on any one of these factors in the investment decision is largely subjective. The World Bank does not include either time costs or environmental costs in the investment criterion they consider for Hungary.

- **Infrastructure** -- Modifications to Hungary's transportation infrastructure system are proceeding, hampered by the limited availability of funds. A comprehensive assessment was not conducted at this stage of the study. Noteworthy, however, is the planned completion of the southwest section of the Ring Road around Budapest in approximately two years.

- **Traffic Management** -- A comprehensive system assessment was not conducted at this stage. Noteworthy, however, is the planned addition of a traffic flow control system in northeast Budapest with funding assistance by the World Bank.

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[3] The plans for the fuel distribution system as well as fuel production was provided by Mr. Szommers (MERP/GOH, December 1991). Planned fuel production in Hungary is set at 500 tons total. This is composed of 180 tons of unleaded 95 for 4 strokes. This leaves 320 tons of unleaded 95 which is insufficient to cover the 2 stroke fleet, therefore octane levels will be reduced to provide 450 tons of 92 octane fuel for 2 stroke vehicles.

[4] Reviewed in discussion with Dr. Atilla Voros, Head of the Division for Network Planning and Traffic Engineering, December 1991.

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Supporting Policy Framework:

- **Catalytic Converter Measures** -- A combination of no consumption taxes on catalytic converters as well as lower vehicle taxes on vehicles with catalysts are intended to yield price parity between cars with or without catalysts.

- **Import Control Measures** -- A variety of import control measures will restrict imported vehicles to those with valid emissions stickers for 6 months, will restrict imports to cars with catalysts beginning in 1993, and will potentially (this measure is currently in negotiation stages) restrict imports to vehicles less than 7 or 8 years old.[5]

3.3 PROPOSED MEASURES CONTAINED IN THE AUTO FUEL CHARGE

The Government of Hungary is currently considering an Auto Fuel Charge (AFC) proposal to raise revenues that will be used to finance programs designed to mitigate air pollution emissions from mobile sources. Hungary's transportation emissions control strategy could be significantly enhanced by the programs contained in the Auto Fuel Charge proposal, depending on the economic and environmental effectiveness of any particular program. In this section we will provide an overview of the program options contained in the AFC proposal, as well as address those that were analyzed as a part of this study.

The objective of the Auto Fuel Charge is "to eliminate the environmental damages caused by vehicles and accumulate the financial resources required to prevent damages to be caused to the environment and motivate activities aimed at reducing environmental pollution" (Legislation of 30 September 1991). Revenues (from $18 to $46 million per year, depending on the legislative outcome) will accrue via an environmental product fee assessed on leaded fuels sold.

The revenues generated by the AFC environmental product fee are aimed at technical improvements for both individual vehicles and public transport, the development of infrastructure, and to finance supplementary activities needed for the operation of a responsive system including informational materials, subsidies to relevant social organizations, and administration. The mechanism for distribution of funds for technical measures is likely to be extending credit under favorable terms and/or refunding lost revenues. Support for infrastructure projects shall be limited and designed to mobilize local resources and create a multiplicative effect to the funds generated through the environmental product fee.

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[5] This overview was obtained in an interview in December 1991 with Mr. Szommers (MERP/GOH).

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The program options included in the AFC proposal are numerous and are specified in varying degrees of detail. The various program options are summarized in Table 3-1 and are clustered according to the categories for a transportation emissions control strategy described above. The proposed funding level as set forth in the draft legislation of 30 September 1991.

Table 3-1
The Auto Fuel Charge Program Options

Program Option	Funds (M Ft)	Pct of Total
Clean Personal Vehicles		
2 Stroke Cars	3,000	25%
4 Stroke Cars	600	5%
Clean Public Vehicles		
Bus Fleet	800	6.7%
Trams & Trolleys	900	7.5%
Alternative (CNG) Fuel Vehicles	700	5.8%
Infrastructure - Urban	2,000	16.7%
- Miscellaneous	600	5%
Other - Waste	400	3.3%
- Noise	600	5%
- Miscellaneous	1,000	8.3%
- Lead Free Credit	1,400	11.7%
Total Program	12,000	100%

Half of the AFC program funds are targeted to technical investments designed to improve the emissions performance of both personal and public vehicles. Personal vehicle programs

garner 30% of the environmental product fee while programs aimed at public vehicles constitute another 20% of fund revenues. Approximately 22% of program funds are targeted for infrastructure improvements that may reduce transport-related air pollution. The remaining 28% of the funds generated by the environmental product fee are targeted for programs that will mitigate environmental impacts other than air pollution, such as waste management programs for disposal and recycling of used vehicle parts, noise abatement through infrastructure investments, education and advertising. Many of the technical measures (e.g., retrofitting catalytic converters onto autos), plus the change in relative fuel prices imposed by the AFC (taxing leaded fuels), will result in an increased demand for unleaded fuels, with the preferential tax treatment of unleaded fuels resulting in foregone AFC revenues (labeled as a "lead free credit") totaling 1,400 million forint.

This report is focused on determining the environmental and economic implications of the programs that directly mitigate air pollution emissions. These programs are specified in more detail in Table 3-2, along with their anticipated level of funding, the number of units targeted for improvements, the amount of subsidy that the program option will provide, and indication of whether a detailed cost-benefit analysis of the program was conducted as a part of this study (see Chapter 5).

For the programs in Table 3-2 that were analyzed, the draft legislation for the AFC provided a varying amounts of guidelines regarding the nature of the program. In some instances, either more time or more data (e.g., two stroke vehicle retirement, public transport - trams/trolleys) was required to complete an analysis of a particular program. In other cases, we developed program parameters sufficient to analyze a viable option (e.g., CNG buses were used for the Alternative Fuels option, traffic flow assumptions were tested for the Roads and Repaving and/or Traffic Control systems options).

The AFC fund will subsidize the program options to varying degrees. The percent subsidy was determined based on the amount available per unit provided for by the AFC fund as a percent of the current costs of the measure called for. None of the program options subsidize the full technical investment. Whether a program option will actually be implemented depends on the willingness and ability of the target population to act in the specified manner, as well as the ability to back up the program option with supporting laws and enforcement practices. Many of the policies described in Section 3.2 will motivate target populations to implement the technical changes in the AFC programs in spite of the less than 100% subsidy. For instance, the new Inspection & Maintenance policy effective in May 1992 will create additional incentives for the automotive vehicle options. As well, the requirement for taxis to achieve the emissions performance levels of two stroke vehicles retrofitted with catalytic converters may be incented with the two stroke subsidy, if that program's guidelines are drawn up such that they may be recipients of that subsidy.

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Table 3-2
AFC Air Pollution Programs

AFC Program Option	Funds (M Ft)	No. of Units	Percent Subsidy	Analyzed
Two Stroke Autos				
Catalytic Converters	1,800	140,000	51%	yes
New Engines	700	10,000	35%	yes
Retirement	500	15,000	na	no
Four Stroke Autos				
Catalytic Converters	600	45,000	53%	yes
Bus Fleet				
Fuel Additives, I&M	300	5,000	na	no
Turbochargers	250	2,500	42 to 125%	yes
Up-to-date Engines	250	400	44%	yes
Public Transport				
New Trams/Trolleys	400	50	na	no
Fare Subsidies (trips)	500	23x10=6	100%+	no
Alternative Fuels				
Natural Gas/Bio-Fuels	700	na	na	yes
Infrastructure				
Roads & Repaving	1,300	170 km	17%	yes
Park'n'Ride (spaces)	400	6,000	10%	yes
Traffic Controls (systems)	300	5 to 6	na	no
Other	600	na	na	na

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The decision regarding the appropriateness of the AFC program options depends on a host of factors including the economic efficiency of the options in meeting environmental objectives, the ability and willingness of the public to pay, political and territorial issues. The methods and results of the economic analysis of the AFC programs are provided in the two chapters that follow.

4.0 METHODOLOGY

4.1 INTRODUCTION

A series of programs designed to reduce air pollution emissions from mobile sources are envisioned as possible uses of the revenues generated from the proposed Auto Fuel Charge (AFC). The purpose of this report is to help evaluate these expenditure program options, using benefit-cost (BC) and cost-effectiveness (CE) techniques. These analyses are intended to help design the specific programs so that they are economically efficient, and to evaluate whether some of the programs deserve greater levels of expenditure than others.

This chapter lays out the methodologies used to assess the various program options under consideration. Section 4.2 gives a general description of the merits and logic of BC analysis and CE approaches. The weighted CE approach is described in Section 4.3. Section 4.4 presents the weighting scheme for the CE approach, and Section 4.5 develops a "damages per hazard unit" concept for measuring benefits. A sample application of these methodologies to specific program options is presented in Section 4.6. Finally, Section 4.7 discusses the strengths and limitations of the methodology.

4.2 OVERVIEW OF BENEFIT-COST ANALYSIS AND COST-EFFECTIVENESS APPROACHES

BC analysis and CE techniques are used to assess the potential magnitude of the benefits and the cost-effectiveness of the various program options under consideration.

Benefit-cost analysis refers to estimating the benefits of a policy option, and subtracting its costs to derive net social benefits. According to the economic objective of maximizing social well-being, projects should be selected that generate the greatest expected present value of net benefits. In other words, those policies that generate the largest present value benefits in excess of present value costs are the most preferred from a social welfare maximization perspective.

While the theory underlying the benefit-cost criterion is widely understood and well accepted, in practice it is very difficult to conduct comprehensive benefit-cost analyses, particularly for environmental programs. These difficulties typically arise with respect to estimating the benefits. Estimating the benefits involves: (1) identifying the desirable outcomes of the policy (e.g., reduced risk to human health); (2) quantifying these outcomes (e.g., the estimated reduction in the number of individuals suffering from respiratory disease), and (3) assigning monetary values to these outcomes, to the extent feasible (e.g., society's willingness to pay to reduce the expected number of respiratory disease cases). To accomplish these three steps, a complex chain of causal links must be understood. For

example, to estimate the benefits of a policy to retrofit catalytic converters onto automobiles, the expected reduction in auto pollutant emissions must be estimated, then the change in ambient air quality estimated, then the reduction in estimated health risk must be projected, and so forth.

Because benefits estimation is extremely difficult, especially given appreciable data gaps, the simpler approach of cost-effectiveness analysis often is used to evaluate polices. In its simplest and most common form, a CE analysis will consist of dividing the cost of a program into the estimated mass of pollutant emissions reduced (e.g., obtaining the dollar expenditure per ton of air pollutants controlled). Programs can then be ranked, with priority assigned to those that yield the greatest pollutant removals per monetary expenditure.

While cost-effectiveness analysis typically is more feasible than BCA, it is of very limited informative value if it is pursued for each pollutant individually, with the results expressed as the cost per ton of emissions reduced per individual pollutant. This simple type of CE analysis is of limited value because different types of vehicles emit different levels and mixes of pollutants, and because each pollutant is in turn associated with its own set of damages (i.e., the types and levels of benefits obtained per ton of emission reduced).

4.3 THE POLLUTANT-WEIGHTED COST-EFFECTIVENESS APPROACH

A potential analytic approach that strikes a balance between a complete BC analysis and simple CE analysis is to develop a weighting scheme that will allow for a meaningful aggregation of the various pollutants of relevance. This approach is referred to as a "toxicity weighted" cost effectiveness analysis whereby the mass of each pollutant removed is multiplied by a factor that reflects its environmental toxicity relative to other pollutants. This approach enables the CE analysis to aggregate the pollutants and thus account for a number of different types of pollutants. This in turn facilitates comparisons across programs that affect different segments of the vehicle fleet (i.e., that reduce emissions of different types of pollutants).

The results of a toxicity weighted CE analysis are presented in terms of "cost per *hazard unit*" removed rather than cost per ton of each pollutant individually. This is a much more useful result than the simple CE can generate because: (1) it reflects the level of benefits associated with pollutant reductions (i.e., it is a quasi benefit-cost analysis rather than a simple CE analysis) and, (2) by incorporating benefits-based weights, it converts different pollutants to a common unit of measurement that can be aggregated.

For example, suppose a policy option reduced emissions of NOX by 2 tons and CO by 1 ton. If an alternate program of equal cost reduced NOX by 1 ton and CO by 2 tons, then which program should be selected? Because both options remove the same total of 3 tons of

pollutants, a simple CE analysis would not be able to distinguish which option was preferred. However, if a weighting scheme indicated that reducing NOX was three times more important than reducing CO (i.e., the benefits of reducing NOX emissions by one ton were thought to be three times greater than the benefits associated with reducing a ton of CO), then the first program can be credited with removing 7 "hazard-weighted" tons (3*2 + 1*1), while the second program removes only 5 (3*1 + 1*2). Thus, the application of toxicity weights allows the analysis to indicate which option is more cost-effective at improving the environment.

A practical example of how the toxicity weighted CE approach is used can be found in how the US EPA evaluates its programs for limiting pollutant concentrations in industrial wastewater. Pollutants are assigned weights according to their toxicity to aquatic organisms, with copper used as the numeraire (if a pollutant is lethal to fish at half the concentration that copper is, then one pound is weighted as two "toxicity-weighted pounds" whereas one pound of copper is one toxicity-weighted pound). The development of this weighting scheme is facilitated through the use of established scientific threshold values for the lethal doses of the various pollutants.

4.4 DEVELOPING A WEIGHTING SCHEME FOR THE COST-EFFECTIVENESS APPROACH

As mentioned in Section 4.3, one analytic approach that strikes a balance between a complete BC analysis and simple CE analysis is to develop a weighting scheme that will allow for a meaningful aggregation of the various pollutants of relevance. This "toxicity weighted" approach to CE analysis multiplies the mass of each pollutant removed by a factor reflecting its environmental toxicity relative to other pollutants, thereby enabling the CE analysis to aggregate the pollutants and thus account for a number of different types of pollutants. As a result, comparisons across programs that affect different segments of the vehicle fleet (i.e., that reduce emissions of different types of pollutants), is facilitated.

For mobile source air pollutants, developing toxicity weights presents some difficulties. This is because pollutants are associated with multiple damages, including: (1) human health effects (e.g., respiratory disease), (2) impaired visibility and aesthetics, (3) materials damages (soiling or deterioration of buildings, statues, etc.), and (4) ecologic impacts (e.g., acid deposition lowers the pH of streams and lakes, and is damaging to crops, forests, and wildlife).

Developing Weights Based on Health Risks

Even where the focus is solely on human health effects, there are challenges associated with accounting for different types of health risks (e.g., mortality v. morbidity) and the type of

dose-response function (especially if thresholds are applicable, as is typically the case for noncarcinogenic risks, because thresholds require explicit conside.ation of baseline and post-policy pollutant concentrations and levels of exposure).

To fashion a rough but useful index of toxicity weights for evaluating the pollutant emission reductions attributable to potential AFC-funded transportation sector policies, the following approach was used: Each pollutant is evaluated in terms of its likely toxicity for human health, with the rankings developed according to US-based National Ambient Air Quality Standards (NAAQS) for the applicable pollutants. The "Primary" standards were used as these reflect "the level of air quality necessary, with an adequate margin of safety to protect the public health" (California Air Resources Board (CARB), ARB Fact Sheet 38, 1986). Comparable Hungarian national ambient air quality standards were also used, and as shown below, the results are highly similar.

The NAAQS used for the pollutants are based on annual average standards (rather than shorter duration standards, such as 1 hour or 24 hour standards) since our analysis does not account for short-term peaks in emissions and air quality measurements. Given the basis for how these standards are developed, weights can be devised on the logical premise that the lower the standard (in terms of μ/m3), the proportionately greater the health risk.

US NAAQS are shown in Table 4-1, along with the implied relative hazard weights using SO2 as numeraire; i.e., the weights are equal to the SO2 NAAQS divided by the other pollutants' NAAQS. Thus, for example, the hazard weight for hydrocarbons is equal to 80/60 = 1.3. With this formulation, it is irrelevant which pollutant serves as numeraire because the relative weight of each pollutant with respect to the others is constant.[1]

[1] The numeraire is selected only as a matter of convenience. SO2 is used here simply because it is in the middle of the NAAQS distribution, thereby allowing the weights to make it more obvious which pollutants are of above median hazard (weights > 1) or below the median hazard (weights < 1).

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Table 4-1 US NAAQS, and Health Effects-Based Relative Weights		
Pollutant	NAAQS	Hazard Weight
Carbon Monoxide (CO)	2000[2]	0.04
Hydrocarbons (HC = PM10)	60	1.3
Nitrogen oxides (NO2)	100	0.8
Lead (Pb)	1.5[3]	53.3
Sulfur Dioxide (SO2)	80	1.0
Soot (PM10)	60	1.3

In Table 4-2, a comparable index is created based on the Hungarian ambient air quality standards for "Category I Protected Areas" (typical residential/non-industrial areas):

Table 4-2 Hungarian NAAQS, and Implied Hazard Weights		
Pollutant	NAAQS	Hazard Weight
Carbon Monoxide (CO)	2000	0.04
Hydrocarbons (HC = PM10)	60	1.4
Nitrogen oxides (NOX)	100	0.7
Lead (Pb)	0.3[4]	233.3
Sulfur Dioxide (SO2)	70	1.0
Soot (apart from PM above)	25	2.8

[2] There is no annual average standard for CO, so it has been extrapolated from the eight hour standard (10,000 µg/m3) based on the relationship between the daily average standards and annual standards for SO2 and PM10.

[3] Based on the 120 day standard as no standard has been established on an annual basis.

[4] The lead standard is a 30 day average as there is no stated annual average standard. For other pollutants, the Hungarian annual average standards are typically half to two-thirds the 30 day standard (which would imply a hazard weight of half to two thirds the level shown in Table 4-2). The Hungarian 30 day and annual standards are equivalent for some pollutants, however, so no adjustment is made here to the 30 day lead standard.

As can be seen by reviewing the hazard weights shown in Tables 4-1 and 4-2, there is a comparable weighting scheme derived from use of either the US or Hungarian standards. In both cases, lead is the most toxic pollutant by far (for a given mass of the pollutant in a cubic meter of air). Likewise, CO is the least toxic per ton. The remaining pollutants are relatively equivalent. One key difference is the "soot" category, which in the US assessment is considered part of PM10 (along with HC), but which is reported as a separate category in Hungary. Thus, an important issue to resolve is to clearly define what is included in the "soot" category, and to thereby determine if it should be weighted as PM10 or based on a more specific list of constituents. Because the "soot" category appears to include a broader range of harmful pollutants than PM10, the Hungarian weight is adopted for this analysis.

Accounting for Damages other than Risks to Human Health

It is important to consider that the weights described above are based on avoiding adverse human health effects. Several of these pollutants deserve additional consideration because of their association with important nonhealth effects such as materials damage and soiling, visibility impairments, and ecologic concerns. In particular:

- PM10 (HC and soot) is important because of its soiling and other materials damages, impaired visibility, and contributions (in conjunction with NOX) to ozone formation.

- NOX emissions (along with the HC component of PM10) result in ozone formation that in turn has adverse effects on crops, forests and other vegetative resources, and also imposes materials damages.

- SO2, and resulting acidics, are associated with visibility impairment, ecologic damages to aquatic and plant life, and materials damages.

In contrast, lead and CO are not strongly associated with non-health effects. Thus, if the hazard weights illustrated in Tables 4-1 and 4-2 are to be adjusted to reflect environmental concerns beyond human health, then a simple approach adopted here is to reduce the weights assigned to lead and CO. Given that a predominant concern is reducing risks to health, however, it is suggested that the weights not be adjusted dramatically.

Accordingly, the following adjustments are made to account for ecologic and welfare concerns apart from human health: (1) the hazard weight applied to lead emissions is based on the US standard, resulting in a lower weight than would be obtained from use of the Hungarian standards (53.3 rather than 233.3); and (2) no adjustment is made to the CO weight as it is already given an extremely low weight (0.04) relative to the other pollutants evaluated.

Conclusions

It is important to recognize that the toxic weights presented here are somewhat subjective. Although the US-derived weights are based upon national air quality standards that reflect peer reviewed scientific assessments for human health protection, they are established in a federal policy setting that may embody more than science, or that may incorporate informed professional judgement in a different manner for different pollutants (as the standards are not set simultaneously).

Nonetheless, these weighting schemes provide a useful starting point for the analyses and are illustrative of how such indices can be developed and applied to enlighten policy-making. In the long run, more robust analysis may be desired to formulate more reliable weights. And, particularly where the weights assigned here have a definitive impact on the evaluation and ranking of specific policy options, sensitivity analyses should be used to reveal the extent to which the weights dictate the final analytic outcomes, rankings and policy conclusions.

4.5 MEASURING BENEFITS AS DAMAGES PER HAZARD UNIT

In progressing from emissions reductions to estimates of benefits, the basic approach utilized here involves weighting emissions estimates by assigning "hazard units" as described in Section 4.4 above to reflect the relative damage they are likely to cause. Thus, emissions estimates for different pollutants, from different components of the vehicle fleet, are assigned "hazard units" in order to enable development of a single, unified hazard weighted measure of emissions.[5]

Emissions and "Hazard Units"

Emissions data were obtained from "Air Pollution in Budapest" and reflect KTI estimates for autos, busses and trucks for Budapest in 1987.[6] The emissions of different types of pollutants (HC, CO, Pb, NOX, SO2, soot) were weighted and then aggregated according to their relative risks to health, as reflected in ambient air quality standards (as described above).

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[5] To perform the analysis, a spreadsheet model named HUNFLEET, embodying several data components, was developed and utilized. This model, which can also be used to conduct sensitivity analyses, or tailored to evaluate other policy options, is described in the Appendix.

[6] The KTI estimates are derived from a detailed trip generation model of road use and emissions patterns, accounting for three fourths of road traffic emissions in Budapest. Because of the manner in which the emissions data are used in this study, being normalized by hazard weights, the emissions do not need to be pro-rated up to Budapest-wide levels.

The results are shown in Table 4-3, which indicates, for example, that over 44% of the "hazard units" emitted from vehicles consists of hydrocarbons (HC) from autos. Also indicated is that although busses account for only 2.5% of emissions, the composition of these emissions is such that busses account for 5.2% of the "hazard units" emitted from vehicle traffic. Trucks also create a share of hazard units (25.9%) that is disproportionately larger than the mass of their total emissions (17.9% of the total).

Damages and Benefits

The "hazard units" can be used to conduct informative cost-effectiveness analyses. But in order to provide a measure of benefits which to compare to program costs, one additional step was pursued. This step converts "hazard units" into a monetary measure of damages. This is accomplished through the use of estimates of the social damages attributed to the transport sector, as described previously in Chapter 2.

To estimate the benefits of pollution reduction policies, a linear damage function is assumed. This implies that benefits (damages avoided) can be estimated as directly proportional to the percent reduction achieved from the baseline hazard units emitted. For the purposes of this discussion of methodology, we use 4,400 M HUF (approximately $57 million) adopted as the lower bound estimate of the annual level of damages caused to society due to vehicle fleet air emissions in Budapest.[7] Thus, the total lower bound damages attributed, at baseline, for the various pollutants, by vehicle class, are shown in the righthand columns of Table 4-4. For example, the benefits of policies that reduce emissions of auto HC by 30% can thus be evaluated as a 30% reduction in damages (i.e., lower bound benefits are 584 M HUF, i.e., 30% of 1,948 M HUF).

Finally, it is important to reiterate that the benefits (damages) estimates are highly uncertain. Nonetheless, the use of these estimates in this preliminary assessment provides a useful benchmark. And, the benefit-cost assessment can easily be modified for sensitivity analyses if more robust or alternative damage measures are developed. Furthermore, even though the magnitude of the benefits estimated for any given policy option may be uncertain, the analytic approach will reveal the relative benefits of alternative policy options (so that options can be effectively compared to one another).

[7] Although the current analysis is focussed on Budapest, the methodology can be extended to investigate the benefits and costs of mobile source emissions reduction policies in the rest of Hungary. And, if a disproportionate share of benefits accrue in Budapest, then some equity concerns may arise if the programs are funded by fuel charges levied on all Hungarians. In such a case, equity issues may be moderated if, for example, some AFC funds are directed towards worthy rural area infrastructure needs.

TABLE 4–3
EMISSIONS AND HAZARD UNITS FROM BUDAPEST ROAD VEHICLES (1987)

AUTOS ONLY (Budapest)

Pollutant	Weight	Tons/yr (1987)	Haz Units (HU)	% Fleet HU
CO	0.04	92159	3686	9.6%
HC	1.3	13084	17009	44.3%
NOX	0.8	3286	2629	6.8%
Lead	53.3	56	2985	7.8%
SO2	1	151	151	0.4%
Soot	2.8	0	0	0.0%
TOTAL		108736	26460	68.9%
(percent)		79.7%	68.9%	

BUSSES ONLY (Budapest)

Pollutant	Weight	Tons/yr (1987)	Haz Units (HU)	% Fleet HU
CO	0.04	1618	65	0.2%
HC	1.3	91	118	0.3%
NOX	0.8	1232	986	2.6%
Lead	53.3	0.8	43	0.1%
SO2	1	228	228	0.6%
Soot	2.8	197	552	1.4%
TOTAL		3366.8	1991	5.2%
(percent)		2.5%	5.2%	

TRUCKS (Budapest)

Pollutant	Weight	Tons/yr (1987)	Haz Units (HU)	% Fleet HU
CO	0.04	17727	709	1.8%
HC	1.3	822	1069	2.8%
NOX	0.8	3194	2555	6.7%
Lead	53.3	10	533	1.4%
SO2	1	1284	1284	3.3%
Soot	2.8	1361	3811	9.9%
TOTAL		24398	9961	25.9%
(percent)		17.9%	25.9%	

GRAND TOTAL	136501	38412	100.0%

Source: Emissions data from KTI, Hazard units from RCG Analysis

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TABLE 4–4
DAMAGES ATTRIBUTED TO BUDAPEST ROAD VEHICLES*

AUTOS ONLY (Budapest)

Pollutant	Weight	Tons/yr (1987)	Haz Units (HU)	% Fleet HU	Damages Caused/Yr (M HUF)	(M US$)
CO	0.04	92159	3686	9.6%	422.3	$5.6
HC	1.3	13084	17009	44.3%	1948.4	$25.6
NOX	0.8	3286	2629	6.8%	301.1	$4.0
Lead	53.3	56	2985	7.8%	341.9	$4.5
SO2	1	151	151	0.4%	17.3	$0.2
Soot	2.8	0	0	0.0%	0.0	$0.0
TOTAL		108736	26460	68.9%	3031.0	$39.8
(percent)		79.7%	68.9%			

BUSSES ONLY (Budapest)

Pollutant	Weight	Tons/yr (1987)	Haz Units (HU)	% Fleet HU	Damages Caused/Yr (M HUF)	(M US$)
CO	0.04	1618	65	0.2%	7.4	$0.1
HC	1.3	91	118	0.3%	13.6	$0.2
NOX	0.8	1232	986	2.6%	112.9	$1.5
Lead	53.3	0.8	43	0.1%	4.9	$0.1
SO2	1	228	228	0.6%	26.1	$0.3
Soot	2.8	197	552	1.4%	63.2	$0.8
TOTAL		3366.8	1991	5.2%	228.0	$3.0
(percent)		2.5%	5.2%			

TRUCKS (Budapest)

Pollutant	Weight	Tons/yr (1987)	Haz Units (HU)	% Fleet HU	Damages Caused/Yr (M HUF)	(M US$)
CO	0.04	17727	709	1.8%	81.2	$1.1
HC	1.3	822	1069	2.8%	122.4	$1.6
NOX	0.8	3194	2555	6.7%	292.7	$3.8
Lead	53.3	10	533	1.4%	61.1	$0.8
SO2	1	1284	1284	3.3%	147.1	$1.9
Soot	2.8	1361	3811	9.9%	436.5	$5.7
TOTAL		24398	9961	25.9%	1141.0	$15.0
(percent)		17.9%	25.9%			

GRAND TOTAL	136501	38412		4400	$57.8

* Based on lowerbound damage estimates of 4.4 Billion HUF per year

4.6 SAMPLE APPLICATION TO PROGRAM OPTIONS

The logic and data described in the above sections has been used to analyze the benefits and costs of some of the policy options under discussion for use of AFC revenues. The following example illustrates their application specific program options, specifically, the retrofitting of 2 stroke cars with catalytic converters, and the retrofitting of 4 stroke cars with catalysts, and the retrofitting of 2 stroke engines with 4 stroke engines. The example draws on the emissions data, assignment of "hazard units", and damage estimates detailed in Section 4.5.

Allocating Auto Emissions Among 2 and 4 Cycle Cars

The auto emissions shown in Tables 4-3 and 4-4 are not differentiated by type of vehicle. In order to evaluate policies that are targeted to components of the auto fleet, baseline emissions and damages are separated for 2 and 4 cycle engine cars. The allocations are based on three factors:

1. The percentage of the fleet that is 2 cycle (36.2%, Tamas Meretei, KTI, personal communication);

2. The emissions rates for 2 and 4 cycle cars, under alternative operating modes (urban speeds and idling, and at 80 km/hr); and

3. The percent of average vehicle use at each running mode (e.g., 80% urban, 20% at constant higher speed mode).

Based on the ratio of emissions from 2 cycled engines to 4 cycled ones, as weighted across running modes, the total auto emissions can mathematically be disaggregated to the two parts of the auto fleet:

$$EM2 = [TE/(F2*(e2/e4)+F4)]*(F2*(e2/e4) \quad (1)$$

$$EM4 = [TE/(F2*(e2/e4)+F4)]*F4 \quad (2)$$

where:

EM2 = emissions from 2 stroke fleet
EM4 = emissions from 4 stroke fleet
TE = total auto fleet emissions of a pollutant = (EM2+EM4)
F2 = percent of auto fleet that is 2 stroke (.362)
F4 = percent of auto fleet that is 4 stroke (.638)
e2 = run mode weighted average of emissions per km from 2 stroke cars
e4 = run mode weighted average of emissions per km from 4 stroke cars

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The emissions allocation results are shown in Table 4-5(a), and the baseline emission and damages results are provided in Table 4-5(b).

Applying the Approach to Program Options

For these sample applications of the approach, benefits are estimated as the percent reduction in damages attributable to the option-specific reductions in emissions (as measured in hazard units). Emission reductions, and costs, are based on data obtained from various parties regarding the likely operating effectiveness of catalytic converters over typical driving times and distances (i.e., 50% reduction in NOX, HC and CO and, due to the need to use unleaded fuel with a catalyst, 100% reduction in lead emissions--adjusted to reflect 1992 reductions in the lead content of auto fuels).

Benefits are estimated on an annual basis, and then the present value of 5 years of vehicle operation is used, at a 5% rate of social discount, to derive the present value of benefits. Costs are then subtracted from the benefits to derive the present value of net benefits (PV net benefits > 0 for benefits that exceed costs).

Calculations and results for two program options are shown in Table 4-6. On the left portion of the table are baseline damages per 1000 vehicles in the 2 stroke fleet (below which is shown damages per 1000 4 stroke vehicles). To the right of the baseline are two columns that indicate the benefits of retrofitting 1000 autos with catalytic converters. The emission reductions obtained, as described above, result in a lower bound estimate of 5.2 M HUF in annual benefits per 1000 2 stroke cars with catalysts added. The 5 year present value of lower bound benefits is 22.6 M HUF. The estimated costs of 1000 retrofits amounts to 25.0 M HUF (25,000 HUF per auto, about half of which is for the catalyst, and the remainder for the installation cost (T. Meretei, KTI)). Therefore, using the lower bound benefits estimate, the present value of net benefits is estimated to be a negative 2.4 M HUF. This indicates that under the most restrictive benefit level scenario, this program option is likely to generate benefits to society that approximate its costs. And, as shown in Chapter 5, the moderate and high benefit scenarios result in positive net social benefits.

Other program options assessed in similar fashion suggests a mix of results. Retrofitting catalysts onto 4 stroke autos is less desirable than doing so on 2 stroke cars. As shown in Table 4-6, the present value of net benefits is negative; 14.8 M HUF per 1,000 vehicles, under this lower bound benefit scenario.

This example reveals how the methodologic approach is applied to specific policy options. It is important to note that these examples are based on the most conservative (i.e., lowest) of the benefit estimates. In the next chapter, these and other policy options are evaluated for a broader range of benefit scenarios.

TABLE 4–5a
AUTOMOTIVE EMISSION ALLOCATION ASSUMPTIONS

Pollutant	Emissions Ratio (gram/km)			
	2 Stroke		4 Stroke	
	idle/urban	80km/hr	idle/urban	80km/hr
CO	39.5	9.6	36.2	8.0
HC	10.6	5.3	2.4	1.4
NOX	0.3	0.8	2.3	3.2

Pollutant	Emission Ratio (2 stroke/4stroke)			Emission Levels (t/yr)	
	idle/urban	80km/hr	combined*	2 Stroke	4 Stroke
CO	1.09	1.20	1.11	35,658	56,501
HC	4.34	3.78	4.23	9,237	3,847
NOX	0.14	0.23	0.16	272	3,014
Lead			1.00	20	36
SO2			1.00	55	96
Soot			1.00	0	0

Fleet Composition	%	# Vehicles
2 Stroke =	36.2%	162,900
4 Stroke =	63.8%	287,100
TOTAL FLEET		450,000

* Run mode – 80% urban

TABLE 4–5b
EMISSIONS AND DAMAGES FROM 2 AND 4 STROKE AUTOS

2 STROKE AUTOS						
Pollutant	Tons/yr (1987)	Hazard Weight	Haz Units	% of Fleet Haz units	Damages Caused/Yr (MHUF) LOW	HIGH
CO	35,658	0.04	1,426	3.7%	163.4	1,292.4
HC	9,237	1.3	12,008	31.3%	1,375.5	10,880.0
NOX	272	0.8	218	0.6%	25.0	197.5
Lead	20	53.3	1,080	2.8%	123.8	979.0
SO2	55	1	55	0.1%	6.3	49.5
Soot	0	2.8	0	0.0%	0.0	0.0
TOTAL	45,243		14,787	38.5%	1,693.9	13,398.4
(percent)	33.1%		38.5%			

4 STROKE AUTOS						
Pollutant	Tons/yr (1987)	Hazard Weight	Haz Units	% of Fleet Haz units	Damages Caused/Yr (MHUF) LOW	HIGH
CO	56,501	0.04	2,260	5.9%	258.9	2,047.8
HC	3,847	1.3	5,001	13.0%	572.9	4,531.6
NOX	3,014	0.8	2,411	6.3%	276.2	2,184.4
Lead	36	53.3	1,904	5.0%	218.1	1,725.4
SO2	96	1	96	0.3%	11.0	87.3
Soot	0	2.8	0	0.0%	0.0	0.0
TOTAL	63,493		11,673	30.4%	1,337.1	10,576.5
(percent)	46.5%		30.4%			

Total Autos	79.7%		68.9%	68.9%	3,031.0	23,975.0

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TABLE 4-6
BENEFITS AND COSTS OF RETROFITTING CATALYTIC CONVERTERS
ON 2 & 4 STROKE AUTOS (Based on low benefits scenario)

2 STROKE AUTOS

	BASELINE				CATALYST CONVERTER			
	Annual Damages per 1000 cars				Benefits per 1000 cars			
Pollutant	Tons	HU	M HUF	M US$	Tons/5 yrs	HU/5 yr	M Ft/yr	PV*
CO	218.9	8.8	1.003	$0.013	547.2	21.9	0.501	2.17
HC	56.7	73.7	8.444	$0.111	141.8	184.3	4.222	18.28
NOX	1.7	1.3	0.153	$0.002	4.2	3.3	0.077	0.33
Lead	0.1	6.6	0.760	$0.010	0.3	16.6	0.380	1.64
SO2	0.3	0.3	0.038	$0.001	1.7	1.7	0.038	0.17
Soot	0.0	0.0	0.000	$0.000	0.0	0.0	0.000	0.00
TOTAL	277.7	90.8	10.398	$0.137	695.2	227.8	5.218	22.593

4 STROKE AUTOS

	BASELINE				CATALYST CONVERTER			
	Annual Damages per 1000 cars				Benefits per 1000 cars			
Pollutant	Tons	HU	M HUF	M US$	Tons/5 yrs	HU/5 yr	M HUF/yr	PV*
CO	196.8	7.9	0.902	$0.012	492.0	19.7	0.451	1.95
HC	13.4	17.4	1.995	$0.026	33.5	43.6	0.998	4.32
NOX	10.5	8.4	0.962	$0.013	26.2	21.0	0.481	2.08
Lead	0.1	6.6	0.760	$0.010	0.3	16.6	0.380	1.64
SO2	0.3	0.3	0.038	$0.001	1.7	1.7	0.038	0.17
Soot	0.0	0.0	0.000	$0.000	0.0	0.0	0.000	0.00
TOTAL	221.2	40.7	4.657	$0.061	553.7	102.5	2.348	10.165

PARAMETERS		
Discount rate	5%	
Catalyst life	5 years	
Total Damages	4400 M HUF/yr	
Ft per $US	76.06	
Ft per DEM	46.09	
Catalyst cost**	25000 HUF	$329
Replace engine** =	200000 HUF	$2,630

EMISSIONS REDUCTIONS			
	2 stroke catalyst	4 stroke catalyst	replace engine
CO	50%	50%	58%
HC	50%	50%	94%
NOX	50%	50%	3%
Lead	50%	50%	0%
SO2	100%	100%	0%
Soot	0%	0%	0%

* Present Value benefits in millions HUF
** equipment plus installation

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5.0 ANALYSIS AND RESULTS

5.1 INTRODUCTION

Results of the analyses assessing the environmental and economic impacts of options to mitigate transport-related air pollution are provided in this section. First, an overview of the results of the nine programs contained in the Auto Fuel Charge proposal is framed in terms of cost-effectiveness and benefit-cost analysis to assist decision-makers in determining the relative merits of the programs. Then, in Section 5.3 the results of the analysis is described for each specific program option. Conclusions and recommendations for policy and future research are discussed in Section 5.4.

5.2 ANALYSIS OF POLICY OPTIONS

The nine options evaluated are arrayed by functional area in Table 5-1. The results are portrayed in terms of the net present value (NPV, the present value of benefits minus costs) per specified number of vehicles. The cost-effectiveness of each option also is provided. The cost-effectiveness for each program option measures the amount of costs required to reduce one hazard unit of pollution.[1]

A ranking of the policy options from best to poorest performer is provided in Table 5-2. The benefit-cost per unit measures the present value of benefits accruing in the form of avoided damages as a result of implementing the specified number of units (e.g., vehicles, pollution control devices in vehicles, or km), net of the implementation costs. Since the vehicles do not have the same emission reduction performance, and because the rankings are influenced by the benefit scenario selected (low, medium, or high), Table 5-3 provides a ranking based on the cost-effectiveness per hazard unit that is reduced.

The overall evaluation of each program option is indicated in Table 5-4, as determined by multiplying the number of units (e.g., vehicles, pollution control devices, or km) proposed for implementation times the present value of net benefits per unit. While the benefit-cost measures incorporate all of the equipment and installation costs for implementing the technologies specified by the proposed programs, the AFC program itself is not intended to provide a full subsidy of these costs for each option. Consequently, the percent of the

[1] The hazard unit (HU) measurement, as described in Section 4.0, creates a weighted average of six transportation pollutants (i.e., carbon monoxide, hydrocarbons, nitrous oxides, lead, sulfur dioxides, and soot) permitting a comparison across different program options that impact these pollutants to varying degrees. The weighting scheme is based on Hungary's National Ambient Air Quality Standards (NAAQS), with some adjustments for the non-health impacts of the pollutants.

TABLE 5–1
SUMMARY EVALUATION OF AFC PROGRAM OPTIONS
(NET BENEFITS AND COST EFFECTIVENESS PER NO. VEHICLES)

Programs Proposed	Cost per Hazard Unit (Ft/HU)	PV NET BENEFITS PER VEHICLES			
		Low (M Ft)	Medium (M Ft)	High (M Ft)	Vehicles (No.)
Two Stroke Automobiles					
Catalytic Converters	109,756	(2)	20	155	1,000
New Engines	647,581	(125)	(88)	181	1,000
Four Stroke Automobiles					
Catalytic Converters	243,942	(15)	(5)	56	1,000
Bus Fleet					
Fuel Additives and I&M	NA	NA	NA	NA	NA
Turbochargers	56,777	62	132	545	100
"Up–to–Date" Engines					
Total Cost (1)	8,428	449	944	3,877	100
Envir Cost (2)	(1,892)	505	1,000	3,937	100
Vehicle Replacement					
Total Cost (1)	210,297	(655)	(161)	2,764	100
Envir Cost (2)	32,940	315	809	3,731	100
Alternative Fueled Busses					
Total Cost (1)	191,258	(567)	(58)	2,951	100
Envir Cost (2)	59,284	(7)	(1)	3,694	100
Infrastructure					
Park'N'Ride (3)	3,212,900	(656)	(613)	(586)	1,000
10% speed increase (4) roads & repaving	848,644	(6,816)	(5,987)	(1,074)	170km

(1) The "Total Cost" is the inclusive investment costs for the "green/clean" technology including price, taxes, and any modifications required.

(2) "Environmental Investment Only" represents the incremental cost of the "green/clean" technology over and above the cost of the most likely technology to be adopted. In this way, the costs of the technology that provide numerous benefits separate from the environmental benefits will not be included in the environmental cost/benefit analysis.

(3) Cost estimates shown are at the low end of those provided. However, these costs may still be too high and require confirmation.

(4) Cost estimates used are from the low end of those provided. The analysis assumes that traffic flow improves by 10% due to roads and repaving improvements, which is optimistic given that the system is operating above capacity. Nevertheless, the analysis bounds the results of such a program under "good" conditions.

TABLE 5–2
AFC PROGRAM RANKING BY ESTIMATED PRESENT VALUE OF NET SOCIAL BENEFITS
(PV Net Benefits per # Vehicles)

Benefit–Cost (1) Option	PV Net Benefits Low (M Ft)	Medium (M Ft)	High (M Ft)	Per Units (#)
High Net Benefit Options				
1a. Diesel bus engines environmental cost (1)	505	1,000	3,937	100
1b. Diesel bus engines total investment costs (2)	449	944	3,877	100
2a. Diesel bus replacement environmental cost (1)	315	809	3,731	100
3. Bus turbochargers	62	132	545	100
Moderate Net Benefit Options				
4. 2 Stroke Catalysts	(2)	20	155	1,000
5a. CNG Buses environmental cost (1)	(7)	(1)	3,694	100
6. 4 Stroke catalysts	(15)	(5)	56	1,000
Negative Net Benefit Options				
7. 2 Stroke engine replacement	(125)	(88)	131	1,000
5b. CNG Buses total investment costs (2)	(567)	(58)	2,951	100
2b. Diesel bus replacement total investment costs (2)	(655)	(161)	2,764	100
8. Park'N'Ride	(656)	(613)	(586)	1,000
9. Roads & repaving (per KM)	(6,816)	(5,987)	(1,074)	170

(1) Environmental costs are incremental costs of the policy option attributable strictly to emissions reductions.

(2) Total investment costs are total cost of the policy option, incorporating costs associated with objectives other than air quality improvements (e.g., fuel savings, safety, comfort, etc.)

TABLE 5–3
COST EFFECTIVENESS RANKINGS
(COST PER HAZARD UNIT REDUCED)

Option	M HUF per 1000 HU Reduced	HU Decline per Vehicle (HU)
1a. Diesel bus engines environmental cost (1)	(1.9)*	55
1b. Diesel bus engines total investment costs (1)	8.4	55
2a. Diesel bus replacement environmental cost (1)	32.9	55
3. Bus turbochargers	56.8	7
5a. CNG Buses environmental cost (1)	59.3	56
4. 2 Stroke Catalysts	110.7	0.2
5b. CNG Buses total investment costs (1)	191.3	56
2b. Diesel bus replacement total investment costs (1)	210.3	55
6. 4 Stroke catalysts	243.9	0.1
7. 2 Stroke engine replacement	647.6	0.3
8. Roads & repaving	848.4	53
9. Park'N'Ride	3,212.9	0.2

(1) "Environmental costs" represent the cost increment over standard technology while the "total cost" is the full cost of the environmental technology.
* Negative value reflects foreign subsidies on bus engines.

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TABLE 5-1
SUMMARY EVALUATION OF AFC PROGRAM OPTIONS
(NET BENEFITS AND COST EFFECTIVENESS PER NO. VEHICLES)

Programs Proposed	Cost per Hazard Unit (Ft/HU)	PV NET BENEFITS PER VEHICLES			
		Low (M Ft)	Medium (M Ft)	High (M Ft)	Vehicles (No.)
Two Stroke Automobiles					
Catalytic Converters	109,756	(2)	20	155	1,000
New Engines	647,581	(125)	(88)	181	1,000
Four Stroke Automobiles					
Catalytic Converters	243,942	(15)	(5)	56	1,000
Bus Fleet					
Fuel Additives and I&M	NA	NA	NA	NA	NA
Turbochargers	56,777	62	132	545	100
"Up-to-Date" Engines					
Total Cost (1)	8,428	449	944	3,877	100
Envir Cost (2)	(1,892)	505	1,000	3,937	100
Vehicle Replacement					
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Envir Cost (2)	32,940	315	809	3,731	100
Alternative Fueled Busses					
Total Cost (1)	191,258	(567)	(58)	2,951	100
Er vir Cost (2)	59,284	(7)	(1)	3,694	100
Infrastructure					
Park'N'Ride (3)	3,212,900	(656)	(613)	(586)	1,000
10% speed increase (4) roads & repaving	848,644	(6,816)	(5,987)	(1,074)	170km

(1) The "Total Cost" is the inclusive investment costs for the "green/clean" technology including price, taxes, and any modifications required.
(2) "Environmental Investment Only" represents the incremental cost of the "green/clean" technology over and above the cost of the most likely technology to be adopted. In this way, the costs of the technology that provide numerous benefits separate from the environmental benefits will not be included in the environmental cost/benefit analysis.
(3) Cost estimates shown are at the low end of those provided. However, these costs may still be too high and require confirmation.
(4) Cost estimates used are from the low end of those provided. The analysis assumes that traffic flow improves by 10% due to roads and repaving improvements, which is optimistic given that the system is operating above capacity. Nevertheless, the analysis bounds the results of such a program under "good" conditions.

costs that are covered by the program (in the form of a payment mechanism as yet to be specified) are provided in the right-hand column of Table 5-4.

5.3 DISCUSSION AND INTERPRETATION OF THE RESULTS

The three transportation programs assessed that will generate the greatest positive net social benefits for Hungary (benefits in excess of the costs) are bus fleet related.

The top three program options in terms of having the largest positive net present value (NPV) per vehicle were all in the bus fleet. When the net benefits are measured on the basis of hazard units reduced, the same bus options remain the top performers. This is to be expected because the emissions reductions of buses is very large since they pollute more to begin with. The costs associated with buying and installing environmentally benign diesel engines, paying the incremental costs for "green/clean" technology in the case of a bus replacement, or purchasing and installing pollution control equipment in existing buses are more than offset by the benefits resulting from the reductions in pollutants as well as the fuel savings from the more efficient "green" engines. These bus options would contribute to mitigating the consistent violations of the NOx and soot air quality standards in Budapest.

Diesel Bus Engine Replacement

The highest ranking option is the introduction of a "clean" DAF engine into an existing chassis, where the costs include only the difference between the new "clean" engine and a standard engine (Option 1(a)). The net present value for every 100 engines replaced with a "clean" DAF engine rather than a RABA engine ranges from 505 million forints to 1,000 million forints. Use of the incremental cost (amounting to 1.4 million ft per engine including VAT, customs and transport charges) paid to obtain the environmental benefits of the "clean" engine provides a valid criteria against which to measure the return on those costs in terms of environmental benefits. However, even if the total costs of the "clean" DAF engine (totaling 2 million forints per engine inclusive) are used (Option 1(b)), replacing standard engines with DAF engines is the second highest ranking option with a net benefit ranging between 449 to 944 million forints per 100 engines.

The reason for the stellar performance from replacing bus engines is twofold. First, the emissions reductions obtained by using a DAF engine versus a RABA engine range from 50% to over 80% for CO, HC, NOx, and particulate matter. In addition, the DAF engine is 9% more fuel efficient than the RABA engine. If the fuel savings are removed from the benefits, the net benefit based on the total investment costs of the DAF engine declines from 505 million forint per 100 engines to 354 million forint -- still well in excess of costs. Furthermore, the net benefits are a conservative measure in that all the bus options are based on the emissions reduction performance of a new "clean" engine versus a new

standard engine, when in fact, the new "clean" engine will replace a *used* standard engine, consequently higher rates of emission reduction will be achieved.

This analysis suggests that using "clean" (e.g., DAF or similar) diesel engines should be pursued. In fact, a recent proposal for assistance has been made to the Dutch government amounting to a subsidy of 834,000 forints per DAF engine purchased by Hungary. Incorporating this subsidy into the benefit-cost analysis increases the net benefit from the diesel engine replacement -- total investment cost basis -- by 18% from 505 million forints per 100 engines to 588 million forints. The limiting factor in replacing with the DAF engine is the configuration of the bus chassis. Currently, only the Ikarus 415 chassis can accommodate the DAF engine. In the BKV (Budapest's transportation company) fleet of almost 1,700 buses, only 30 Ikarus 415 chassis exist. Inventory of other transportation companies should be pursued to determine other eligible vehicles.

Diesel Bus Replacement

Since the number of buses with chassis that can accommodate the "clean" DAF engine are limited, an examination of total vehicle replacement was conducted. The incremental environmental investment for a DAF engine and Ikarus 415 chassis (purchase price of 13 million forint) over a RABA engine and Ikarus 260 chassis (9.7 million forint) amounted to 3.3 million forints. This investment resulted in a decline in total lifetime emissions of 20,238 hazard units (see Table 5-4) composed primarily of NOx and HC, for a net benefit of 315 to 809 million forints per 100 buses.

Retrofitting Buses with Turbochargers

Retrofitting a turbocharger in a diesel bus costs 80,000 forints and effectively reduces NOx emissions by approximately 20%. The net benefit per 100 retrofits is 62 million to 132 million forints per turbocharger. Even if the cost of the turbocharger doubled or tripled, the net benefit remains positive.

> The net benefits per vehicle of the next three highest ranking options generate positive net benefits, or, under the most conservative scenarios, roughly break even. These options include retrofitting catalytic converters into 2 and 4 stroke vehicles and the incremental "environmental" investment for CNG buses.

The second set of ranked policy options include retrofitting catalytic converters in 2 stroke and 4 stroke cars, and making an incremental environmental investment for the "clean" technology of compressed natural gas (CNG) buses.

Retrofitting Catalysts On 2-Stroke Autos

Hungary's automobile fleet of 1.9 million cars in 1990 has almost 31%, or 600,000 two stroke vehicles, over half of which are pre-1970 models. Within Budapest the percent of 2 strokes is somewhat higher at 36% of the car fleet. In Budapest, two stroke cars account for 39% of total transportation emissions. Retrofitting catalytic converters in two stroke cars is, at worst, a break-even option ranging from a net cost of under 1,000 forints per catalyst installed to a net benefit of 23,000 forints per catalyst installed in the "moderate" benefits scenario.

Beginning in January 1992, all two strokes vehicles providing transportation services (e.g., taxis, of which there are over 20,000 comprised of both 2 and 4 stroke vehicles in Budapest) are required to comply with the emissions performance of a two stroke that is retrofitted with a catalytic converter. Whether this program option of subsidizing retrofits will be used as the carrot that complements that regulation has yet to be determined. Since taxis have higher usage rates and consequent overall emissions levels, the benefits of retrofitting them with catalysts would increase significantly over the average vehicle benefits provided in this analysis. On the other hand, arguments are advanced that there is an excess supply of taxis in Budapest, by more than twofold, and that increasing competitive factors, such as compliance with this regulation, would winnow the ranks of fleet.

CNG-Fueled Bus Engines

The 3.3 million forint incremental "environmental cost" of gas-driven (CNG) buses is constituted by the difference in the CNG bus's total cost including infrastructure costs (10.8 million forints per vehicle) less that of a standard RABA engine housed in an Ikarus triple axle chassis (7.4 million forint). The CNG bus reduces emissions of CO, HC, NOx and particulate matter from 70 to 90%, hence mitigating Budapest's air quality standards violations in CO, NOx and soot, as well as the high levels of HC. Under conservative benefits scenarios, this option results in a negative net benefit (i.e., a net cost) ranging from 10,000 forints to 700,000 per bus, but generates positive net benefits under the high benefits analysis.

Retrofitting Catalysts in 4-Stroke Autos

Sixty-four percent of Budapest's car fleet is comprised of 4 stroke vehicles. The HC emission rates of 4 stroke vehicles are significantly better than those for 2 stroke vehicles. Retrofitting catalytic converters in 4 strokes reduces CO, HC, and NOx emissions by half and eliminates SO2 emissions -- comparable to their impact in 2 stroke vehicles. This option is clustered with the roughly break-even programs with a negative net benefit (i.e., a net cost) ranging from 2,000 to 13,000 forints per catalytic converter installed. Retrofitting catalytic converters in 2 stroke cars reduces almost twice the amount of hazard units as in

4 stroke cars (i.e., 0.2 compared to 0.1) primarily because the higher HC emissions of 2 strokes compared to 4 strokes outweigh their higher nitrous oxide emissions.

The remaining options perform with moderate to substantial negative net benefits when measured in terms of environmental impacts alone. However, in some cases there are significant benefits other than those accounted for in this study that would accrue to these options.

Engine Replacement in 2-Stroke Autos

Replacement engines in 2 stroke vehicles is a relatively costly option. While emission reductions for CO are 58% and for HC are 94%, the engine cost substantially outweighed the benefits. The negative net benefit of a single engine replacement ranged from 89,000 to 125,000 forints. Since the number of hazard units reduced by replacing the engine in a car is substantially less than for a bus, the 2 stroke engine replacement option declines below that for total investment costs of replacing a bus.

Bus Fleet Options (if full investment costs attributed to air quality)

"Clean" diesel buses and CNG buses include benefits other than the environmental benefits of emissions reduction and increased fuel economy accounted for in this analysis. Consequently, the decision to fund these programs should be based on the larger decision involving maintaining optimal bus fleets. At this time, it has been asserted that over 200 buses in BKV's fleet are operating well beyond their lifetime with guarantees only for their safety, and with significant deterioration of their emissions performance (Budapest News, 12/16/91). Given a replacement decision, then the choice for "clean" diesel or CNG buses is based on the "environmental" net benefits discussed earlier.

If, however, we include total vehicle investment costs in the benefit-cost calculation (rather than the air quality-related incremental costs), then negative net benefits (i.e., net costs) of 58 million to 567 million forints for every 100 CNG buses will be incurred. For the total investment in a "clean" diesel bus, negative net benefits are somewhat greater, ranging from 161 million to 655 million forints for every "clean" diesel bus.

Infrastructure: Road Construction and Repaving

Budapest's role as the hub in the national and international highway systems compound its air quality problems in terms of magnifying both its emissions burdens as well as the difficulty in assigning cost responsibility for the infrastructure. Completion of the southwest section of the ring road which will divert traffic out of Budapest and hopefully bring significant environmental relief, is slated for 1994.

Budapest's transportation funding is suffering and funding is declining rapidly. In 1991, only 44% of Budapest's transportation budget was funded. In 1991, funding declined to 21% of the budget, or 1 billion forint. Within Budapest, there are 484 km of main roads and 4,228 km of all types of roads. Traffic is estimated to operate at 110% of capacity (Mayor's Office). The high level of traffic will make it difficult to increase urban speeds. Over 500 traffic lights regulate Budapest's traffic with one Siemans traffic system connecting 200 crossings in the southeast-central section of the city. A new traffic light system connecting 80 lights is planned for the north part of Budapest with World Bank funding.

In the amount of time available for the study the infrastructure programs could only be assessed on a hypothetical basis by assuming the potential impact of investments in road improvements or traffic light systems on traffic flow. An extremely optimistic assumption was made that the programmatic funding for 170 km of road improvements would increase the mode of traffic running at 80 km by 10% from the current 20%. The most modest cost assumptions were used for the benefit-cost calculation, amounting to 45 million forint per km. Of course, there are many other benefits that accrue from road improvements including reductions in traffic accidents, decreased time spent in commuting and consequent productivity gains. Furthermore, road improvement programs can provide jobs and employment, consequently boosting overall GDP. But excluding all these potential benefits and based on only the resultant emission reductions, a negative net benefit (i.e., a net cost) ranging from 35 to 40 million forints per km was obtained.

Infrastructure: Park and Ride

Currently, Budapest has a park and ride system with 4,158 spaces. The location of the lots is crucial to the use of these spaces. On average, 54% of the spaces are used. However, the South Rail Station utilization exceeds 200% of planned capacity and is speculated to provide parking for the surrounding neighborhoods. A recent local study posits that Budapest needs 15,000 spaces by 1995, in time for the World Expo, and 20,000 by 2000. The study estimates that this would result in traffic reductions on the order of 12 to 14%. These results need further examination and research.

The problem with park and ride in Budapest is twofold. The investment costs are quite high, amounting to 700,000 forints per space excluding land costs. Completion of the Hotel Korona garages cost over 1 million forint per vehicle (land cost may not be included in this estimate). The other dimension to the problem is that there are few prohibitions against parking in Budapest, and few parking fines are dispensed.

The result of the analysis reveals the impact of the high investment costs for a parking space in Budapest. The negative net benefit (i.e., net cost) ranges from 613,000 to 656,000 forints per space assuming 100% utilization.

5.4 CONCLUSIONS AND RECOMMENDATIONS FOR POLICY AND RESEARCH

Policy makers can take several dimensions into consideration, either implicitly or explicitly, in the decision-making process. A threefold framework for decision-making includes: 1) an economic analysis of the costs and benefits of a proposal, such as provided in this report; 2) consideration of both the willingness and ability of the populace to pay for the programs; and 3) the territorial questions of where to intervene in the problem. While this report focusses on assessing the relative economics of the various options, it is important to note that there are interlocking and systemic components in a transportation program. It is noteworthy that the Auto Fuel Charge is framed from a whole systems perspective in that it targets most of the key dimensions that need to be addressed for a comprehensive transportation pollution control strategy. Consequently, the exercise of judging the relative merits of options is intended to suggest refinements in both the analysis as well in the framing of program options. The aim, therefore, is to address a critical situation where air pollution standards are violating national and international standards by enacting those programs that are most effective in mitigating transport-related air pollution damages within applicable budget constraints.

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