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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

CONFERENCE ON NOISE ABATEMENT POLICIES

7th-9th MAY 1980

CHÂTEAU DE LA MUETTE
2, RUE ANDRÉ PASCAL 75016 PARIS

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CONCLUSIONS OF THE CONFERENCE

Part I (Conclusions of the Conference) will be included in the final version of this publication to be issued after the Conference.

PART II

INTRODUCTION

by

Laurens Jan Brinkhorst
President of the Conference

In the course of the last decade, the governments of OECD countries have adopted comprehensive policies to protect the environment. These policies were aimed at reducing the principal causes of pollution and nuisance, and at protecting the natural environment and the quality of life. What have been the results of these policies? Exactly one year before this Conference on Noise Abatement Policies, Environment Ministers meeting at OECD(*) were able to state that, although significant improvements had been brought about in some areas of environmental protection and the quality of life, this was not the case with regard to noise.

Indeed, during the last twenty years, the quality of the noise environment has steadily deteriorated, mainly as a result of rapid urbanisation, the growth in mobility, and the rapid development of mechanised activities in OECD countries. Currently, 15 per cent of the population of OECD countries, that is about 100 million people, are exposed in their daily environment to levels of noise which are regarded as unacceptable (more than 65 dBA), and more than half the population of these countries is exposed to a level of noise higher than that corresponding to a level of comfort (**) (more than 55 dBA). To this disturbing statement may also now be added pessimistic forecasts which show that, unless vigorous noise abatement policies are quickly put into effect, the situation will continue to worsen over the course of the next twenty years.

Why has this worrying situation arisen?

The public authorities were slow to recognise the problem, and it can be a difficult problem to grasp in a coherent and effective way; both these factors have delayed progress in noise abatement at

*) Environment Committee Meeting at Ministerial level, 7th-8th May, 1979.

**) Daytime outdoor noise levels measured at the most exposed façade of dwellings. The measure is expressed in decibels (A) on the Leq index. Outside noise level considered to be the maximum limit of acceptability; 65 dBA: outside noise level considered to be the maximum limit for comfort; 55 dBA.

the international, national and local levels. But it is clear that the quality of life cannot be acceptable without a satisfactory noise environment and that there can be no real environmental policy without an overall and sustained policy against noise.

It is the specific objective of the OECD Conference on Noise Abatement Policies (7th-9th May, 1980) to study and to make proposals for such strategies. In particular, the aims of the Conference are:

- to assess progress to date in the field of noise abatement and to examine prospects for the future;
- to evaluate and discuss the policy instruments available for a more effective implementation of noise abatement policies;
- to take into account the economic aspects of noise (abatement costs, social costs, noise charges and compensation for damage); and
- to recommend measures that would lead to greater international co-operation and harmonization in noise abatement policies.

These different aspects of noise abatement strategy are analysed in the Conference Reports which follow, and rather than summarising them here, I should simply like to highlight what I see as the main implications concerning future policy directions.

Firstly, noise abatement must be systematic, that is to say progress must be based on a co-ordinated range of actions and methods programmed over time. In accordance with the OECD Recommendation(*), comprehensive programmes and legislation for noise abatement are now more necessary than ever.

Secondly, the implementation of legislation and policies must be strengthened and supported; it is often because of a lack of means or of the political will to enforce regulations and through a lack of public information and active public participation that noise has continued to increase. Each partner, whether public authority, private individual or community, has a part to play: it is not simply a question of improving legislation, it is also necessary to change behaviour.

Equally, noise abatement must be dynamic, that is to say policy must include varied and complementary strategies, such as economic incentives, in order to maintain a constant stimulus on efforts and technology aimed at reducing noise.

One essential element of this dynamic approach must be a progressive and marked reduction in noise emission limits, in particular with regard to means of transport which constitute the main source of noise in OECD countries. Forecasting studies on transport noise show that a major reduction of this noise at source is the essential element in obtaining a significant improvement in the noise environment in the years to come.

*) Recommendation on Noise Abatement Policies adopted on 3rd July, 1978.

Finally, and above all, noise abatement policy must aim at prevention, through being integrated from the outset in the conception of infrastructure projects, town planning, housing developments, etc. It is in this way that noise abatement measures can be fully included in policies concerned with managing and improving the quality of life.

This principle can and must equally be applied in measures aimed at energy conservation: as far as possible, such measures must be drawn up in such a way as to take noise problems into account. In fact, noise abatement is not in general incompatible with energy conservation; on the contrary it often happens that both policies are complementary. For example, acoustic insulation of buildings can be combined with good thermal insulation; in the same way, careful motor vehicle design aimed at reducing fuel consumption can also bring about a reduction in noise emission.

Unlike air or water pollution, noise does not constitute a form of transfrontier pollution (although noisy aircraft fly across continents and motor vehicles cross frontiers); on the other hand, there is a significant amount of international trade in many noise-producing products, such as motor vehicles. International co-operation must therefore be strengthened, in particular to compare experience and to encourage a strengthening of noise limits. I hope that this Conference of OECD countries will not only constitute a significant stage in this process, but that it will also give a new stimulus to the fight against noise within each country.

On the basis of an analysis and an assessment of noise abatement policies, the following reports put forward proposals for new and innovative policies for the future.

SUMMARIES

1. THE PRESENT AND FUTURE STATE OF THE NOISE ENVIRONMENT

Past trends and current surveys show an increase in noise, especially traffic noise, with ever increasing areas of OECD countries being affected and for longer periods of time. The report examines the main factors causing this increase, and looks at how exposure to noise varies from one country to another and from one city to another. Current forecasts demonstrate that, unless more stringent noise abatement policies are adopted, there is little likelihood of any general improvement in the noise environment; on the contrary the evidence suggests that noise, especially from road traffic, could increase seriously in the future. The report therefore suggests that existing noise abatement policies should be reassessed, and new approaches to the problem investigated.

2. THE IMPACT OF NOISE

The first part of this report examines the way in which noise affects man's physical and mental health; in particular the physiological effects (e.g. damage to hearing, increased blood pressure), the effect on daily activities (disturbance of sleep, interference with conversation), and the psycho-sociological effects (annoyance, stress, etc.). In the light of these effects, the report addresses the question of what levels of ambient noise can be regarded as providing satisfactory protection from the point of view of health and welfare.

However, health and welfare effects are not the only element to be taken into account in noise abatement decisions; there are also economic, technical and other elements which have to be weighed up. The second part of this report discusses the rationale and the various methods that have been adopted for assessing the impact of noise on people and the benefits of noise abatement measures in monetary terms. The report concludes that the present state of the art is not satisfactory for policy decisions, and that further work is needed to value the social cost of noise in monetary terms. On the other hand, cost effectiveness analyses using physical measures of noise nuisance, health damage, etc. do enable the policy-maker to make more informed decisions.

3. REGULATING FOR NOISE ABATEMENT

Noise control presents a difficult legislative problem which requires somewhat different solutions to those which have classically been applied to other pollution problems. This report examines the major features of noise abatement legislation in OECD countries, and assesses what has been achieved so far, and what difficulties have been encountered. In many countries a "scattered" system of legislation has evolved, where individual measures have been pursued separately to deal with specific aspects of noise pollution. A few countries, however, have adopted a comprehensive approach, binding together all the elements of an overall noise abatement strategy into a single legislative framework and/or into a comprehensive programme. The report concludes that this latter approach is the most appropriate for the properly co-ordinated effort over a broad front which is necessary for a fully effective noise abatement policy. For the future, the report suggests that the keynote should be planning, financing and enforcement. Noise programmes need to be fully thought out; they should have a clearly defined overall framework, looking ahead as far as possible, and specifying objectives, priorities and means of enforcement.

4. LOCAL ACTIONS AND PILOT "QUIET TOWNS"

Local government has an important noise-abatement role, and a variety of approaches have been adopted at the local level in OECD countries. The report considers the conclusions that can be drawn from experience gained so far, for example from the pilot "quiet town" experiments in some countries and the innovative traffic management schemes etc. in others. It can be difficult to evaluate the success or failure of local measures aimed at reducing noise, but the report concludes that for effective results, local government authorities need to be highly motivated and well organised, and should concentrate their efforts on types of noise that are amenable to action at the local level, seeking the co-operation of the public as far as possible. The report proposes a number of strategies that are likely to bring effective results.

5. NOISE CHARGES

This report considers the effectiveness of noise charges as an incentive measure to complement legislation. This is an approach which has been gaining ground considerably over the last few years. Some countries are considering the introduction of charges on the noisiest cars, lorries and motorcycles; while others already impose charges on aircraft noise. The report discusses the rationale for such an approach and concludes that there is much in its favour.

Various methods of calculating and implementing the charges are examined in detail.

6. COMPENSATION FOR DAMAGE DUE TO NOISE

It often happens that no satisfactory preventive or protective measures can be taken to avoid serious noise nuisance. Such is the case particularly for people who live alongside main roads or railways or in the vicinity of airports. This report considers what can be done to provide some measure of relief, as far as one can, to people exposed to this sort of noise; it examines the role of compensation as an element of noise abatement policy; and sets out the various forms of compensation that are available, for example the provision of noise insulation or monetary payments to compensate for a fall in land or property values. The report concludes that, while compensation must remain a last resort, fair and effective legislation and administrative procedures for compensation must be available when all else fails.

7. EDUCATION AND INFORMATION

Some types of noise nuisance, e.g. from aircraft, can be dealt with only at the national or international level. This report argues, however, that a great deal of the noise we suffer in our daily lives could be reduced at little cost if people generally were more noise-conscious. Substantial noise reductions could be achieved if engineers, designers and planners were better informed of the scope for simple noise control techniques. The general public could help by buying quiet products rather than noisy ones, and by using potentially noisy equipment in a considerate manner. The report proposes a number of measures which could help to improve the situation, for example more widespread study of accoustics and noise-related matters, specialised training courses, publicity campaigns and product labelling systems; and stresses the role of schools in creating a greater sense of altruism in future generations.

8. THE COSTS OF NOISE ABATEMENT

This report contains a detailed analysis of the costs involved in reducing noise at source, in transmission, and at reception of all the major noise sources; road traffic, aircraft and industrial installations. Some global estimates are given, and the report assesses the cost effectiveness of various noise abatement measures. One general conclusion is that substantially increased research on noise abatement costs is needed to help policy-making.

9. NOISE ABATEMENT IN THE CONTEXT OF ENERGY CONSERVATION AND OTHER POLICY OBJECTIVES

This report considers how far measures taken to reduce noise can be compatible with other policy objectives, especially the need to save energy. Particular attention is paid to road transport, since motor vehicles are both a major source of noise nuisance and major consumers of energy. On this aspect, the report concludes that in general there is no significant conflict between noise abatement and energy conservation. Other sources of noise (railways, aircraft, industrial plants) and abatement measures (such as sound insulation of buildings) are also considered in the context of energy policy. Again, the broad conclusion is that noise abatement is not incompatible with energy conservation. Indeed, as with motor vehicles, in some cases the best strategies for each objective are mutually reinforcing. The report identifies some other policy objectives which may have a bearing on noise policy; for example visual pollution, safety, urban planning, and so on. Little systematic evidence is available, however, on the relationship between such policy areas and noise control.

10. INTERNATIONAL CO-OPERATION AND HARMONIZATION IN THE FIELD OF NOISE ABATEMENT POLICIES

This report considers what benefits might be gained from greater international harmonization and co-operation in the field of noise abatement policies, and examines the role of the various international organisations involved. The report suggests that a dynamic approach to harmonization could do much to promote steady progress towards a better noise environment, as well as benefitting manufacturers and international trade. The report suggests, in particular, that benefits could be gained from greater co-operation in the field of motor vehicle noise limits and measurement procedures, construction equipment standards, product labelling, the conditions of use of noisy equipment, and from regular exchanges of experience and information.

The following reports were prepared by the OECD Secretariat under the guidance of a Steering Group which was set up to help in the preparation of the Conference. The reports remain the responsibility of the Secretariat and do not necessarily reflect the views of OECD Member Governments.

BACKGROUND REPORT NUMBER 1

THE PRESENT AND FUTURE STATE OF THE NOISE ENVIRONMENT

CONTENTS

1. INTRODUCTION

Surveys, records of complaints, and physical measurements generally show noise to be one of the major nuisances of modern life, particularly in urban areas. Indeed, recent opinion surveys in the United States and Japan put noise first among the nuisances experienced in residential areas, and show that it has increased over the last five years.(1) In the United States, noise ranks very high as a reason why people move out of their neighbourhood.(2) In Japan there are currently more complaints about noise than about any other form of pollution.(3) This is the measure of the importance which people attach to the reduction of noise. In everyday life, at home, in the street and during leisure time, people are exposed to a noise level varying between 30 and 90 decibels and sometimes exceeding that figure.(4)

Various indices exist for measuring synthetically the overall level of fluctuating sound sources but there is a definite tendency to adopt the Leq index in decibels(A), internationally,(5) which

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1) a) Noise - Toward a Strategy for Noise Control, United States, EPA, 1977

b) "Noise Poll", Sound and Vibration, January 1979, United States

c) Public Opinion Poll on Pollution, Prime Minister's Office of Japan, 1979

d) Japan Environment Summary, Vol. 7, No. 2, 10th February, 1979

2) Annual Housing Survey, Part B, Indicators of Housing and Neighbourhood Quality, Current Housing Reports, Bureau of Census, United States Department of Commerce and United States Department of Housing and Urban Development, 1973-1976.

3) Quality of the Environment in Japan, 1978, Japanese Environment Agency.

4) In workplaces, and especially some noisy factories and workshops, the noise level may exceed 90 decibels, but the question of noise at work is not dealt with here.

5) Leq (equivalent continuous sound level in A-weighted decibels) = a level of constant sound (in dBA) which would have the same sound energy over a given period as the measured fluctuating sound under consideration. The decibel (dB) is a unit of measurement of sound pressure level related to a standard reference level of 0.00002 Newtons per square metre. The decibel scale is logarithmic, so that a very wide range of audible sound can be described in terms of a manageably small range of numerical expressions. A sound of 0 dB at 1,000 cycles is just audible to a person with good hearing. A sound of 120 dB causes pain in the ear. The accustical pressure of the second is one million times greater than that of the first.

The decibel (A-weighted) (dBA) is a unit of sound measurement in which greater emphasis is given to the medium and high frequencies, to which the human ear is most sensitive. The dBA measure, which enables overall acoustical energy to be measured over a given period and is a suitable instrument for measuring exposure to noise (although doubts are sometimes expressed as to how valid an index it is for measuring the impact of night-time noises).

Figure 1 below is an example of a "noise barometer" showing the sound levels of different types of noise (rough approximations - levels can vary widely around the figures shown).

FIGURE 1: NOISE BAROMETER IN dBA

	Typical sound sources and places
120	Aircraft at take-off
110	Pop music group
100	Pneumatic drill (at 1 m. distance)
	Peak levels near an airport
90	Lorry, motorcycle, or older type bus accelerating (at 7 m. distance)
	Older type underground train
80	Busy crossroads
	Pneumatic-tyred underground train
70	Outdoor noise level near a motorway
	Noisy office
60	Busy street through open windows
50	Busy street through closed windows
40	Quiet living-room
30	Quiet bedroom
	Rustling of leaves
20	Broadcasting studio
	Desert

Background Report No. 2 entitled "The Impact of Noise" contains a description of the effects of noise on people.

This report describes the past development and present state of the sound environment, and attempts to analyse the foreseeable trends so far as noise is concerned.

2. THE DEVELOPMENT OF NOISE OVER THE LAST TWENTY YEARS

Over the last 20 years noise has extended in time (evening and night-time traffic, weekend and holiday activities) and space

Footnote 5 continued from previous page

is the one most commonly employed in noise abatement and control activities, gives a good correlation with the subjective impression of loudness.

When a sound increases by 10 decibels its subjective intensity, i.e. its perceived strength or loudness, doubles, while doubling the acoustical energy (for instance by doubling the number of identical noise sources such as private cars) produces an increase of only 3 decibels.

(extension of noise into suburbs and the country). This extension is due to continuous urbanisation, increased activities and increased traffic; the number of motor vehicles (including heavy lorries) in the OECD countries has trebled, and air traffic (in passenger/kms) has increased tenfold in 20 years. The urban population of the OECD countries has increased by 50 per cent in 20 years, and the number of towns of more than a million inhabitants has doubled. In addition, large-scale urban renewal and infrastructure building projects (motorways, airports, etc.) have been carried out in many OECD countries during the last two decades.

It is in the field of transport that noise sources have increased most rapidly in numbers and impact; mainly motor vehicles and to a lesser extent aircraft. In the five years from 1973 to 1978 the percentage of the population of the United States exposed to road traffic noise greater than 65 dBA increased from 6.4 to 10 per cent. At the same time measurements and surveys show that the number of people exposed to road traffic noise, and affected by it, is greatly in excess of the number exposed to all other sound sources combined. It is estimated that in Europe and Japan the noise of road traffic is an annoyance to 20 times more people than the noise of aircraft (compared with 3 times more in the United States).(1) Admittedly in several countries neighbourhood noises, especially in residential suburbs, are also an appreciable source of annoyance, (something, mentioned as the second source of noise annoyance, after traffic noise), but there is no satisfactory index for measuring these and no complete statistical survey. The impact of railways is comparatively smaller; generally 1 to 2 per cent of people are subjected to more than 65 dBA by trains (except in Switzerland where it is estimated that 4 per cent of the population are exposed to such a noise level). Industrial establishments and workshops are often the main source of complaints (Japan, United Kingdom) and building sites the second. This however is due to the fact that it is easier to find out to whom to make a complaint where fixed sound sources are concerned, than with moving ones (vehicles). It should be noted that neither the acoustical measurements nor the surveys of representative samples of the population include the noise of industrial establishments or building sites among the most significant sources of noise.

It is estimated that in 20 years, the total acoustical energy has more than doubled in the OECD countries. But this general statement masks a rather more complex pattern of development. In areas which are already heavily built up, and where the noise level was already high, it has increased rather slowly. On the other hand, in areas that were formerly quiet (residential suburbs) the average

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1) The State of the Environment in OECD Countries, OECD, Paris, 1979.

increases in noise in Leq have been from 7 to 10 dBA and sometimes even more. A difference of 10 dBA, incidentally, is that between the average noise in a small town such as Blois in France and a large capital city such as Paris or London.

Table 1 shows the percentage of the population exposed to the noise of road and air traffic in various OECD countries.

It appears that for these 12 countries taken together (amounting to 78 per cent of the total population of the OECD area), 15 per cent of the population are exposed to an outdoor noise level greater than 65 dBA(1), corresponding to approximately 100 million inhabitants for the whole of OECD. This level of 65 dBA is regarded as an absolute upper acceptable limit, and in several cases is used as the basis for regulations concerning sound insulation and compensation.

In a large capital city like Paris, nearly half the population is exposed to this 65 dBA noise level.(2) It is also estimated that over 50 per cent of the population of the OECD countries is exposed to a noise level exceeding 55 dBA, considered by several countries as a target figure specifically mentioned in their noise abatement programmes. There are sometimes significant differences from one country to another. These differences can moreover be exacerbated by the level of sound insulation in buildings. Thus in countries where outdoor sound levels are fairly high, where many houses are still built of wood, and where there is a high population density, indoor sound levels are distinctly higher than in some other countries where outdoor sound levels are lower and where the houses are usually double-glazed.

3. NOISE IN THE FUTURE

Forecasts in some countries(3) suggest that despite the current regulations the impact of noise will increase from now until the year 2000, mainly on account of road traffic.(4)

So far as the noise of commercial aircraft is concerned, different national estimates of noise exposure use different timescales. If all known noise reduction measures were applied it has been

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1) Measurement expressed in daytime Leq. It should be noted that such a noise level is measured in front of the façade of the house which is the most exposed to noise.

2) Enquête nationale sur l'exposition des Français aux nuisances de transports, IRT, Lyon, France, 1978.

3) Forecasting models have been developed in the United States (for road traffic and aircraft noise), in France (mainly for road noise), Switzerland (for road, rail and air noise), and the United Kingdom (for traffic noise and aircraft noise).

4) The OECD forecasts are for 360 million passenger cars in 2000 (compared with 260 in 1980) and 90 million commercial vehicles in 2000 (compared with 60 in 1980 and 20 in 1960).

Table 1

POPULATION EXPOSED TO AIRCRAFT AND ROAD TRAFFIC NOISE, SELECTED COUNTRIES OR REGIONS, mid-1970s (per cent)

AIRCRAFT NOISE % of national population exposed to given levels (a) (b)				NOISE LEVEL in Leq (dBA) outdoor measures		ROAD TRAFFIC NOISE % of national population exposed to given noise levels (b)											
United States(c)	Canada(d)	Japan(c)	Europe(e)			United States(a)	Japan(f)	Belgium(f)	Denmark(f)	France(f)	Germany(f)	Netherlands(f)	Norway(a)	Spain(f)	Sweden(a)	Switzerland(f)	United Kingdom(g)
13	2	3	3	> 55	Sleep can be disturbed if windows are open	40	80	68	50	47	72	..	22	74	38	66	50
5	1	1	1	> 60	Sleep and conversation can be disturbed if windows are open	18	58	39	..	32	46	30	12	50	24	28	27
2	1	0,5	0,2	> 65	Sleep and conversation can be disturbed even if windows are closed	6,4	31	12	20	14	18	7,4	5	23	11	12	11
0,6	0,3	0,2	0,05	> 70	Sleep and conversation disturbance; possible complaints	1,8	10	1	..	4	4	1,6	2	7	4	1	4
0,2	0,1	0,1	0,01	> 75	Possible long-term danger for hearing ability	-	1	-	..	0.5	-	0,1	-	1	1	-	1

(a) Expressed in Leq over 24 hours.

(b) Data refers to various years in the early Seventies for different countries. Since many measurements and surveys do not give results in Leq, equations relating Leq and other indices have been used. The margin of error due to national estimates, different years, and to this transformation is probably very important, especially at lower level of noise (± 10%).

(c) For all airports.

(d) For 5 major airports (Edmunton, Montreal, Ottawa, Toronto, Vancouver).

(e) For 34 airports. Broad assumptions were made concerning densities around some airports

(f) Expressed in Leq over the period 6-22 h.

(g) Expressed in Leq over the period 6-24 h, England only.

Source: Table taken from the OECD Report The State of the Environment, Paris, 1979.

estimated that in the United States, the area impacted by aircraft noise could be reduced to 20 or 30 per cent of 1979 values(1) but that could not be achieved until well beyond the year 2000 since the more realistic projections of possible noise exposure for that year indicate substantially less reduction. In terms of the percentage of population exposed to an aircraft noise of more than 65 dBA, the impact in the year 2000 could be reduced in the United States to 58 per cent of what it was in 1975 (and to 50 or even 15 per cent if stricter strategies are adopted).(2) In the United Kingdom, it is forecast that in 1990 the number of people in the vicinity of Heathrow Airport, London, predicted to live within the 35 NNI contour (i.e. around 60 dBA in Leq), will be one seventh of the number in 1974.(3) Forecasts have been made for Schipol Airport in the Netherlands which show a reduction by the year 1990 in the number of households affected to 42 per cent of 1975 figures with a fully noise-certificated fleet. These results will be achieved mainly by a reduction in the noise made by new aircraft, the use of less noisy flight procedures, and so on. There are a number of uncertainties to be taken into account when forecasting future levels of aircraft noise, but in general terms there are good grounds for saying that the population seriously affected in OECD countries will be halved by the end of the century, if noise reductions are not counterbalanced by too large an increase in air traffic volume.

So far as the <u>noise of road traffic</u> in the United States is concerned, however, the impact in the year 2000 will be 23 per cent greater than it was in 1970 if the present regulations (concerning heavy lorries) continue unchanged; it would in fact have been twice as great in 2000 as compared with 1970 if there had been no regulations at all. Even if new, stricter standards are applied to heavy lorries in about 1985, the impact in the year 2000 will still be the same as in 1970.(4)

Moreover if the noise of private cars increases - as may happen in the United States with the increase in the numbers of average and small-sized cars - the effect of stricter standards for heavy lorries will be cancelled out. Road traffic in terms of vehicle/kms is expected to double in the United States between 1970 and 2000.(5) In the

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1) <u>Noise Exposure of Civil Aircarrier Airplanes through the Year 2000</u>, Wyle Laboratory for United States EPA Noise Abatement Office, 1979.

2) Ibid.

3) <u>Airport Strategy for Great Britain</u>, United Kingdom Department of Trade, HMSO, 1975.

4) <u>National Exposure to Highway Noise through the Year 2000</u>, Wyle Laboratory for United States EPA Noise Abatement Office, 1979

5) <u>Transportation Projections 1985-1990-2000</u> by Jack Faucett for the United States DOT, Washington, 1977.

United Kingdom, while 11 per cent of the population was subjected to a level of 65 dBA (Leq) daytime noise in 1970, this proportion will be 14-16 per cent in 1985 and 17-20 per cent in 2000, thus nearly doubling between now and 2000.(1) For the overall situation not to deteriorate, the noise of heavy lorries will have to be reduced by 10 dBA; and for it to improve it will also be necessary to reduce the noise of cars, without overlooking the serious problem of motorcycles. In Switzerland by the year 2000 the proportion of the population exposed to a traffic noise level higher than 65 dBA (daytime Leq) will reach 15-20 per cent compared with 8-12 per cent in 1974, unless greatly reduced noise limits are introduced for motor vehicles. But if very stringent noise emission limits are introduced by the year 1986 (75 dBA for cars, 80 dBA for buses and motorcycles, 82 dBA for heavy lorries), the proportion of people exposed to a level of noise of 65 dBA would fall to 3-4 per cent.(2)

The impact of different development scenarios and anti-noise strategies (higher standards; traffic plans; changes in urban development and traffic routes) has also been simulated in a French study on traffic noise in urban areas of over 20,000 population in the year 2000.(3) This study indicates that even if emission limits are slightly strengthened, the number of people exposed to more than 65 dBA will not diminish (about 8 million people out of a population in 2000 of 40 million living in urban areas with a population of more than 20,000); moreover the number of people exposed to more than 55 dBA will increase by about 20 per cent. On the other hand, if a very vigorous strategy of reduction of noise at source is applied (- 7 dBA for cars and - 9 dBA for heavy vehicles) the number of people exposed to more than 65 dBA could be reduced to 1 million (i.e. eight times less than in 1975). In order to substantially reduce exposure to more than 55 dBA, urban development and traffic route construction would also have to be modified to take into account noise reduction requirements. In this way the number of people exposed to more than 55 dBA could be reduced by half. The French study concludes that a significant reduction of exposure to more than 65 dBA (acceptable limit) can be achieved by reducing noise at source, while for a reduction of exposure to more than 55 dBA (quality target), action affecting the built environment itself must be undertaken.

1) Forecasts of Exposure to Traffic Noise in Residential Areas, D.G. Harland, TRRL, United Kingdom, 1976 (Leq 6-24 h).

2) Report presented by the Swiss Delegation at the Ministerial meeting of the OECD Environment Committee, Paris, 7th and 8th May, 1979.

3) Noise in the year 2000 - Perspectives and strategies, report of French Institute of Transport Research and CERPA, for the Noise and Vibration Committee of the Ministry of the Environment and Quality of Life, Paris, January 1980.

These forecasts suggest that unless road traffic noise is significantly reduced, the proportion of the population exposed to more than 65 dBA (the noise level considered in several countries to be a maximum acceptable threshold) will exceed 20 per cent of the population in the year 2000, or an increase in the sound impact on the population of at least 30 per cent compared with the present time. What is perhaps more serious is the suggestion in some forecasts that noise will increase not only in urban areas but also in tourist regions (the seaside, mountains, inland waters), and wild country (forests, isolated areas, natural parks), especially at weekends and holiday periods.(1) The causes of this will be the continuing growth of leisure activities and tourism, and the increase in the number of secondary residences. The increase in the number of recreational vehicles, the invasion by motor vehicles of areas hitherto spared, and the greater use of tourist aircraft and helicopters, will tend to reduce the number of places and times where there is still silence (or only natural noise).

4. CONCLUSIONS

Many surveys show that noise is considered to be one of the most important environment problems. There are many forecasts suggesting that noise, and especially road traffic noise, is going to increase seriously in the future if much more stringent noise abatement strategies are not implemented.

Present legislation and noise abatement measures will not in themselves suffice to reduce the present impact of noise. At the most, they will stabilize the situation in some cases while allowing it to deteriorate in others.

Only ambitious and comprehensive noise abatement programmes, using a variety of techniques and policy instruments, will enable the present state of the noise environment to be improved. What are those techniques and policy instruments? To answer that question is the precise purpose of this OECD Conference on noise abatement policies.

1) Exposition des Français au bruit et à la pollution dûe à la circulation automobile, IRT-CERNE, Lyon, 1975.

BACKGROUND REPORT NUMBER 2

THE IMPACT OF NOISE

CONTENTS

THE IMPACT OF NOISE

PART I. THE EFFECTS OF NOISE ON MAN

1. INTRODUCTION

Several surveys and opinion polls have shown that noise is a major (sometimes the major) disturbance and source of complaint in the daily life of citizens in OECD countries(1), noise being defined as any sound that may cause undesirable or adverse physiological and/or psychological effects on individuals or groups.(2)

The effects of noise on people are various and often interrelated. For instance, speech interference can result in tiredness and annoyance; but tiredness may exacerbate annoyance and exacerbated annoyance may increase the feeling of tiredness. There are also interrelationships between the general state of health of an individual and the various effects of noise: stresses due to noise induce various reactions in the body and a permanent effect of "adaptation" to noise. That is why the idea that people "get used" to noise is considered by some experts to be a myth: apparent habituation to noise may mean, in fact, biological changes and psychological reactions even if these are unnoticed or unconscious.(3)

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1) a) Toward a National Strategy for Noise Control (results of 1974 annual hearing survey), United States Environmental Protection Agency (EPA), Washington, D.C. 1977.
   b) Results of a poll reported in Sound and Vibration, January, 1979.
   c) Japan Environment Summary, Vol. 7, No. 4, Environment Agency, Tokyo, 1979.
   d) Japan Environment Summary, Vol. 7, No. 2 (results of a survey undertaken in 1978), Environment Agency, Tokyo, 10th February, 1979.
   e) The State of the Environment in OECD Countries, OECD, Paris, 1979.

2) Report to the President and Congress on Noise, United States EPA, Washington, D.C., 1972.

3) a) Effects of Noise on People, United States EPA, Washington, D.C., 1971.
   b) The Social Impact of Noise, " " " "

The effects of noise can be classified in three main categories:

- the physiological effects;
- the effects on activities;
- the psychosociological effects.

2. PHYSIOLOGICAL EFFECTS OF NOISE

2.1 Hearing Loss

It is well known that long-term exposure to high noise levels can result in permanent hearing loss. This is, in particular, the case for people working in a noisy factory. Permanent deafness will probably arise if one is exposed over more than twenty years and during eight hours per day to a noise level of more than 90 dBA Leq.(1)

There is now some fear, however, that noise levels experienced in the day-to-day environment, e.g. in noisy streets, very close to airports, or in some transportation or recreational vehicles, may cause, in the long term, loss of auditory acuity (partial hearing loss). In fact, it seems that hearing damage is determined by the total sound energy entering the ear on a daily basis (noise at work, plus noise in transport, plus noise at home, etc.). As a result, in the United States, the Environmental Protection Agency has concluded that there is risk of permanent hearing damage after 40 years of exposure to a steady daily noise level expressed in Leq. of:

- 75 dBA during eight hours per day, or
- 78 dBA during four hours per day, or
- 81 dBA during two hours per day, or
- 84 dBA during one hour per day.(2)

Along busy streets, near highways, and around airports, noise levels higher than 75 dBA are not uncommon. That is why there is now a fear that auditory acuity of populations living in noisy environments (noisy cities, airports, industrial zones, etc.) could be progressively decreasing with all the psychological consequences of deafening. For instance, it is estimated that 13 million Americans are exposed to an Leq. of 75 dBA or greater in transportation and recreational vehicles(3) and recent OECD estimates suggest that

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1) The ISO recommendation No. R 1999 indicates that the risk criteria is situated at an Leq. of 90 dBA.

2) See Reducing Noise in OECD Countries, OECD, 1978 and Protective Noise Levels, United States EPA, 1978.

3) Toward a National Strategy for Noise Control, United States EPA, 1977.

0.1 to 1 per cent of the population (the proportion varying from one country to another) are exposed to daily noise levels above 75 dBA.(1)

It is also important to realise that the levels quoted above, and those levels actually in current legislation (generally 85 or 90 dBA for eight hour occupational exposure), are based on an assumption of total quiet for the remainder of the day. High environmental noise levels are therefore of great concern, since they will not allow the hearing of a worker in a noisy industry to recover adequately during the period assumed to be "quiet" by protective legislation, rendering the levels in that legislation of limited value.

2.2 Non-Auditory Physiological Effects

Noise induces in the vegetative system a series of functional changes as physiological response reactions: for instance, blood pressure rises, heart rate and breathing speed up, muscles tense, and hormones are released into the bloodstream. This is particularly true for high noise levels or sudden noise events, but it is also true for noise levels commonly experienced in noisy environments such as busy streets, etc.

It is now considered plausible that some disorders (especially cardiovascular disorders and increase of susceptibility to disease) are caused or accelerated by higher levels of noise.(2) This has been and is still the subject of epidemiological studies.

3. EFFECTS ON ACTIVITIES

The effects of noise on activities are the most significant and the best identified ones. They can be classified under three main categories:

- the effects on sleep;
- the effects on communication;
- the effects on performance.

3.1 Sleep

The impact of noise on sleep may at the same time produce physiological effects, disturb an essential activity and, as an indirect effect, reduce performance during the day and create a feeling of annoyance. Such an impact depends (i) on the type and level of noise, (ii) on the psychophysiological state of the person, and (iii) on the time of the night when noise is produced, since sleep is not

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1) The State of the Environment in OECD Countries, OECD, Paris, 1979.
2) The Effects of Noise on Man, K.D. Kryter, Pergamon Press, United States, 1971.

a continuum but is composed of various stages organised in repetitive cycles over the night (light sleep, deep sleep, dreams).(1)

Many studies undertaken so far have been undertaken in the laboratory under artificial conditions. In recent years, however, several studies have been undertaken in situ, i.e. at home, (in France, the United States, etc.). According to these various studies, disturbance of sleep, (prolongation of time for getting to sleep, awakenings, shortening of certain sleep steps) increases above levels of 35-40 dBA Leq. and this disturbance is particularly pronounced in cases of noise peaks above a low background level. The stages of light sleep (50 per cent of the night) seem to be particularly sensitive to noise and the sleep of aged people is even more affected by the impact of noise.(2)

Since the stage of sleep varies from one person to another at any time of the night, one cannot say that one period of the night needs less protection than another. On the same grounds, since aged people are distributed randomly among the population, one cannot have different limits for the general adult population and for the aged. In order to protect the sleep of the whole population, one should therefore take into account the special sensitivity of that important group composed of aged people, especially since this group will become increasingly numerous in OECD countries, according to demographic forecasts.

The question of adaptation to noise during sleep is still subject to debate. Some apparent habituation (no awakening) seems to occur for low intensity levels of well known, usual noise. However, there seems to be very little or no adaptation of the cardiovascular system to high noise levels (above 60 dBA indoors).(3) This raises a double problem: there seems to be little or no habituation to noise; the most important effect of noise on people (in the long run and in terms of public health) may be that noise could lead to or accelerate chronic disorders of the cardiovascular system.(4)

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1) Noise and Audiology, Ed. D. Lipscomb, University Park Press, 1978.

2) a) Report to the President and Congress on Noise, op cit.
   b) Proceedings of the International Congress on Noise as a Public Health Problem, Dubrovnik, 1973.
   c) Protracted Noise Exposure and Cardiovascular Functions, Federal Noise Research in Noise Effects, United States EPA, March 1978.
   d) National Approaches to Community Noise Problems, ECE Task Force, Geneva, 1978.

3) Effects of Noise on People, op cit.

4) a) "The Cardiovascular Response to Acoustic Stimuli", Gerber, S.E. et al., Audiology 16, 1-10, 1977.
   b) Urban Traffic Noise: Audiology and Extra-Auditory Effects, G. Rossi, ed., Acta Otolaryngologica, 1976.

3.2 Communication

The most obvious effect of environmental noise is its interference with communication - speech, and listening to radio and television - because at a certain level noise masks the sound one is listening to.(1) If the communication is impaired, i.e. if a part or the totality of the sound is lost or if special efforts have to be made to overcome the interference (speaking louder, greater attention, etc.) there is a double effect of annoyance and of loss of information. The fundamental nature of speech and listening, and the frequency of their use in almost all human activities, make it clear that interference with speech and listening is one of the worst effects of noise (effects of loss of expression and emotional tone through raised voice, simplified speech forms, etc.). The degradation of our main channel of communication with the world is of serious concern for the protection of human well-being. Loss of information caused by noise interference can be particularly dangerous in cases of masking of auditory warnings, cries of children, malfunction of equipment and approach of vehicles. It can also seriously reduce the quality of teaching and affect the ability of children to learn reading and speaking.(2) The level of a normal voice inside a dwelling ranges around 50-60 dBA. Therefore a safe, background, indoor noise limit for perceiving communication with good intelligibility is between 45 and 50 dBA.(3)

Because of the number of circumstances in which interference with communication can happen - at home, in the office, at school, in recreation areas - and since such interference can occur day and night, this limit is of utmost importance to protect daily life. It should be noted that the level which interferes with communication, contrary to annoyance or sleep disturbance, does not vary greatly from person to person and does not have subjective connotations since the process of communication interference by noise is a straightforward matter of physical objective masking of desired sounds (speech, music). The loss of communication may, however, also result in annoyance and other more serious effects in the long term. These include breakdown of group cohesion, inhibition of close social bonds, and particular problems with education of hearing-aided deaf children.

1) a) Reducing Noise in OECD Countries, OECD, Paris, 1978.
b) Report to the President and Congress on Noise, op cit.

2) "Noise and Children: a Review of Literature", J.H. Mills, JASA 58(4), pp.767-89, 1975.

3) Damage and Annoyance Caused by Noise, Commission of the European Communities, Brussels, 1975.

3.3 Performance

There have been few, if any, realistic studies on the effects of noise on human productivity in general, as the World Health Organisation points out(1), and the effect of noise on specific tasks and performance has mainly been studied in the laboratory. Knowledge concerning this type of effect is slight and contradictory.(2) Noise can distract a person involved in a specific task, this distraction depending on the meaningfulness of the noise and on the psychophysiological state of the person. Because noise can change the state of alertness, it may decrease or increase efficiency. It seems, however, that mental activities involving vigilance, listening and information gathering, and high-complexity tasks are particularly sensitive to intruding noise.

Possible indicators of the effects of noise on performance could be (i) an increase of accidents in very noisy places, and (ii) a less than average language development and reading ability among children exposed to high noise levels at school and at home (see the above section on effects of noise on communication).

4. PSYCHOSOCIOLOGICAL EFFECTS

In addition to the direct effects of noise on sleep, communication and performance, there are indirect and more ill-defined effects of annoyance which result from these direct effects, but which are influenced by various psychological and social factors. These direct and indirect effects can culminate, in certain instances, in complaints and even in organised movements of protest. Such a culmination depends not only on psychophysiological factors but also on social, economic and political variables which are difficult to predict and questionable as a basis for the decision-making process.

In several surveys concerning living conditions, noise is one of the most frequently cited of annoyances in the neighbourhood. The annoyance people feel when exposed to noise is the most outward expression of the stress building up inside them. In certain exceptional circumstances, noise seems to act as a trigger for acts of violence. Several murders and suicides have been initiated by this mechanism, and study in this area is commencing.(3) There are possible psychological effects of noise other than annoyance, but these have not yet been studied in detail with well-defined methods. These are: the fatigue that some people feel when exposed to noise,

1) WHO document EHE/EHC/77.4.

2) "Effects of Noise on Human Efficiency", G.R.J. Hookey, J. Sound and Vibration 20(3), 299-304, 1972.

3) a) The Impact of Noise Pollution, Bugliarello et al., Pergamon Press, 1976.
b) Information Sheet on Noise-Induced, Anti-Social Behaviour, United States EPA.

the irritability and nervousness caused by noise, and even perhaps some mental health effects. Much more research is needed in this area before one can draw precise conclusions.(1)

According to the World Health Organisation(2), noise annoyance may be defined as a feeling of displeasure evoked by the noise. It is generally measured through questionnaires administered to a representative sample of the population. But because of the complexity of subjective reactions and the unreliability of present survey and measurement methods, individual annoyance cannot be predicted as accurately as one would need (correlations generally below 0.45).

The individual annoyance due to noise depends upon the personality and physiological state of the persons exposed, their social habits and activity, and the time of the day.(3)

In order to accommodate the range of individual variations around the average reaction, certain policy decisions rely on statistical relationships showing the percentage of people annoyed or highly annoyed as a function of the noise level. A recent study by T. Schultz tends to indicate that the proportion of people "highly annoyed" increases sharply above an outdoor noise level of 60 dBA Leq.(4) Below an outdoor level of 45 dBA, almost nobody is highly annoyed; around 10 per cent are highly annoyed at a level of 55 dBA; over one-fourth of the population are highly annoyed at a level of 65 dBA; half the people are highly annoyed at 75 dBA and three-quarters are highly annoyed when the noise reaches 85 dBA Leq. [This is in fact a "power" function which may reflect the intensity (severity) of the noise impact as well as its extensity (number of people exposed)]. Some studies (e.g. in Sweden) find even higher proportions however of highly annoyed: 40-45 per cent at 65 dBA, for example and many studies find a linear or sigmoïdal relationship between the proportion of "highly annoyed" and the noise level.

Roughly speaking, the percentage of highly annoyed doubles for each 10 decibels increase on the Leq. index except at very high noise levels, where the increase of the proportion of highly annoyed may somewhat flatten. It is on the basis of psychosociological surveys on noise annoyance that some countries have already adopted limits of noise acceptability to protect residential areas (in the United Kingdom and France, for example). In some countries these upper limits are set at a maximum outdoor noise level of 65 dBA Leq., which however are considered by many countries as fairly high, in

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1) Effects of Noise on People, United States EPA, 1971.

2) WHO document EHE/EHC/77.4.

3) "Subjective Annoyance from Noise Compared with Some Directly Measurable Effects", O. Arvidsson and T. Lindvall, Arch. Env. Health 33(4), 1978.

4) "A Synthesis of Social Surveys on Noise Annoyance", T.J. Schultz, Journal of the Acoustical Society of America, 64(2) August, 1978.

particular for the night period. That is why, for instance in the United States, noise levels perceived during the night are "weighted" 10 decibels more than if they were perceived during the day time.(1)

5. CONCLUSION

The most precise and accepted health criteria concerning noise relate to (i) its interference with communication and (ii) its impact on auditory acuity. In certain countries community response is also an accepted criterion (in the United States, for example). Policy decisions can be taken, and in fact already are, on the basis of these criteria.

Limits based on annoyance and stress criteria are not so easily defined since, for example, reactions to the same sound level vary according to the source type, frequency spectrum, social conditions and many other factors. However, levels can still be set based on current knowledge, provided the necessity is recognised to refine these as more precise information becomes available.

The results of research concerning sleep interference are not widely accepted but they allow derivation of exposure limits which seem to be statistically valid, even if these limits do not take into account all individual reactions. Here again and in spite of some uncertainty, policy decisions have already been taken.

The knowledge concerning performance effects, cardiovascular effects, combined effects with other physical and chemical influences (including vibration) and more generally the possible long-term medical effects, does not yet allow one to derive precise limits of exposure. But these effects are now a subject of concern and need to be further investigated.

Taking into account the above observations, it is possible to propose limits for exposure to noise. In the first column of Table 1, the noise exposure limits already adopted by some countries are shown; in the second column, targets for noise exposure limits are presented.(2)

All these levels refer to relatively steady sounds in urban areas, from e.g. traffic noise.

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1) The United States EPA has adopted the Ldn index which adds a "penalty" of 10 decibels to the noise events perceived at night.

2) a) Reducing Noise in OECD Countries, OECD, Paris, 1978.
   b) Damage and Annoyance Caused by Noise, Commission of the European Communities, Brussels, 1975.
   c) Protective noise levels, United States EPA, 1978 (EPA 550/9.79.100)
   d) Noise Research and Criteria, J.B. Large (mimeograph from the Institute of Sound and Vibration, Southampton, United Kingdom).

Table 1

Situation	Limits adopted by some countries (dBA)	Targets (dBA)
Protection of auditory acuity	85-90 Leq. 8 hours	75-80 Leq. 8 hours
Protection against excessive indoor intrusion	65 Leq. 24 hours outside	55 Leq. 24 hours outside
Protection against excessive communication disturbance (speech, music, television, radio listening)		40 Leq. daytime inside
Protection against excessive daytime annoyance		40 Leq. daytime inside
Protection against excessive sleep disturbance		30 Leq. nighttime(*) inside

*) It should be noted that in several countries the Leq. index is considered as probably insufficient to take into account possible sleep disruption by noise peaks.

It is important to note that due to the subjective nature of some noise reactions, even these levels will not protect all people all the time. In certain cases, at night, in rural areas, for very sensitive groups, etc., levels below the indicated targets may produce annoyance. For this reason, some countries would favour limits which are lower than these in some areas. In addition, the indicated limits and targets are expressed in Leq. whereas it is considered that even at low Leq. values, disturbance may be caused by noise peaks which are not taken into account in the above table.(1) Finally, it should be stressed that more severe noise limits may be required in new situations than in existing situations, (e.g. construction of new roads or new districts).

In spite of still important gaps of knowledge concerning some of the biological effects of noise, it is therefore possible, without awaiting the results of further research, to define noise limits and targets which would protect the population.

However, in order to help those responsible to take decisions which are more effective from the point of view of noise prevention and the protection of the future noise environment, more research is needed in the field of long term effects of noise, including possible cardiovascular effects, (especially the risk of hypertension), stress, sleep disturbance and progressive effects on the hearing

1) The Leq. is an index, integrating the total noise energy. It is a better measure of fluctuating noise than of isolated events.

acuity of the general population. Relationships between noise and these effects have now been established, but what is not certain are the long-term health effects of the short-term changes. It must be recognised, however, that uncertainty in this area is not a reason for delaying action. It is rather a reason to set limits as stringent as practicable until we are more certain of the wider effects of noise.

It appears also that the Leq. scale is not without its shortcomings (at low levels, with discrete events at night, etc.) and therefore, in spite of the widespread use of the Leq. scale, much remains to be done in order to improve the measurement of noise and its effects.

PART II: THE ECONOMIC EVALUATION OF THE SOCIAL COST OF NOISE

6. THE RATIONALE FOR PRICING NOISE

Abating noise costs money(1), although some abatement measures may take place "naturally" through technological progress and through changes in behaviour. The cost of abating noise is measured in money terms but the corresponding benefits are not. If we could express this benefit in money terms, we would have a simple method of calculation that would permit us to define the "best" level of abatement. This will be where the difference between the money benefits of abatement and the money costs of abatement is greatest. It must be underlined that costs and benefits in the sense we will be using are social costs and benefits - they include any costs borne by firms and any benefits received by the public at large.

However, the practice of cost benefit calculation is not necessarily well fitted to the noise problem; since it requires a money estimate of benefits, it raises several theoretical and practical difficulties which will be analysed below.

Nevertheless, for the policy maker, there is a need for an evaluation of social cost, for, in the absence of money measures, he must take his decisions on the basis of costs and whatever "physical" or sociological data exist. Perhaps he has knowledge of "threshold" values for noise beyond which health damage is feared; perhaps he has data on annoyance taken from social surveys, and so on. He can relate this to the money costs of achieving any specific level of noise (this is "cost-effectiveness" analysis) and make a judgement based on the amount of financial resources available for noise abatement or on the number of people who will be exposed to

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1) See Background Report No. 8, The Costs of Noise Abatement.

high noise levels. The attraction of the cost-benefit approach, where both costs and benefits are in money terms, is that this judgement is supposed to be avoided, and what was necessarily a partly subjective and political exercise becomes a more objective exercise, at least in economic terms.

There is an additional theoretical advantage to the policy maker. When seeking methods and instruments for controlling noise nuisance, outright prohibition or regulation provides one set of measures. More likely is that some standard might be set either for the receiving environment or at the source of noise emission. To set those standards again requires some knowledge of the benefits of abatement and we might legitimately argue that the "best" or "optimum" standard (in economic terms) is the one that maximises the net benefits from noise control.(1)

Finally, there are far more valuable aspects of knowing the money value of noise nuisance. One example should suffice. In many discussions on noise abatement policy one comes across the view that the aim is to eliminate noise, or to secure maximum possible noise reductions. This cannot be a legitimate policy objective since it invites the response "at what cost?". That is, such objectives may well mean incurring expenditures which yield extra benefits (measured in money) which are less than the expenditures made to achieve them. These extra expenditures could have been diverted elsewhere. The cost-benefit "model" therefore enables the policy maker to be forearmed with answers and queries about policy statements of this kind.

Some examples of how the cost-benefit approach might be applied can be given in order to focus attention on the policy implications.

In building a motorway planners may wish to give attention to its impact on urban noise levels (noise levels are clearly less important for inter-urban roads, but other effects, such as aesthetic impact can then be more important). The option will generally exist to cut the road below ground level, thus attenuating the noise. Or noise barriers may be placed along the sides of the road. Or special road surfaces to reduce surface noise may be used. The first two policies and probably the last will add to the cost of the road compared to a situation in which these abatement policies were not

1) Moreover, the policy maker may wish to set a noise charge on the source of noise, whether it is motor traffic, aircraft or a stationary source. Such charge proposals exist and some noise charges actually operate, although it would be untrue to say that they are related to anything like the economic calculations outlined above. Nonetheless, if a noise charge is under consideration, the cost benefit approach again permits determination of that charge. For it should be just equal to the extra benefit obtained from reducing noise by one unit at the "optimum" level of noise as previously determined. Such a charge cannot be determined without knowledge of the "optimal" level of noise. See also Background Report No. 5, Noise Charges.

undertaken. Clearly, then, the planner and policy maker need to know whether such measures are worth the expenditure. If it is possible to secure a money value for the <u>benefit</u> that urban residents place on the reduced noise level (compared to what it would have been), <u>then this value can be compared to the costs</u>. If it exceeds the costs, the measures are worth undertaking. If the value is less than the costs this does not mean that the measures should not be undertaken. Rather, consideration should be given to introducing <u>some</u> of the measures, or providing barriers in some places only, and so on. Then the cost of these lesser measures can be compared to the benefits. Perhaps this time the benefits will outweigh the costs. If not, a further analysis should be carried out for even more limited measures, and so on. Only if the policy maker is satisfied that no measure of abatement can be justified by the benefits should he permit the road to be built without any noise attenuation measures.

This example underlines the idea of comparing costs and benefits. It also serves to remind us that we need to look at the costs and benefits for <u>differing levels</u> of noise abatement. Making one observation is not enough.

<u>With an airport</u>, abatement measures may be of two general types. To reduce noise at source requires abatement technologies in aircraft and the same principles as outlined for the road would apply. But care should be taken to ensure that a given noise reduction is achieved at the lowest cost. For example, it may be cheaper to reduce noise by the double-glazing of housing, schools and so on rather than replacing aircraft engines by quieter ones. The issue is complicated by the fact that insulation measures do not reduce "out-of-doors" noise. The cost-benefit approach would then require that an estimate be obtained for the money value of reducing this type of nuisance <u>alone</u>. This value should then be compared to the cost of reducing out-of-doors noise, a reduction that will generally only be achievable by abatement measures in the aircraft (some other measures are possible - e.g. careful specification of take-off and landing routes).

It should be noted however that in addition to noise abatement at source, there are other efficient measures to reduce the noise impact of an airport:

- reduction of aircraft movements;
- time limits (curfews);
- noise charges;
- quieter take-off and landing procedures.

7. THE BASIS OF BENEFIT VALUATION

How then can we attempt to measure the money value of noise nuisance? The economic logic proceeds roughly as follows. If noise is perceived and is not liked, the individual will undertake some avertive behaviour. He may install double-glazing, take sleeping pills at night, engage in political activity to re-route heavy lorries or change flight paths, or he may try to move house so as to secure a quieter (not necessarily a noise free) environment.(1) If we can suppose that there exists some continuum of people, each sensitive to noise in different degrees, and each free to move to that location which satisfies them, then we shall observe changes in the housing market which should show up in the form of differential house prices. In general, we would expect prices in the noisiest districts to be lower than those in the quiet districts. Similarly, the noisiest districts would be inhabited by the least noise sensitive persons and the quiet districts by those who are most noise sensitive.

If housing markets operated this way we might argue that those who have moved have incurred costs which represent their willingness to pay to achieve the level of peace and quiet they desire. All that is left is to observe these costs and we can take them as a proxy for the individuals' willingness to pay for peace and quiet. When summed across all individuals affected by noise we then have the aggregate willingness to pay for noise abatement. Of course, it could be important to try and observe as many different noise levels as we could and to obtain the willingness to pay at each of these levels. In other words, we would have only one observation when what we need are many at differing levels of noise. Otherwise we would not be able to trace out the function relating money values to noise levels and if we could not do this we could not determine the optimum level of noise using our cost-benefit principles. Whether the studies that have taken place succeed in doing this is something we shall discuss shortly. For the moment let us observe one possible oddity in this cost-benefit approach.

Noise nuisance is invariably introduced into a community as a by-product of some legitimate activity (driving a car, flying by air, industrial production). The costs of that noise nuisance are not incorporated into the decisions of those who drive cars, fly by air or produce industrial goods. This is because societies have generally evolved in such a way that "property rights" are vested in the creator of noise and not in the sufferer. That is, the person suffering noise often does not have the "right" to peace and quiet, whereas the noise

1) It might not be always possible to identify such behaviour as noise often induces changes in attitudes rather than in observable actions.

creator does have the "right" to produce and/or use the product which happens to generate noise as a by-product.(1)

If we adopt what we have called the "willingness to pay" approach, what has implicitly happened is that property rights have been vested in the polluter. We are asking the victim to express a valuation of what noise nuisance means to him in money terms and we seek that expression by observing how he behaves in spending his money.

Given the fact that concepts of fairness would seem to demand the opposite - that there is some right to peace and quiet - it seems appropriate to look for different measures of social cost. The one that would fit the argument expressed above is one based on compensation: i.e. finding out what the individual wants by way of compensation to tolerate the noise. Notice that this does not mean the noise levels that exist should be tolerated. After all, the objective of the exercise is to seek values to be used in a cost-benefit study to determine just by how much noise levels should be reduced.

This argument matters a great deal, for two reasons. As we shall see, most studies of noise costs have used the concept of willingness to pay and not compensation. Second, while there are circumstances in which willingness to pay and compensation measures will differ little in practice, for significant changes in noise levels they will matter. Moreover, the compensation figure will generally exceed the willingness to pay figure for the simple reason that the former is not (or is less) constrained by the individual's income whereas the latter is.

8. MONETARY INDICATORS OF THE SOCIAL COST OF NOISE

We may briefly survey the three main methods that have been used to value noise in money terms. The first of these methods has been the most thoroughly researched.(2) The methods are:

i) The house price differential approach;
ii) The exclusion facilities approach;
iii) The survey approach.

We omit some other methods which rely on experimental situations in which individuals are placed in "simulated" conditions and asked to state preferences for certain alternative states of the environment which are artificially presented to them. We also omit some survey approaches which seek to solicit responses from individuals

1) Of course, in some countries, sufferers do claim such rights and often succeed in having them honoured through court awards.

2) For fuller details see OECD (1978). (See Annex 3 for a list of the References cited in Part II of this Background Report).

who are presented with hypothetical budgets and who are asked to distribute these between environmental benefits such as peace and quiet, proximity to shops and so on. It seems fair to say that these studies remain in their infancy and that their success is open to question.

8.1 The House Price Differential Approach

8.1.1 Theory

The House Price Differential (HPD) approach attempts to translate observed HPDs between noisy and less noisy zones into the money valuations that reflect the preferences of the noise sufferers. It is also worth noting that the HPD approach is now widely referred to as the "hedonic" approach. Any house may be thought of as comprising a bundle of attributes whether number of rooms, size of garden, availability of garage, proximity to shops or schools and so on. The level of noise is one more attribute and indeed, can be thought of as a negative attribute. Alternatively, the "inverse" of noise - peace and quiet - can be thought of as a positive attribute. Any household is assumed to aim to satisfy as many wants as possible within its income constraint.

This maximisation procedure leads to the idea of housing expenditures being a function of the various attributes of the house, or in other words, the rental of any house will be determined by the attributes of the house. We may then convert from a rental to a property value since the latter is only the capitalised value of the former at some discount rate ruling in the housing market. In this way, the value of the house is dependent upon the attributes of the house. Noise levels will then be one of the many attributes contributing (in this case negatively) to the property price.

To find the willingness to pay of the householder for an extra unit of any attribute (the "marginal" valuation) we simply see how the price of the property would change if that attribute was changed by one unit. This change in valuation is the "hedonic price" or the "marginal willingness to pay" for the attribute. If we can obtain this change in house price with respect to a small change in noise levels we shall have secured the requisite hedonic price.

What it essentially reduces to, is a statistical exercise of observing the values of the selected attributes of houses including noise, observing house prices and relating them to each other through a statistical regression procedure.

8.1.2 Practice

Numerous studies exist which adopt the approach outlined above. Annex 1 summarises the results for aircraft noise, although it must be borne in mind that there are some serious problems of comparing one study with another. Few studies use the same noise measure and all use different functions forms for the regression equations. Nor is the methodology always clear from the studies. Annex 1 is therefore a "best guess" approach to comparing these studies.

Of course, there is no particular reason why HPDs in any two areas should be the same. Advocates of HPD approaches might argue that individuals in noise-affected zones in Chicago and Los Angeles have similar taste patterns such that their valuations will be the same. If this were so, one might adduce the similarity of results as confirming the similarity of "utility" functions. However, Annex 1 shows that estimates are not the same and, indeed, diverge quite widely between areas.

Annex 1 has attempted to "normalise" the various results in terms of a percentage depreciation for a standard house of US$28,000 in 1970. There are formidable difficulties in doing this since noise measures differ between studies and in some cases functions have been used which imply valuations which are increasing functions of house price, as noted above. As far as possible, however, the results have been standardized.

The comparable statistics in Annex 1 are shown in the penultimate columns inside "boxes". The major point to note is that a one unit change in NNI leads in all United States cases to a <u>less</u> than one per cent change in house price. Arguably, a one per cent change in house price per unit NNI change in the United States is therefore an upper limit of the damage cost estimate. Note, however, that the Third London Airport study results are well <u>above</u> unity. Certainly, the one per cent figure has been seized upon in other practical studies of noise changes (see COWAPS, 1977). However, the <u>range</u> of estimates in Annex 1 is wide and is certainly too wide to support the view that the similarity of results is evidence of the validity of HPD approaches.

Thus, <u>the depreciation index varies from 0.18 to 1.46</u>. Walters'(1) range for the United States studies is 0.4 to 0.8, although he takes the range 0.4 to 0.7 to be representative. In fact, however, the range for the United States studies is 0.18 to 0.90. Thus, whereas Walters suggests a valuation of US$100 to US$175 per unit NNI in the United States, Annex 1 makes the range US$50 to US$252. The data suggest that little faith can be placed in policy proposals that rest on interpretations of the empirical results of HPD studies.

The situation with respect to <u>urban traffic noise</u> is even more unsatisfactory. Annex 2 attempts to draw together in as comparable

1) Walters (1975).

a form as possible the results of property price approaches which relate to noise from road traffic.(1) If we consider these results we find a significant range in the house price depreciation index: 0.18 to 2.20. However, the Gamble study ranges over four areas and the depreciation indices range from 0.20 to 0.43 for US$33,000 houses in North Springfield (Virginia), Rosedale and Towson, up to 2.20 for a US$29,100 house in Bogota, New Jersey. These figures may be compared with Nelson's value of 0.18 for a similarly priced house. Annex 2 also shows that the Vaughan and Huckins result relates to a US$25,000 house. They report values for differently priced houses and different noise levels. Their value of depreciation rises (rather slowly) with the level of dBA - i.e. it is not a linear function, but for any given noise level the depreciation value is a constant percentage regardless of the value of the property.

To try and secure some comparison we take the 75 dBA level in the Vaughan/Huckins study since this is nearest to the levels in the Gamble study and the Hall study. Then for a US$33,000 house we secure a depreciation index of 0.76 per cent per dBA. Thus, interestingly, if it were legitimate simply to "scale up" in terms of house prices, this would imply about US$240 per dBA compared to the US$600 per dBA reported in Hall for a very much higher priced house. The Vaughan and Huckins study secures results well above those obtained by Nelson and only one of the results secured by Gamble can be thought of as giving support to Nelson's findings. Note that the study years are close together so that house price inflation is not likely to have much influence.

Clearly, the results for traffic noise indicate that one can have no faith at all in money measures of benefits based on HPD approaches. Even where results are positive and comparable, we must conclude that house price studies show a wide divergence of outcome. Now, if we draw attention to the studies securing no correlation, we note that Nelson's urban study and Diffey's study secure statistically insignificant relationships. Towne's study also secures little impact, while Colony's study secures a result but we have no direct way

1) Four results in Annex 2 can be considered comparable. The Vaughan and Huckins study uses dBA as its noise measure, while Nelson's study uses dBA but measured as the difference between peak (L_{10}) and background (L_{90}) noise. Moreover, the Nelson result is constrained to areas where $L_{10} - L_{90}$ is at least 8 dBA. The Gamble study uses NPL which has two components - the first of which is noise intensity and the second a variability (standard deviation) measure. NPL as used by Gamble has dBA as a measure and terms in $L_{10} - L_{90}$ (as suggested by Robinson - see footnote to Annex 2). Hence, the noise measures used by Gamble, Vaughan/Huckins and Nelson are broadly comparable. The Hall study also uses dBA but notes that a statistically meaningful result emerges only at levels above 73 dBA.

of comparing it to the others. When the statistically insignificant results are allied with the variation observed in the studies reporting positive results, we must conclude that the "state of play" in traffic noise/property value studies is very much inferior to that for aircraft noise.

8.1.3 Conclusions about the House Price Differential Approach

What can be concluded about the house price depreciation approach?

As a matter of fact, noise seems to influence house and land prices, but results are widely dispersed and sometimes of little significance. The general question is whether those figures mean anything: what do they measure? In fact the social cost of noise encompasses many elements, and various types of damages:(1) which types of damage are actually measured by house price depreciation?

An important criticism relates to the fact that the theoretical conditions to be fulfilled in order to ensure that an observed price differential be a valid measure of benefits are so restrictive that they are never likely to be met.

One of these assumptions is that all individuals have the same utility function, i.e. they value the components of their welfare and happiness (including noise and quiet) the same way. It is immediately apparent that, since people's tastes differ, such a requirement is far too restrictive.(2) In fact, one is measuring single observations of many different individual utility functions, whereas it is the reverse which is required, i.e. many observations of the same function.

Also, the housing market must itself be very efficient in the sense that immediately when there is any change in noise levels, people must move houses so that the population adjusts itself to locating each individual in the area where he finds the level of noise most acceptable (given that high noise will, on this analysis, be offset by lower house prices, other things being equal). Even casual observation of the housing market suggests that no such adjustment procedure takes place except in the most limited fashion. Only the rich can afford to move with such comparative ease and many residents will be "tied" to an area by their job of work or by the simple fact that they cannot afford to move (an effect which is of course made worse if their house falls in price).

Now, looking at the empirical results shows that indeed HPD estimates diverge quite widely between areas. If some depreciation is actually identified, the most one can say is that a financial loss is taking place. But it does not reflect the social cost of noise.

1) See Part 1: The Effects of Noise on Man.

2) The theoretical criticism is somewhat complex; it is detailed in Harris (1978) and Pearce Harris and Edwards (1979).

What are the implications for policy making? The conclusion must be that no reliance can be placed on house price studies for use in the formulation of policy measures. That is, house price depreciation measures should not be used for the formulation of noise charge proposals nor for decision-making about the level of noise abatement to be introduced surrounding airports, industrial installations or roads. Nor can they be aggregated to secure some measure of "national" benefit to be secured by national anti-noise legislation. The empirical results simply do not support the use of such approaches; neither does the theoretical analysis.

8.2 The Exclusion Facilities Approach

We have dwelt extensively on the HPD approach since this methodology has dominated the literature and appears to be the only one which has so far influenced policy-makers. We may briefly look at the exclusion facilities approach as developed by Starkie and Johnson (1975). This rests on the observation of one of the other forms of avertive behaviour that noise sufferers may take, namely to double-glaze their houses. Clearly, in spending money to reduce noise these householders have indicated something about their willingness to pay to reduce noise. The full methodology is given in Starkie and Johnson (1975) and it is also surveyed in OECD (1978).

From data on expenditure on double-glazing, Starkie and Johnson estimated that individuals were willing to pay about £90 (1975 value, i.e. about £130 or US$260 in 1978 prices) for the insulation of five rooms in order to secure a reduction of 14 dBA. This amounted to about 5 per cent of the incomes of the individuals concerned. This is in keeping with the findings of the Commission on the Third London Airport study, although per decibel we may note that it implies a very small sum, only £5 per decibel. In addition, we must remember that double-glazing serves more than one function - it also insulates the house against cold and has anti-theft properties. The implied price per decibel is therefore lower than £5 since noise reduction is a "joint good" with these other features.

8.3 Social Surveys

Despite the abundance of social surveys on noise nuisance few attempts have been made to elicit money valuations from them. This perhaps reflects doubts about the value of survey responses, especially after the attempts by the Commission on the Third London Airport Research Team to elicit responses as to householders' willingness to accept compensation in order to move from a hypothetically development designated site. These questions resulted in a significant number of persons stating that "no price" would compensate them. They have since become known as the celebrated "infinites", since they apparently implied a valuation of infinity on noise nuisance. This is not in fact correct since their answers are consistent with the possibility that they were unable to translate such questions into money, or that they saw the idea as some infringement on a right to stay where they were. Nonetheless, it is understandable that suspicion surrounds survey approaches.

Direct questionnaire approaches have been used by Ollerhead (1973). Residents at London, Heathrow Airport were asked (a) "What amount per year would be fair and satisfactory compensation for the noise nuisance?" and (b) "How much per year would you be willing to pay to keep the area completely free of aircraft noise?". The non-specification of the noise levels creates a slight problem in that respondents were being asked for valuations of the total noise at Heathrow rather than for valuations of changes in noise levels. However, the results accord with intuition insofar as requirements for compensation were £77 per year and willingness to pay was £27 per year (i.e. respectively in 1978 value, £158 - US$316, and £55 - US$110). Some 47 per cent of those asked were not prepared to pay anything to reduce noise, a result which accords with the view that people do not see why what they regard as a "right" should be something they have to pay to secure.

A recent study done for the French Ministry of Environment (1979-unpublished) shows that the great majority of persons questioned refuse to give any form of money evaluation. On the other hand, the willingness to pay of those who accept to reply appears to be fairly high /between Frs.3,000 (US$696) and Frs.6,000 (US$1,392) per year for Orly airport, and Frs.2,400 (US$556) to Frs.4,100 (US$950) per year for a suburban highway7.

9. CONCLUSIONS AND PROPOSALS

The outcome of this brief analysis may be summarised as follows: much as the cost-benefit approach to determining noise abatement policy is desirable as a method of thinking, it has no practical application because no satisfactory way of estimating the money value of benefits has been achieved. This conclusion holds despite the enormous research efforts of recent years. Indeed, it is these very research efforts that have revealed exactly what has to be assumed in order to construe some of the money valuations obtained as measures of the benefit of noise abatement. We may note too that, even if these measures had validity, they are largely based on the idea of what a noise sufferer is willing to pay and not on what he requires in compensation. We have suggested that this violates a principle of fairness in that noise sufferers should be seen to enjoy natural rights to a clean and quiet environment.

At the level of policy we may state the following conclusions:

i) It is important to measure the costs of abatement as accurately as possible in money terms.

ii) Unless there is some major breakthrough in economic methodology, it is dangerous to make use of empirical results from economic studies for purposes of estimating the benefits of noise abatement.

iii) The measures of benefit so far achieved offer very limited guidance to minimum or maximum estimates of benefit for both theoretical and empirical reasons.

iv) Because of conclusions (ii) and (iii), monetary approaches to the social cost of noise cannot be used to give the perfect "objective answer" to the policy maker as cost-benefit analysis is supposed to do.

v) The state of the art in the use of the social survey does not permit reliable estimates of the social cost of noise in monetary terms. Further investigations are needed.

Therefore the policy maker should rely more on cost effectiveness analysis. Here the costs of abatement are related to various physical measures of noise nuisance, health damage and so on; for instance, the policy maker can now use quite reliable non-monetary estimates of the effects of noise (so called "non-monetary damage functions"), e.g. establishing the relationship between various noise levels and the percentage of highly annoyed people (see Part I on the health effects of noise). By comparing the two (cost and damage), the policy maker can then see how much nuisance reduction he will secure for how much money. In setting policy he must therefore use judgement. In the cost-benefit approach we may note that the scope for judgement is reduced since, as much as a policy maker may wish to use money benefit measures as a "benchmark" only, there is a clear temptation to accept the money measure as at least an approximate order of magnitude.

But in using judgement in a cost-effective approach, is there not as much room for error as in using the cost-benefit approach? Arguably there is, but the suggestion here is that the cost-effective approach makes it much clearer to the policy maker what it is that he is going to secure for a given level of expenditure.

ANNEX 1

HOUSE PRICE DEPRECIATION INDEX: AIRCRAFT NOISE(1)

Author Study	NELSON (NEF)(2)	WALTERS (NNI)(3)	NELSON (NNI)(4)	WALTERS [NNI + adjusted(5) price]	AIRPORT
McCLURE (1969)	-(6)	0.7	-	0.78	LOS ANGELES
COLMAN (1972)	-	0.7	-	0.78	ENGELWOOD, CALIFORNIA
PAIK (1970) (1972)(7)	1.6-2.0	0.7	0.7-0.9	0.78	KENNEDY
EMERSON(8) (1969)	0.4	0.55	0.18	0.62	MINNEAPOLIS
DYGERT and SANDERS (1972)	-(9)	0.4-0.8	-	0.45-0.90	SAN FRANCISCO
DYGERT (1973)	0.5	-	0.20	-	SAN FRANCISCO
PRICE (1974)	0.4	-	0.18	-	BOSTON LOGAN
NELSON (1975, 1976)	1.0	-	0.44	-	WASHINGTON
MIESKOWSKI and SAPER(10) (1976) (i) (1976) (ii)	(CNR) 0.3-0.5 0.8-1.0	-	(NNI) 0.2-0.34 0.54-0.67	(NNI adj) 0.18-0.31 0.49-0.60	TORONTO
CTLA (1970)	- -	1.0 1.3	- -	1.12 1.46	HEATHROW GATWICK

NOTES TO ANNEX 1

1) House Price Depreciation Index = % change in house price with respect to a unit increase in noise. The full references to the studies can be found in Pearce and Edwards (1979).

2) Nelson's original results per unit NEF (Noise Exposure Forecast) with house price of US$28,000.

3) Walters' original results per unit NNI (Noise and Number Index) with house price US$25,000.

4) Nelson's results converted to NNI using 1 NEF = 2.5 NNI. Some dispute exists as to whether this simple transformation is legitimate and, if so, what its numerical value should be.

5) Walters' original results converted to a US$28,000 "standard" house. In Emerson's study, depreciation is an increasing function of house price so that the result here may understate the "true" value. However, Walters (1975) doubts the validity of the assumed increasing function in Emerson's study.

6) A dash means that the study in question was not considered by the relevant author.

7) The figure of 1.6 is obtained from Paik's study but Nelson reports an adjusted figure of 2.0. In fact, the Paik study has a range of 1.85 - 2.46 for 20 - 40 NEF.

8) It is not clear why Walters and Nelson report such different results for Emerson's study.

9) The Dygert and Dygert and Sanders studies report the same results.

10) The Mieskowski/Saper study was not considered by either Nelson or Walters. Noise units used were CNR and the conversion used for Annex 1 is 1 CNR = 1.5 NNI. Study (i) relates to Etibicoke for CNR = 95 - 105, house price of US$35,000 and an apartment price of US$25,000. Study (ii) relates to Mississuaga for the same noise and price levels. Houses and apartments are in the approximate ratio of 60:40 so we have used a weighted average of US$31,000 as the price to be converted to US$28,000 to secure comparison with other studies: i.e. a conversion factor of 0.9.

ANNEX 2

HOUSE PRICE DEPRECIATION INDEX: TRAFFIC NOISE(1)

STUDY	NOISE UNIT	HPD %	COMMENT
Vaughan and Huckins (1975)	dBA	0.66 - 0.76	US$25,000 house, Chicago. See text.
Gamble et al. (1974)	NPL(2)	0.24 - 2.20	US$25,100-US$33,000 houses, various areas See text
Colony (1966)	distance	20 - 30	See text
Towne (1968)	-	negligible	Rental values used
Nelson	L_{10} - L_{90} (dBA)		See text
(i) Suburban (ii) Urban		0.18 0	
Diffey (1971, 1975)	dBA	0	
Hall(3) (1978)	dBA	1.3	House prices of between US$50-60,000

NOTES TO ANNEX 2

1) The full reference to the studies cited can be found in Pearce and Edwards (1979).
2) NPL = Noise pollution level. See Robinson, (1971).
3) For noise levels above 73 dBA daytime Leq. Note that this study finds 60 - 65 dBA as "causing annoyance" but not affecting house prices.

ANNEX 3

REFERENCES (PART II)

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BACKGROUND REPORT NUMBER 3

REGULATING FOR NOISE ABATEMENT

CONTENTS

1. INTRODUCTION

The regulatory approach has always been the principal method by which the authorities have attempted to control the noise pollution problem. Records of local noise statutes date back to the days of the Roman Empire, when a law was passed to limit the nuisance produced by chariot wheels on cobbled streets, and in more recent times there are many examples of regulations attacking the modern equivalent of this problem. Almost without exception until fairly recently, noise regulations have been based on the concepts of "nuisance" or "annoyance", and were often unenforced, and indeed unenforceable in many cases. The history of noise abatement is full of local attempts to solve specific problems, with the occasional brave attack on a broader front which failed because of lack of understanding of the difficulties.

It is important to distinguish between the basic philosophy behind the early types of regulation, and the philosophy which is becoming accepted as more realistic now that the problem is better understood. In general, authorities were stimulated to introduce regulations by vigorous complaints from residents or other interested parties. Such regulations were usually added to other groups of minor miscellaneous legislation which were put together for administrative convenience, such as general police regulations, or regulations for public nuisances or health.(1) In more recent times, however, noise has been recognised as a general form of pollution and a health hazard, differing of course from air or water pollution, but being even more pervasive.(2)

It also became evident that effective control of the major elements of noise pollution (motor vehicles, aircraft noise, some industry) was well beyond the unaided expertise of the local authorities which historically had tried to do the job, and national and international bodies are now major regulators in the noise abatement field. This is partly because many major noise sources evidently need control on an international scale on the highest level of authority possible (aircraft and motor vehicles), and partly because of the particular problems that noise as a form of pollution presents to those who try to regulate it.

1) See Reducing Noise in OECD Countries - OECD 1978.

2) See Background Report No. 2, The Impact of Noise.

The major difference between noise and other pollution forms is its breadth and depth of social interaction. This contrasts with for example, chemical pollution, with which the bulk of the general public has no direct connection, and where there is therefore little sense of public responsibility or involvement. With noise, the population is involved much more widely and directly, as both producer and sufferer. Every person who drives a car contributes to the overall noise problem, and indeed such a large range of human and particularly urban activities involve noise production or exposure that there is a natural defensive reluctance for the man in the street to admit that a general problem exists, even though he may complain vigorously about his neighbour's noisy parties.

There is thus a sociological and psychological side to noise pollution. The abatement problem is closely linked to human behaviour, and failure to recognise this contributed to early lack of progress in dealing with the situation.

Noise is a unique legislative problem, which requires solutions which are somewhat different to those which have classically been applied to pollution problems. As the following sections will show, it is not nearly as amenable to a "brute-force" attack by means of simple direct regulations as are most other pollutants, and requires a much more broadly based approach.

2. APPROACHES TO NOISE REGULATIONS

Existing national approaches to noise regulations fall into two main categories: "scattered" regulations and laws, and comprehensive laws. The distinction between the two is that the individual regulations in a "scattered" system aim to control individual specific types of noise pollution (e.g. traffic noise, industrial noise, land planning aspects, etc.) without necessarily relating control of one source to that of another. A comprehensive law system aims to set up an overall philosophy for a group of interrelated laws and attempts noise abatement through a co-ordinated effort on a broad front.

2.1 "Scattered" Regulations

Most OECD countries have a system of "scattered" regulations, though some of these systems are being modified gradually to become more comprehensive, without the more formal structure of a true comprehensive law. The usual form of a "scattered" system is that regulations controlling, say, construction noise, are grouped with other construction regulations; those dealing with traffic noise are with other general transport regulations, and so on.

The advantages of "scattered" regulations are several. Firstly, since there is usually no major noise abatement law involved, the political passage of the law or regulation is easier; it is usually just a matter of adding to or modifying existing rules on the same subject. Secondly, the responsibility for the noise regulations is normally given to the department which already deals with the rest of that group of, say, traffic regulations, so no new controlling authorities need be set up. Thirdly, if changes are necessary at some time in the future to improve the law or adapt it to changing conditions, there is no great political or administrative problem involved in so doing. In summary, "scattered" regulations are politically and administratively simple to introduce and modify.

The disadvantages of "scattered" laws are more numerous, but rather less well defined, being much more dependent on the situation in the country involved.

Firstly, the system tends to lack coherence because the individual regulations are each designed for a limited and very specific purpose, and even sometimes for purely local and temporary conditions. Even where the law has a clear and more general purpose, it can be difficult to ensure compatibility with other laws, particularly between laws of neighbouring local jurisdictions, without a clear and overriding national or international guideline. The problems this can cause are demonstrated by the failure of a law which was introduced in New York to combat construction noise by placing restrictions on equipment. To avoid the restrictions, the plant owners simply removed their machines to a neighbouring district which had no such controls.

Secondly, the past lack of recognition of noise as a serious problem has tended to linger in many places, and those enforcing the law are likely to ignore its noise clauses in order to concentrate on parts dealing with problems that seem to them to be more important or urgent, for example air pollution, or speeding infringements. This neglect also can become a feedback mechanism; the lack of legal activity means that the responsible department, the lawyers and the courts do not become familiar with noise and the laws concerning it. Each case becomes a test case, and the authority is consequently even less inclined to apply fully the legal abatement tools available to it.

Thirdly, the lack of coherence has the result that it is much more difficult to programme objectives (such as reducing motor vehicle noise levels) because with no overall pattern to the legislation, and little co-operation between departments, improvements cannot be co-ordinated with other areas of progress, making prediction of potential successes very difficult. Another important planning goal which is very difficult to achieve under a "scattered" system is programming and control of expenditure on noise control. Where noise abatement effort is distributed among a number of departments, it is far more difficult to arrive at an accurate assessment of the costs of noise abatement, and worse, it is almost impossible to establish cost effectiveness of the programme.

The most serious long-term defect of "scattered" laws is that they lack an overall sense of purpose. There is no definitive framework within which minor policy decisions can be made consistently, and no basic stated philosophy which is always accessible to indicate desirable future directions. This means that decisions may often be made having too much regard for factors which are not related to noise abatement at all (local politics in particular), and makes it much more difficult to set priorities and arrange the inter-departmental co-operation which is necessary for an overall noise control programme.

During the 1960s it became recognised that countries which had set effective controls on some noise sources were suffering from the lack of activity of their neighbours, particularly where mobile sources like cars and aircraft were involved. This resulted in pressure for international co-operation, and pressure between countries where problems existed. This external influence rapidly showed up the incoherent nature of many noise laws, and moves began to provide a basic structure, prompted also by the results of the many commissions of enquiry that were set up. (The United Kingdom's Wilson Committee, which was set up in 1960 and reported in 1963, is probably the best known of these.)

More widely based laws were passed in some countries (Germany, Sweden, Switzerland's noise reception standards) in the hope of improving the performance of legislation without changing to a fully comprehensive structure. In fact, in 1963, a Swiss Commission of Experts, while recommending substantial detail changes to the law in that country on noise, came to the conclusion that "it does not seem necessary to unite in one noise abatement law all the different existing federal regulations".

2.2 Comprehensive Programmes

A comprehensive programme is one which attempts to bind together all the elements of a noise control effort: education, regulation and other direct and indirect methods, into a single body. The only OECD countries that have fully comprehensive programmes (embodied in comprehensive laws) at the present time are the United States and the Netherlands, although Germany has a programme with comprehensive elements, and France, Switzerland and Norway are in the process of drafting comprehensive laws. Some states in Australia are also moving towards comprehensive structures.

The advantages of a comprehensive programme are many, but in the main stem from one basic fact: it gives a structure to noise abatement. Without the necessity of replacing fully a system of scattered regulations, it can fill the gaps in existing legislation (particularly where indirect methods such as labelling schemes, education and noise charges have been lacking) and weld the whole into a set of laws that can truly be called a noise abatement programme. It provides a single reference document for deciding questions of priority and responsibility in order to avoid the overlap or inaction problems that easily occur otherwise, and it allows the timetabling of clear objectives into the programme, with some hope of being able to predict progress - a valuable asset which certainly cannot be achieved with scattered regulations. In addition, a comprehensive programme gives the ability to accurately programme expenditure and allows cost-effectiveness to be monitored. Comprehensive programmes give the ability to avoid problems of major inconsistency between jurisdictions (for example the New York case referred to earlier), and this co-ordination and definition of precise objectives means that progress can be achieved for far less cost by encouraging efficient use of resources. In addition, if there is a single specialised body with overall (but not detailed) responsibility for administering such a programme, a team could be assembled to look into all the aspects of noise regulations - enforcement, economics, education etc. - avoiding the problems caused by the inevitably limited viewpoint of, say, a Department of Health trying to administer a small part of a noise campaign.

In summary, a fully comprehensive programme contains the structure to allow use of all the most effective abatement methods for a given source of noise, and not just emission controls for motor vehicles, for example, or land use restrictions only for areas around airports. Such a programme need not be centrally administered if it contains a definite enough structure - it can supply the legal tools, and often the local enforcing authority can decide which to use in a particular case. These advantages are becoming recognised as significant, and there is a definite move in the direction of more and more comprehensive legislation and/or programmes. In fact, the OECD Council adopted in July 1978 a recommendation on noise abatement policies, the first paragraph of which recommends that Member countries "develop comprehensive noise abatement programmes".(1)

3. TRAFFIC NOISE CONTROL

There have now been so many surveys and studies on the subject of the relative impact of different noise sources that there can be no doubt that traffic noise affects by far the most people. By its

1) Recommendation of the OECD Council, C(78)73(Final), 3rd July, 1978.

nature it is obviously related to population density, and is therefore principally an urban problem, but the inherent mobility and large number of the sources spreads the undesirable effects and makes in-use regulation difficult, as the slow progress in the field indicates.

3.1 Source Regulation

Most countries now have emission regulations for the main classes of new motor vehicles. This type of control is now almost uniform between countries in its general principles (with the exception of the system of setting levels in the United States), due mainly to the great degree of international co-operation in the interests of harmonization particularly in the European Economic Community and the United Nations Economic Commission for Europe Working Party No. 29.

The general features are that specific levels are set for each class of vehicle using a test method that is usually ISO R362 or a modification of it. New vehicles are "type approved" to these standards, with occasional sample checks at intervals to ensure continuing quality.

3.1.1 The Case of the United States

The exception to this general rule is the system in the United States where the Noise Control Act (1972) states that the Environmental Protection Agency (EPA) must study and formally identify major noise sources, then set regulatory levels for them. The sole exceptions are interstate road and rail carriers, which the Act specified must be controlled within time limits stated in the legislation.

EPA regulations were promulgated to be effective on 15th October, 1975, limiting the noise emissions of interstate road carriers. The responsibility for enforcing this law lies with the Department of Transportation, and with the states and localities. In addition, in October 1977, EPA requested Congress to amend the Noise Act to allow civil penalties, and this was done as part of the Quiet Communities Act in 1978. EPA opinion is that this move should considerably strengthen enforcement efforts.

Under the terms of the Noise Control Act, EPA has formally identified and published regulations for medium and heavy trucks, and proposed regulations for tractors, motorcycles, buses, truck-mounted waste compactors and truck refrigeration units. It is at present studying automobiles, light trucks and tyres prior to making the identification decision required by the Act.

All the major motor vehicle regulations in the United States are implemented and enforced by either the Department of Transportation (in the case of interstate carriers) or the states and municipalities in other cases. EPA is the national "approving body", but its enforcement effort is more or less limited to sample testing of new products. As in other areas of noise abatement, however, the states and local authorities can regulate vehicle emissions themselves until the federal government "pre-empts" with its own regulations. At that time, the lower level authorities must adapt their own rules to correspond with the national standards.

One of the reasons for the apparently slow progress on these regulations is that the Act requires explicitly that the available technology be taken into account in the regulated levels. This, combined with the high probability that the regulated levels will be challenged in court, means that studies to decide the basis for the regulations must be extremely thorough and wide ranging.

3.1.2 Other Countries

The situation is much simpler in other countries which do not have the statutory requirement for the national agency to formally identify sources prior to acting. The difficulties here come more from conflicting interests such as the desire to both regulate noise nuisance, and simultaneously protect an important national industry from severe economic impact. The problem becomes particularly acute when regulations are being set at international level, and some countries have much stronger industries than others. The end result tends to be that the regulated levels are a compromise weighted towards avoiding trade barriers and protecting weaker producers, rather than environmental protection.

3.1.3 Results of Emission Controls

Although emission standards have been on the statute books in several countries since the 1950s, it is only recently that they have been widespread enough for some significant effect to be expected. Even now, it would be hardly possible to detect the drop in actual measured traffic noise levels, partly because the replacement cycle for motor vehicles limits the speed of change (it takes a high proportion of quiet vehicles to make a significant difference to total traffic noise), and partly because the actual in-use emission depends so much on the way the vehicle is operated. (More comment on this aspect of the problem will be made in the section on enforcement).

Even for individual vehicles there is not yet very much clear information available. Data from the Netherlands has shown that the median noise emission for cars submitted for type approval has dropped from 78dBA in 1971-73, to 77dBA in 1976-77. Figure 1 shows that even in 1977, some 80 per cent of vehicle types already bettered the 1980 EEC limit (for new models of vehicles) so there is

Figure 1 NOISE LEVELS PRODUCED BY PASSENGER CARS, CALCULATED ACCORDING TO THE EEC DIRECTIVE (7.5 m DRIVING PAST THE NOISE METER) MEASURED OR BETTERED BY THE PERCENTAGES SHOWN (The Netherlands)

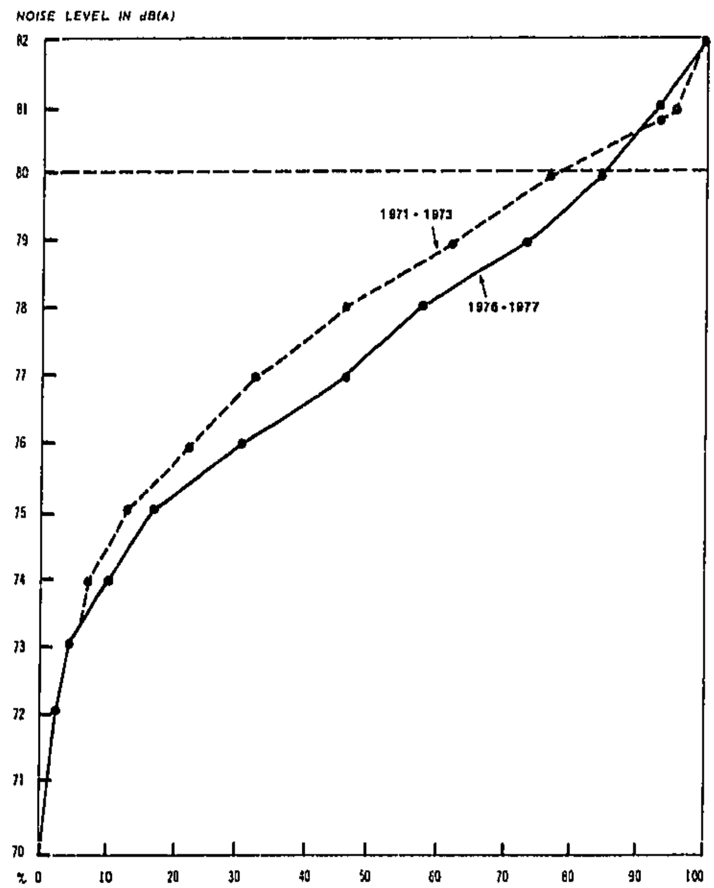


TABLE 1

MOTOR VEHICLE NOISE LIMITS AND TARGETS (measured at 7.5 metres)

	EEC Until April 1980 (1)	New EEC limits (1)	USA		Switzerland 1977/82/86	Japan 1979/targets	Nordic countries (Sweden, Norway, Denmark, Finland) Proposals for 1985	German proposals for 1985	Compromise Proposals for 1985 of WP.29 GRB
			Current	Proposed					
Automobiles	82	80	86 (4)	-	80/77/75	81 / 78	76	75	77
Vans (less than 3.5t)	84	81	-	-	81/79/77	81 / 78	77	78	79
Buses (less than 3.5t)	84	81	-	-	81/79/77	81 / 78	77	76	79
Heavy buses (more than 3.5t and horsepower less than 200 HP Din)	89	82	-	89-83	85/82/80	86 / 83	80	80	80
Heavy buses (horsepower more than 200 Hp Din)	91	85 (2)	-	89-83	87/84/82	86 / 83	80	80	80 (3)
Lorries (more than 3.5t and horsepower less than 200 HP Din)	89	86	89	86	86/84/82	86 / 83	80	80	80 (3)
Heavy lorries (horsepower more than 200 HP Din)	91	88	89	86	88/86/84	86 / 83	80	80	80 (3)
Motorcycle (maximum size)		86	84 (4)	89-86	85/85/60	81 / 78	80		

1) EEC limits allow + 1 dB tolerance.

2) Applicable from 1982.

3) Limits to be applied at a later date than 1985.

4) California only.

obviously no technical reason why noise limits should not be reduced further in the future (see Table 1). In fact, Germany is proposing to the European Communities a further reduction of noise emission limits for the year 1985.(1) These proposed limits are shown in Table 1. Switzerland has had noise limits of the same order as the 1980 EEC standards since 1977; these Swiss limits will probably be strengthened again in 1982 (See Table 1).(2)

3.2 Other Controls for Traffic Noise

In the previous section, source control has been taken to mean individual vehicles, since "source" and emission controls are usually closely linked or the same. When we must consider a road system as an extended source, controls at reception become more appropriate, and the emphasis on control must change towards planning, both of the engineering details of the road, and of the land use in the bordering area. If traffic noise is to be adequately controlled, measures other than direct source emission control must also be applied, since increases in traffic volume and inconsiderate usage can far outweigh the gains achieved by emission control for new vehicles. The detailed action to be taken in any particular case will vary greatly, but it is possible to set up a general priority list, based on the principles that noise should be regulated as close to source as possible, and that it is more effective and desirable to control noise in the planning stages by avoiding problems, rather than by trying to improve the situation after they have occurred.

Traffic Controls of many kinds (one way systems, prohibitions of heavy traffic, etc.) have been used for a long time and are fairly well understood. In general, direct controls of this nature are only of value in curing particular local problems, and with schemes like one-way systems or motorways, great care must be used because the net effect of such a system can be a worsening of the general noise climate due to traffic diversion into a previously quiet area, rather than the desired improvement. Speed restrictions are probably the most useful measures in urban areas in terms of freedom from undesirable side-effects, and they have the additional value of energy saving. Prohibitions on heavy traffic at night have been extensively used in Switzerland and Germany with some success, and can considerably reduce noise annoyance during the most sensitive hours of the day.

1) Proposal transmitted to the EEC Council by the Ministry of Economy of the Federal Republic of Germany (25.7.79).

2) "Message concernant l'initiative populaire 'Contre le bruit de route', du 1er novembre 1978".

3.2.1 Overall Planning for Traffic Noise

When considering a comprehensive scheme to plan for and control traffic noise, there are many factors to be taken into account. Most countries now require noise to be considered in the planning of highways, but the actual requirements differ widely, resulting in varied effectiveness. In Germany for example, all highway planning must consider noise. In many other places, noise control must be considered for "major" projects (including highways). The definition of "major" can vary - it is sometimes defined by cost, but this definition has shortcomings. It fails to take into account small, inexpensive projects that could have a disproportionate influence on the noise climate (some traffic control measures can come into this category).

Although it is not yet tested in practice, the Netherlands Noise Control Act (1979) provides a good example of the results of the latest thinking and experience in the field of general traffic noise planning. The provisions of the Act are briefly as follows. All roads, whether existing or projected, will have "noise zones" statutorily designated beside them, bounded by a calculated approximation to the 50dBA Leq (24 hr) noise exposure contour. In these noise zones, the basic principle is that special care must be taken of the noise climate, and a basic noise reception limit of 50 dBA applies for all buildings. Other limits (for non-residential premises) are to be set in further regulations empowered by the Act. Whenever plans for construction of a new road or changes to an existing one are made, the proposals must be acoustically evaluated in the context of the area affected. Measures (choice of site, barriers, tunnels etc.) must be taken to limit the noise reception levels at dwellings in the surrounding area, the choice of the actual method used being left to the responsible authority. It should be noted that, in the case of existing roads, "changes" need not mean only reconstruction, but can include such things as a change in traffic lights if this will affect noise levels. The permissible reception limits are flexible according to the circumstances - for example where the road and dwellings already exist, and the measured levels are above the allowed level (which can in special circumstances be up to 70dBA), the local authority must draw up a programme of measures to reduce them to that level. These programmes may be eligible in part for government financing, but in general, the road builder and municipal authority are responsible for the costs. In extreme cases, the Act allows for reconstruction of roads and even demolition of buildings.

The important features of this Act (which are also present in a more distributed form in the newer laws of several countries) are: that, for new projects, the developer pays the costs of ensuring that noise reception limits are met; that the Act clearly lays down detailed procedures for all combinations of existing and new developments; and that there is a requirement for the central government to be informed of progress by the filing of a control programme by the local authority. In this way, the current activity can be assessed, costs calculated, and changes made in the law to improve the effectiveness of the entire programme.

Another approach to new project planning is reflected in the United Kingdom Land Compensation Act (1973) which also displays the "polluter pays principle". Despite the title of the Act, its main thrust can be seen as the avoidance of situations where compensation would have to be paid. It confers on the highway authorities the power to acquire land in addition to the minimum required, and to use that land in such a way as to relieve the physical problems caused by the project. In cases where, despite any measures to attenuate noise by barriers or other special features of road design, dwellings will be exposed to increased traffic noise at or above the level of 68 dBA L_{10} (18 hours),(1) regulations made under the Act require that noise insulation grants must be offered by highway authorities. Provision is also made for grants to insulate against the construction noise of new projects.

Despite the large cost of land acquisition, this is another indication of the almost universal shift to the concept that those who build major developments must pay for the undesirable consequences as part of the cost of the project.(2)

3.3 Enforcement

Regulations to control traffic noise come in three main categories: limitations on the noise emission of new vehicles; "in use" restrictions; and traffic management methods. This last method does not have particular noise-related enforcement difficulties, and the enforcement means are well understood and tested where the management has other objectives, for example road safety or improvement of traffic flow.

New vehicle regulations require mainly administrative support, and little direct enforcement save occasional sampling of a manufacturer's production to verify that standards are being maintained. Little difficulty seems to have been experienced in OECD countries. Indeed, mass production techniques go a long way to making the regulations self-enforcing once standards have been met. The inertia of the production process tends to ensure that the deviations thereafter are small. (A production tolerance of about 2-3dB is normally expected).

1) This level is very roughly equivalent to 65dBA Leq.

2) See also the Background Report No. 6, Compensation for Damage due to Noise.

The natural corollary to new vehicle noise regulations, that is control of modifications and maintenance of noise-producing components of the vehicle, overlaps considerably with the enforcement of "in-use" regulations.

A first obvious measure is to include a noise insepction in the regular vehicle safety inspection where this exists. This course has been taken in, for example, Switzerland, Germany, and part of Yugoslavia, and can be effective in controlling modification and maintenance, particularly of exhaust systems. This is in line with the general tendency to associate pollution controls with safety controls.

Whilst it seems feasible to ensure quiet new vehicles, and to police maintenance where vehicle inspection already exists, controlling offenders in the street is not so easy. In extreme cases, ordinary traffic police or their equivalent can usually bring charges or take some preventive action under "nuisance" type clauses of traffic regulations, relying on the evidence of their ears and personal judgement. Happily, though, these extreme offenders are becoming less common as enforcement tightens up, and a new problem has to be faced. It is not possible to rely on personal judgement in less evident cases, and it seems impractical to issue all police with a sound level meter and train them in its use, even if a suitable kerb-side test for stationary vehicles can be devised. Attempts to design a test that can be used reliably without special surroundings or a skilled driver do not seem to have been completely successful yet,(1) and even the power to order the vehicle to go to a special site to be tested that exists in for example New Zealand, has disadvantages. Perhaps the answer is the creation of a specialised force sufficiently trained to apply a more sophisticated test method to suspected vehicles at the time they are apprehended,(2) or to use a simple kerb-side test as a basis for ordering noisy vehicles to divert to a place where a proper test can be made. This technique has parallels in the use of "breathalysers" as a screening test for drunken drivers.

Even a vehicle which meets stringent noise specifications can be used in such a manner as to cause gross annoyance, because the annoying properties of noise are closely related to the intrusiveness of the noise above the background. It has been shown that a driver with "sporty" inclinations will produce a noise level about 7dB higher than a normal driver in the same vehicle, simply by

1) Several such tests exist, including one developed by ISO (near side measurement), but recent information on their success in practice is not yet available.

2) See Section 8, (Enforcement) for discussion of "noise brigades".

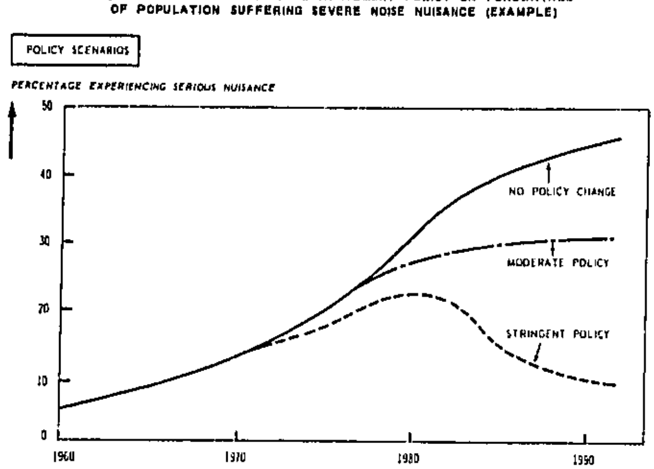
operating it at a higher engine speed and higher acceleration levels. In urban traffic conditions, detection of this type of anti-social behaviour can only be achieved by subjective means, and it is very difficult to bring solid evidence before a court. In free-flowing well separated highway traffic, however, a sound level meter can be used to good effect, and convincing evidence obtained by setting up a "noise" trap in the same way as microwave detectors are used for speed control. This method has been used in California, and again is best suited to a small specialist team.

3.4 Conclusions

As with almost all other noise sources, planning to avoid undesirable situations seems certainly the most effective as well as the cheapest method to control traffic noise. Vehicle emission regulations and traffic control methods are certainly necessary, particularly in the case of heavy vehicles and motorcycles, but in terms of reducing background noise, they are of only limited effectiveness. Their advantage is that they are relatively easy to implement, but there can be no doubt that they are insufficient to bring noise levels down to those recommended.

The results of some noise policy scenarios made by the Netherlands government are of interest here. Figure 2 shows the projected results of a "moderate" policy (more emphasis on source measures, better enforcement, and attempts to avoid conflicts in road and housing developments), and a stringent policy which makes a serious attempt to solve the problem by all possible means.

Figure 2 INFLUENCE OF NOISE ABATEMENT POLICY ON PERCENTAGE OF POPULATION SUFFERING SEVERE NOISE NUISANCE (EXAMPLE)



If these predictions are accepted, and appropriate adjustments made for the different situations in different countries, it seems evident that for most countries, the mild policies of the past will at best only slow the growth rate of the problem, and a much more radical approach is needed to have a great effect. New vehicle emission standards are a part of a programme, but must be combined with other measures which are capable of greater ambient noise reductions than the 5dBA or so that is all that can be expected from improvements in vehicle technology or traffic engineering. According to Lamure,(1) "town planning and careful orientation of housing may easily achieve a reduction of 15dBA, and sometimes as much as 20 or 30dBA in noise levels. Unfortunately, such measures may be expensive and may be applied only to new building. This is why everyone - road and traffic engineers, architects and town planners - should be engaged in the campaign against noise". New laws and regulations should be formulated with these broad objectives in mind. Traffic noise is the most serious of all the elements of environmental noise pollution and is also probably increasing the fastest. In many OECD countries the measures taken so far are only sufficient to slow this rate of increase, and it is evident that a far stronger effort is needed if the situation is to be improved.

4. AIRCRAFT AND AIRPORT NOISE

Few noise sources have been as thoroughly studied as aircraft noise. Although it affects fewer people than road traffic noise, its impact around major airports can be intense. The aerial nature of the source means that measures to control airport noise are almost totally restricted to soundproofing of buildings, source reduction, operational restrictions and land planning.

4.1 Source Regulation

The efforts of the International Civil Aviation Organisation (ICAO) in setting emission standards for aircraft are well known. Considerable reductions have been possible, the most impressive being due to the introduction of the high bypass-ratio type of engine. Since then, new materials and design techniques have allowed steady but less spectactular improvements to be made, to the point that the principal problems are being caused not by the wide-body generation of planes (747, DC10 etc.) but by their smaller cousins, many of which have years of useful life left. The focus of the problem is now shifting as these jets of the 707 and DC8 generation are sold to developing countries which often do not have any noise restriction at all.

1) In Road Traffic Noise, Alexandre, Barde, Lamure, Langdon. Applied Science Publishers Ltd., (1975).

It is unlikely that further great reduction will be made in commercial aircraft noise beyond that which is expected for the latest generation (Airbus 310, 757 etc.), although it may be feasible technically, because the cost could become disproportionately large.

With old aircraft, the idea of retrofitting them with new quiet engines has been discussed for many years, but has been used only on a very restricted scale, since the costs involved compared with the value of the aircraft are very large, and since such a process would most probably extend the life of these aircraft which would still remain quite noisy.(1) It seems that the most cost effective solution is to combine the retrofit of some of the existing aircraft (in particular those powered by JT8D engines - B727, B737) with replacement of other aircraft; hence the need for regulations designed to encourage aircraft replacement as soon as possible.

Such regulations are already being adopted. For example the United Kingdom has adopted not only the third edition of the ICAO Annex 16 (1978), but also a regulation based on an ECAC recommendation prohibiting the use of non-certified subsonic jets acquired by British operators after 30th September, 1978, and prohibiting completely the use of non-certified jets on the United Kingdom register after 1st January, 1986. Other countries have adopted similar laws with differing effective dates.

4.2 Operational Techniques

Operational restrictions are now almost universally used as a noise reduction measure, and range from curfews to highly technical specifications controlling approach angle, use of engines, etc. The overriding constraint on all these methods is safety - they must not significantly degrade the margins for passenger-carrying aircraft, and consequently a detailed discussion of method is out of the scope of this paper. Details may be found in publications of ICAO or the various national aviation authorities.

The use of curfew is one technique which does not have great safety implications, except insofar as it can imply a concentration of traffic. Curfews have been applied both generally (that is, a total prohibition on night flights, as at Sydney, Oslo and at all Swiss airports) and selectively by prohibiting night flights by the noisier types of aircraft. (Heathrow, London is at present phasing in such a system). The main problem with curfews occurs when long international flights are involved. When the airports at both ends of the flight have curfews, it can become very difficult (impossible in some cases) to schedule the flight so as to correspond with the

1) See Background Report No. 8, The Costs of Noise Abatement.

"window" at each end. For this reason, the selective curfew seems more workable at international airports, particularly since the longer routes tend to be flown by newer quieter aircraft.

4.3 Planning around Airports

Even if all aircraft are as quiet as technology can make them, and all possible operational techniques are used, the area around a major airport will still be subjected to noise levels that are unacceptable for dwellings. This can be due to either the airport itself, or to other features which are stimulated by the airport such as road systems, freight vehicles etc. Obviously, indirect methods of protecting the public from the noise must be used, and this generally means land use planning. There has long been substantial agreement among planners that such controls are desirable to limit the spread of noise-sensitive development in noise impacted areas and particularly around airports, but it has also been a subject of contention among local interests, who in many cases pay lip-service to planning principles, and ignore them in practice.

This gives rise to one of the difficulties with land use decisions: that they are often made on a purely local basis, ignoring wider goals. This can lead to conflict where property use restrictions are not imposed uniformly as part of a widely based scheme. Thus where land use restrictions are enforced around an airport (or in fact any major noise source) the responsibility for the scheme should usually be held at a higher level, say regional or state level, to ensure uniform policy, and to reduce the susceptibility of the zoning scheme to pressure from local interests, which can otherwise seriously distort its aims.

There are several possibilities for compatible land use around airports, and much has been written on the subject,(1) suggesting such uses as agriculture, recreation (golf courses, equestrian tracks, botanical gardens, etc.) or municipal utilities. Much depends on the way the scheme is implemented.

Whatever the approach taken, there will eventually be pressure from other potential users, particularly when an industrial belt is designated in the areas of moderate noise exposure. The airport itself acts as a major attraction to incompatible uses due to the social and economic changes it creates as a major transport mode and employer. Even such sensitive uses as housing are in demand for employees both of the airport and the peripheral activities around it. This occurred, for example at Dulles Airport (Washington) and the trend is evident in many other places; so caution must be

1) For example the ICAO Aerodrome Manual - Part 8: "Land use in the vicinity of aerodromes".

exercised that major isolated noise sources are not permitted to negate the intentions of planners by being such an attraction that they spoil their own isolation.

In practice, the systems implemented around airports fall into two categories: direct control by purchase of land or easements on it; and indirect control by zoning schemes, often as a special case in a normal regional planning scheme. If the land is left in the hands of private owners, it must be subject to rigid use controls to the point that, in many cases, it will be legally necessary to offer compensation or even to buy the property. In addition, the acquisition of land around an airport is extremely expensive, as large areas must be purchased if the principle is taken seriously (e.g. Dallas-Fort Worth Airport, opened in 1974, has 17,500 acres under the control of the airport authority).

It is thus only practicable as a buffer zone for the worst affected areas. More general planning is still needed in addition, but is a very slow way of effecting change around existing airports, and in the normal method of application is more applicable to new airports where the planning can be properly comprehensive.

Much more useful in practice are schemes which take special account of the noise-producing qualities of airports and create zones around the airport which are under much <u>stricter</u> control than is usual under normal planning systems.

The general features of most of the zoning schemes in use are exemplified by the German system. The Ministry of the Interior issues decrees establishing noise zones around civil and military airports used for jet traffic. The zones have two parts. The inner (noisier) area has a prohibition on building dwellings of any sort. Other types of building may be permitted according to the noise sensitivity of the activity. In the second zone, dwellings are conditionally permitted if they meet specified sound insulation requirements. In principle, schools, hospitals and similar very sensitive land uses are not permitted in either zone. It should be noted that the zones, which are defined by 75dBA Leq and 67dBA Leq contours respectively, are based not on current noise levels, but on predicted levels for ten years ahead.

Land owners already having developed properties in the noisier zone may be compensated "in kind" for structural noise protection or insulation, or in money, for depreciation due to development restrictions on their land.

The difficulties of predicting contours a decade ahead, with the major economic consequences demanding high accuracy, have not prevented vigorous application of the scheme. At the end of 1978, 30 such zones had been defined in Germany, and the remainder of a total of about 45 were being studied.

In other countries, there are detail differences from the German system - for example more "grades" of zone may be specified with restrictions lessening more gradually as the noise decreases (very often three zones are defined, such as in France, in the United States, etc.), or (as for some airports in Sweden) the options open to existing properties in the inner zones may include purchase by the airport or local government, but the main principles remain relatively constant. There seems to be no current evidence of major systematic difficulty with the basic concept. But zoning has sometimes been applied leniently, leading to inextricable situations. Very strict enforcement is of paramount importance, and zoning regulations must also take into account the long-term probable development of the airport traffic.

4.4 Enforcement of Aviation Noise Controls

There do not seem to be any major enforcement problems with direct aircraft noise regulations. Noise emission of aircraft is largely fixed in the design stages, so action on regulations on new plane noise is mostly concerned with liaison with the manufacturer. The maintenance question is also less important than with say motor vehicles, because of the high standards demanded for safety reasons. Height restrictions and specified approach paths to airports are also not areas that give enforcement difficulty - they are treated in the same way as any other aircraft operational regulation, and in general there is a very high degree of co-operation on the part of pilots with such restrictions. Problems with aircraft noise are associated with actual engine noise levels, traffic volumes and land planning, and not so much with enforcement.

With respect to implementation, the situation in the aviation noise area is unique. Despite the general trend towards centralising administration of noise abatement programmes under one authority, aviation noise has remained universally under the control of civil aviation authorities. The sole reason for this is aircraft safety: the standards are too stringent to be compromised by noise abatement measures which could erode them gradually. This has led to some difficulties and conflicts, but in countries where the ICAO Annex 16 standards are almost automatically adopted, this has not caused major problems.

4.5 Conclusions

The future progress in reducing conflicts between aircraft and the general population must be based principally on improved land use management. Where possible, the administration of the scheme should be in the hands of a regional or state body to reduce the effects of local influence on planning decisions. These decisions will of course vary according to the existing status of the area and the legal system of the country, but particular attention should be paid to the dangers of secondary noise sources (road transport, light industry) which tend to be attracted by airports.

The difficulties in highly developed areas around existing airports are always great, and it seems impossible to achieve any rapid solution (including palliative measures like insulation) without huge cost. The more recent trend to replace airports close to the city with new developments at a greater distance (for example Mirabel in Canada, Narita in Japan) seems one solution, but this too has its problems as both Narita, and the attempt to construct a third airport for London, have shown.

Land use planning is a solution, especially for the long term, but it needs strict and continuous enforcement if it is to be effective.

5. INDUSTRIAL AND CONSTRUCTION NOISE

Measures against construction and industrial noise have taken great strides in most countries in the last ten years, and noise reception standards for nearby dwellings are now controlled in several countries in various ways. The variety of industrial processes is such that attempting to set emission standards makes little sense as a general rule - the acceptable emission depends so strongly on other factors (the industry may be totally surrounded only by other industries, and consequently may not be a nuisance). More realistic is to set reception values for sensitive land uses in the vicinity, and to plan future development to avoid conflict. For construction noise on the other hand, source emission standards are of obvious utility.

5.1 Various Types of Approaches to the Problem

Traditionally, industrial noise was regulated under the "noise nuisance" type of law, with the usual result that only the extreme offenders were dealt with. (See Section 6.2 on Neighbourhood Noise and Section 8 on Enforcement.) In more recent years, however, local planning to reduce noise nuisance has increased considerably, firstly on the initiative of individuals, and later in response to changes in land planning laws and a general environmental awareness. The following sections will concentrate on the more interesting features of the laws of Germany, United Kingdom and the Netherlands with regard to industrial and construction noise.

5.1.1 Germany

The German Federal Pollution Protection Act (1974), grouped together almost the whole of the previous law on protection of the receiving environment (including several forms of pollution, not just noise), incorporating the former Construction Noise Law, and considerably extending the available means of control. It is based around industrial noise, although it also contains important traffic regulations designed to complement other existing legislation. The most fundamental departure of the Act from previous laws is the provision for the first time in Germany of the ability to impose direct conditions on trade and production. The main sections of the Act are aimed at the design, construction and operation of industrial plants and all kinds of equipment.

Construction noise was the first comprehensively controlled type of noise pollution in Germany, since the Construction Noise Law of 1965 provided a single statutory basis for regulation by several different means for noise in the whole country. It took the form of a general empowering law under which regulations could be promulgated, the main set appearing in 1970. The first of these was of fundamental importance to later laws, because it gave a concrete basis to questions of relations between annoyance and hazard, and actual noise levels. It was based on the previous "Technical Guide for Protection against Noise" (TA Lärm).

On the basis of the construction noise law, the obligations of the user of construction equipment were defined (not those of the manufacturers) and it was demanded that noise from construction sites be kept within specified noise reception standards (based on the TA Lärm). To assist in this, emission limits have been issued for many types of equipment, and the EEC activities in this field are actively supported. The system of preannounced, more stringent emission standards has been used for many years, and in fact the success in Germany of this approach is one of the strongest reasons for using it. The pressure brought by this means on the manufacturers has without doubt resulted in the production of considerably quieter equipment. Since the Federal Pollution Protection Act, these provisions have been extended to allow direct controls on trade and production, but because previous methods were relatively successful, this power has not been widely used in practice.

Control of industrial noise in Germany starts in the planning process, when noise limits for the receiving environment are imposed on new industrial developments at the approval and permit stage. The method of achieving these standards is left entirely to the local authority and the developer to allow local conditions to be accommodated. Because of the early date of introduction of these means into Germany, it is possible to see some effects of their performance in practice. They seem to have been successful at least to the extent that recent public surveys have ranked industrial noise last among important sources, and in that they have greatly stimulated the production of quieter construction equipment.

5.1.2 The Netherlands

The Noise Abatement Act (1979) provides for industrial and construction noise mostly through land planning and licensing schemes. It extends the powers of regional authorities to license noisy premises, and deals with the problem of new development in an already noisy area by detailing procedure to be taken in assessing such cases. Conditions can be attached to such licences - for example there may be a specified limit to noise levels at a boundary, and the scheme is also linked with the noise zone system and with a compensation scheme. Compensation can be made to a noise producer if he is required to comply with licensing conditions which exceed his ability to pay or are otherwise considered unreasonable, but this does not detract from the strong general application of the polluter pays principle which underlies the whole law. A novel feature of the use of this principle is that the operators of establishments must actually contribute to the administrative costs of implementing the legislation through charges on all licence holders.

The provisions for industrial premises which are situated in Noise Zones are in general similar to those already described for roads: for new developments, noise reception requirements are set for specified sensitive land use in the area, and for existing industry attempts must be made (usually financed by the industry and the local authority) to reduce any problem that exists. These sections of the Act are normally administered by the local or regional planning authority.

5.1.3 The United Kingdom

The legislation in the United Kingdom dealing with industrial noise is not based on statutory noise reception limits as are the Netherlands and German laws. Such criteria are, however, included in a non-statutory government advisory circular to local planning authorities. This circular advises planning authorities to take noise factors into account in considering applications for permission to build dwellings in noisy locations, or to build factories or other noise-producing installations in residential areas. The main legislative instrument for dealing with noise from existing buildings and premises remains the power of local authorities to serve notices requiring abatement of noise amounting to a "statutory nuisance". This power originally conferred in the Noise Abatement Act 1960, is now embodied in the Control of Pollution Act 1974. The 1974 Act also gives local authorities special powers for dealing with noise from construction sites, and it enables them to set up "noise abatement zones". The zone powers can be used to help preserve existing satisfactory conditions in an area, or to initiate a gradual remedial process where noise emissions from factories etc. are excessive. Where a noise abatement zone is designated by a local authority, a register of measured noise levels from various types of premises (specified in the order setting up the zone) is made, and it is then illegal for the emission of these premises to exceed that level without permission. Orders can also be made under the Act requiring premises to reduce their noise emission.

5.2 General Planning Considerations

One of the problems which has been encountered in control of industrial noise has been that of "creeping" ambient noise levels in industrial areas. This slow increase in background level has been caused in part by the use of one of the standard "rules of thumb" which have been used by planning authorities to decide permission for new industry development: that it should be permitted if the emission from the factory does not exceed the existing background level. As an example, the introduction of a new source 3dBA lower than ambient will increase that ambient by 2dBA. This of course creates legal problems: how can permission be refused (effectively penalising the industry) to a proposed new source which in itself would not be a problem, but becomes a problem by virtue of other unrelated sources already in position. Surely some of the blame must rest with existing industry, and it certainly seems inequitable that one potential source should have to pay the full price for a situation partially caused by others. The solution to this problem, varying in detail according to the legal system, must depend on strict and complete specification of procedures to be followed in such cases, as is done in the Netherlands law, and also preferably on a requirement that all the noisy sources reduce their emissions to produce a downward creeping ambient. In the United Kingdom, the planning system in fact allows for noise from new sources to be held below ambient, and the government advisory circular urges local planning authorities as far as possible to use their powers in such a way that ambient noise levels do not increase. The United Kingdom noise abatement zone procedure provides another way of stabilizing and eventually reversing an upward trend in ambient noise from fixed sources.

5.3 Enforcement

Enforcement of provisions for industrial noise will generally take the form of administrative requirements for permits and the like, and noise measurement to ensure compliance with conditions, followed in some cases by legal action.

There can in principle be less work involved in collecting evidence for a court case against an industrial offender compared to others, since industrial or similar sources are stationary, and do not usually have the intermittent character that can make neighbourhood noise such a headache for an enforcing officer. In fact, however, even more care must be taken because of the high likelihood of the data being challenged by the defence lawyers. For most industrial noise, abatement means expenditure for the emitter, sometimes great, and the reaction against the issuing of an abatement order or a conviction is likely to be strong. This reaction has resulted in timidity on the part of prosecuting authorities, particularly when they are a body with relatively slight resources for noise abatement. The decision has often been made to "tackle small problems first", that is, neighbourhood problems. This approach has the obvious defect that it ignores the fact that each industrial source generally affects far more people than each individual neighbourhood source, and the less obvious one that it ignores the publicity value of a prosecution.

It may be better for an authority to take as an initial prosecution an example of a major, preferably industry-wide, noise problem even though this may be very expensive. If the example is well chosen, and the case is strong, the extra cost in resources may be well spent to reduce future problems, because successful prosecution of a major source should be sufficiently influential to have a real and lasting effect on the rest of the industry in the area, and considerably reduce the need for futher action.

5.4 Conclusions

Industrial noise must be dealt with on the same basis as all other noise sources, i.e. measures taken at the source, in the transmission path, and lastly at the receiver. The range of industrial processes and the impossibility of an enforcing officer being expert in them all means that it is impractical to set universally applicable general noise limits in all but special cases. Noise control must inevitably then depend on co-operation with the industry, and enforcement of noise limits at the receiving environment. Direct measures in the transmission path (enclosures, etc.) can be often used, but there will always be occasions on which it is impossible to enclose the noise producing machinery. Indirect measures must then be used, and land planning is the almost inevitable solution for many industrial noise problems. Separation of source and noise sensitive areas has been the traditional method, but increasing land costs, and the desire to protect as yet unspoiled areas in their pristine state, are making the use of this option more difficult. In answer to this, the sophistication of land planning has been increasing, and some of the conflicts are being slowly resolved. It seems certain that even with increased awareness and co-operation from noise producing industry and improved technology reducing noise at source, land planning methods hold the key to long-term improvements.

6. OTHER FORMS OF NOISE

6.1 Railway Noise

At the moment, only a few countries have laws or regulations covering railway noise. Since administratively, railways are usually owned and managed by the national government, they are more amenable to direct control than is traffic noise. Even in the majority of countries without any formal noise regulations for railways, there have been great efforts to reduce noise (both internal and external), and these are starting to have obvious effects, especially on major routes. Among the countries which have probably done more work in the field of source reduction for rail vehicles than others one should mention Japan, which has particular problems caused by the Shinkansen, which runs at very high speed through a densely populated area.

The seriousness with which railway noise is regarded in Japan is indicated by the fact that for the new line being built in North Japan, about 8 per cent of the total construction budget is being spent on pollution control (principally noise).

In Germany, also, great attention is paid to this problem, and the Federal Pollution Control Act specifies procedures to be taken in planning new railways, including public participation.

Interesting regulatory activity on railway noise has occurred in the United States. Under the Noise Control Act, EPA is required to issue regulations for emission control for interstate rail carriers (which are private companies in the United States). This it did, setting limits for locomotives in both stationary and mobile conditions and including a more strict set of levels to come into effect in 1980. These regulations were appealed against in court by the Association of American Railroads, with the end result that EPA was directed to extend its regulations to cover not just locomotive and rail-car emission, but all aspects of railway operation. These regulations were proposed in April 1979, and are expected to be issued very soon, and they will be by far the most wide-ranging regulatory activity in this field.

6.2 Neighbourhood Noise

In this context, "neighbourhood noise" is taken to mean noise that is produced generally in residential areas, by individuals or groups behaving in such a manner as to cause annoyance, usually to their neighbours. This type of noise has been regulated for longer probably than any other audible nuisance, almost always by an "annoyance" or "nuisance" definition. For the most part, it consists of acts which are anti-social, but very difficult to accurately define in terms of noise emission or reception. The exceptions to this rule are uses of some appliances, such as lawn mowers, which can be treated in the same way as, for example, construction equipment, with emission standards and operational restrictions.

One particular example of regulation in this category is of great general interest because of the basic principle involved, and that is the regulation of lawnmower noise in Germany.

These regulations limit manufacture and sale of mowers according to their noise emission. They incorporate "stepped" standards for the future, a labelling scheme, and severe restrictions on the use of mowers. Operation between 10 p.m. and 7 a.m. is totally forbidden, and only particularly quiet mowers may be used between 7 p.m. and 10 p.m., and at weekends.

The advantages of this type of system (using what is called "reference limits")(1) are: that it stimulates development of quiet mowers by restricting sales of others, and by publishing in advance the new regulatory levels; the in-use regulations both protect the neighbourhood and further encourage demand for quiet products; and the labelling aspect of the scheme makes enforcement very much easier.

This improvement process provides a total result that is far stronger than the individual methods used separately could produce. This is amply demonstrated by at least one success criterion: the first "super-quiet" mowers appeared on the market within a few months of the effective date of regulation.

Outside areas such as this, neighbourhood noise tends to be so indefinable that it can only be dealt with as a nuisance, possibly with specific night-time restrictions to further protect the most sensitive time of sleep. Building codes for noise insulation may be of assistance in cooler climates and in high density apartment buildings, but little can be done where windows are often open for ventilation. The neighbourhood noise problem then becomes primarily one of enforcement.

6.3 Enforcement

Enforcement in this area of noise abatement presents difficulties which are familiar to workers in any field where "public nuisance" is involved. While annoyance is almost impossible to measure in the case of an individual, noise itself is relatively easy to quantify. It is very difficult, however, to successfully set

1) See Reducing Noise in OECD Countries, op. cit.

definite noise limits for neighbourhood noise, and in consequence enforcement in this area tends to be limited by the necessity of proving "nuisance".

To a large extent this sector of noise policing must depend on public participation, particularly through the mechanism of complaint to the appropriate authority.

Thus the avenues of public access for complaint should be kept as simple as possible - either a normal law enforcement agency such as the police (perhaps a specialised section if one exists), or the local authority for the area in which the complainant lives. The key to the problem is twofold - simplicity and publicity. Publicity in this case can not only tell the public how to make a complaint, but even more importantly lets it be known that the responsible body has an interest in noise, and that a community response is not only acceptable, but actually encouraged.

6.4 Conclusions

Neighbourhood noise will almost certainly always be with us. In some circumstances it can be curbed, but its unsystematic nature, and deep involvement with human behaviour, make it an extremely intractable regulatory problem. Paradoxically, a large-scale noise source is often easier to deal with; small but perhaps acute local noise nuisances can be considered one of the few areas that are still best controlled by use of the public nuisance type of non-specific legislation. They are certainly not often amenable to solution by setting specific noise limits, and possibly only education can have any long-term effect, but individual examples requiring drastic measures will surely demand the continuance of efforts at the traditional type of controls for unreasonable neighbourhood behaviour.

7. LAND USE PLANNING: GENERAL CONSIDERATIONS

Problems of noise nuisance are often problems of conflicting land use, whether they are permanent as in the case of a factory or airport and nearby dwellings; or random and temporary, as in the case of the person seeking tranquillity in the country whose repose is shattered by the noise of a trailbike or snowmobile. However it must be stressed that changing land use is a very slow process. Most action on land use can only apply to new situations and therefore the scope for reducing noise through better land use is limited.

7.1 Protection Zones

One aspect of land use controls which has received little attention is the potential to protect certain existing areas which have an unusually good acoustic environment. As areas of unspoilt tranquillity shrink under pressure from the omnipresence of jet aircraft and motor vehicles, it becomes increasingly important to maintain them as far as practicable. In the United States, for example, considerable problems have been experienced with off-road vehicles such as snowmobiles, dune buggies and trailbikes, even in such areas as national parks. State and Federal authorities have tackled the problem, with varied success - in fact recreational vehicles are the vehicle type most commonly regulated at the state level. In the Netherlands, the 1979 Noise Abatement Act has put this type of action on a more formal basis, by declaring an aim of not only noise abatement, but also conservation of unspoilt areas. To this end, it authorises local authorities to declare "Quiet Zones", covering several square kilometres or more, in which the natural sounds are subject to little or no interference from noise from human activity. These quiet zones may be combined with noise zones in which a specified noise level must not be exceeded. A plan must then be drawn up by the local authority and approved by the Health Minister, for the maintenance of the area.

In the United Kingdom also, the noise zone system may be used in an analogous fashion.

7.2 Environmental Impact Assessments

One of the most notable planning introductions of the 1960s was the use of environmental impact statements. The growth of environmental awareness constrained the planning process in many new ways that could not be coped with in the traditional fashion, causing impact studies in one form or another to become regular features in most developed countries. In many cases, noise considerations are an important part of the assessment procedure, which is a further encouraging sign that noise problems are no longer being looked at in isolation.

The promise of these reports lies in the degree of foresight they imply; the more comprehensively one studies a situation, the more one understands it, and consequently, the greater the chance of avoiding difficulties at later dates.

7.3 Enforcement

Despite the advances in understanding, there is still pressure from some sectors of the public in many places for development of areas for housing in severely noise impacted areas. This is particularly true of airport surroundings, and great strength may be needed at local or regional level to resist the temptation to concede even minor points unless these are very carefully considered. It can very easily happen that a series of decisions which in themselves are not important, add up to a severe degradation of planning standards. The ways to avoid this are twofold: firstly, the local or regional policy body must be strongly guided by national legislation, and in the long term, the public must be more educated about the dangers of noise exposure. The present ignorance extends even to those in authority, as is illustrated by a recent proposal by a regional health authority to build a large new hospital under the flight path close to an international airport.

In this case, the national law required the regional planning authority to "avoid or reduce danger, damage or nuisance" caused by noise. The lack of clear guidance (in particular covering noise reception standards) would have allowed the hospital to be built in a totally unsuitable position, to cope with a health demand that was in itself partly caused by lack of control over development of the airport surroundings.

Many countries have used reception values as guidelines for some years, but the change towards adopting these as standards with force of law (e.g. in Germany, the Netherlands) indicates that in many cases, guidelines are not sufficiently effective. There is always need for some flexibility, but it must be carefully specified how much flexibility is available, and how this can be used. The Netherlands scheme is a good example of this.

Economics is an important limiting factor on what one might call "ideal" land use policies. The use of distance, for example, is not generally viable because of the high cost, especially in urban areas, but when used in conjunction with other planning, it may be useful for large developments in relatively isolated areas (airports, large industrial complexes, etc.).

The opportunity cost to the community must also be considered - how much has the community lost by use of a buffer zone? This cost provides good reason to use the buffer zone as intensively as possible while still keeping such uses compatible from the environmental point of view.

8. ENFORCEMENT

Enforcement difficulties are now recognised as one of the most serious problems of the regulatory approach to noise abatement. This realisation has occurred only recently, and seems to have been delayed because most previous regulations had inherent defects that discouraged serious enforcement: the difficulties of enforcement itself were thus masked by the flaws in the legislation. Now that more comprehensive laws are being enacted and experience in drafting environmental laws increases, the former lack of enforcement is left glaringly exposed.

It has been a matter for some concern in many countries that despite the existence of regulations for many years, there has been no overall improvement in the environmental noise climate. Where there have been concentrated efforts to enforce noise abatement measures, some progress has been achieved despite the increase in the number of noise sources (particularly motor vehicles). The efforts of the Swiss "Noise Brigades" in certain cities, and the California Highway Patrol in attacking traffic noise are well-known, but on the more general front, attempts have been less energetic.

8.1 Enforcement Facilities

In considering the general enforcement problem, it is useful to make a distinction between noise sources where an individual is the culpable party, and those where some sort of collective responsibility is involved, such as industrial noise problems, particularly where there are financial reasons against noise abatement.

Where individuals are involved, and the noisy situation is caused more by personal behaviour than by technical problems, there seems to be no substitute for a frontal attack by direct regulation of the type that have been so common since the beginnings of noise abatement. Education and social pressures may be more effective in the long run, but such changes in behaviour patterns take a long time, and in any case, there will always be inconsiderate individuals who must be dissuaded by more forceful means.

Given the manpower demands of enforcement of direct regulation, it is not surprising that such an apparently non-urgent problem as noise should be treated as low priority by a law agency, particularly since when cases are brought to court, the penalties imposed on conviction are often small and out of proportion to the amount of effort needed to bring the case. If a punitive approach is desired for this class of offence, it would probably be best effected by use of a small specialised section of the police force, ("noise brigades"). This section need not be large - only a few individuals for a medium-sized city. This small team could be trained in the use of sound-level meters and other equipment, and would quickly gain a depth of expertise and knowledge in dealing with noise problems that would be impossible if they were not specially assigned to the job.

Such a team could also fill a very important public relations role, participating in school programmes and the like. Perhaps their most important function would be to be visible and well publicised. This in itself may be a strong argument in favour of the system, since the ability to identify a specialised group may have a powerful effect on the public.

The best known example of such a force are the "Noise Brigades" which exist in some areas of Switzerland (notably Zurich and Lausanne). These groups number five to ten, and their duties are almost entirely noise-related, a large part of their work being public relations and education. They also enforce (in co-operation with the ordinary sections of the police) the regulations relating to noise, particularly for motor vehicles and unreasonable noise at night, which are difficult problems for untrained men. The small size of the brigades allows a high standard of training both in technical matters (they are fully equipped with the necessary measuring equipment) and in the more sociological aspects of their job, and their emphasis on prevention rather than punishment, combined with their expertise, has had a marked effect in the communities in which they are active.

Noise brigades for traffic noise are also developing now in France. In 1978, there were 86 brigades composed of specially trained teams of four policemen. Their responsibility extends also to the control of motor vehicle pollution and fumes. In 1978 out of 600,000 vehicles inspected, 85,000 were found in contravention of noise standards, i.e. 15 per cent of motor cycles and mopeds, 17 per cent of diesel vehicles and 2 per cent of gasoline vehicles. Offenders have to pay a fine of Frs.120 (about $30) and must get their vehicle repaired.

8.2 The Need for Standards

As was pointed out in the Section dealing with neighbourhood noise, some of the enforcement difficulty in this field is caused by the difficulty of setting numerical standards for most forms of the neighbourhood noise problems. With other noise sources however (motor vehicles, construction equipment, etc.) standards can be set.

Setting specific standards for these noise sources rather than relying on the traditional descriptive terms which the court must interpret not only closes many of the possible escape-routes through legal argument over technicalities and interpretation, but also more directly aids enforcement by making it easier for officials to bring successful prosecutions. It side-steps the need for a complainant to give evidence in many cases, as is essential in prosecutions involving nuisance statutes. Once the complaint has been made, the enforcing authorities can where necessary bring the case to court solely on their own technical evidence, since there is no need to prove nuisance. Another important effect is to make the treatment of offenders more equal than would be possible under a law which required case-by-case application of subjective standards.

Attempts to set numerical criteria may cause much more difficulty during the drafting stage of a new local law, but it is much more important that the law should work well in practice and be easy to enforce, than that it should be easy to promulgate.

8.3 Public Awareness

In summary, it is possible to draw several conclusions from the enforcement situation as it has existed. Experience in most countries has been that regulations based on prosecution of offenders are a very inefficient way of achieving noise abatement. Laws are much more effective when they use actual court proceedings as a last resort relying instead on negotiation and persuasion to get co-operation from the offender. To assist in this, public awareness should be built up, and the provisions of the law publicised as widely as possible so that both noise maker and sufferer are aware that steps are being taken, and know their own responsibilities and opportunities. To this end laws should be made as simple as possible, and where feasible should be based on unambiguous standards.

8.4 Resources and Training

Once constraints built into the law itself have been eased, the major difficulty is the question of resources. Too often, noise abatement is carried out as part of the responsibility of a group with very wide general tasks to perform - police, health inspectors, etc. There is often no particular priority assigned to noise, which becomes the "poor relation" of all the other jobs which are better defined.

Manpower limitations are often caused by budget limitations. Enforcement is often delegated to the local level, and this can mean to a local body with a small income. Again, this is a matter of setting a clear priority so that noise is not forgotten, and ensuring that special assistance from a regional or national body is available where necessary.

In cases of limited resources, it may be feasible for several authorities to share the costs of enforcement, and it may also be possible for a regional body to have specialists available to start off local noise programmes, train local staff, and to act as advisors later.

That these restrictions are felt to be serious is shown by the results of a survey conducted in the United States, for the Environmental Protection Agency.(1) Following the introduction of the Noise Control Act in 1972, legislative activity in the United States increased rapidly, until in 1977, there were 27 states and 1,067 municipalities with noise laws. In contrast, only twelve states and

1) "The Status of Noise Control in the United States" April 1978.

less than 10 per cent of municipalities had budget items for noise abatement. This survey estimated that for an effective noise abatement programme, a minimum of approximately 3 cents per capita is needed to ensure sufficient resources.

This view is supported by the opinions of the state and local authorities themselves. Their answers to the question "Please indicate the major problems facing your noise control efforts" are summarised in the Table 2.

Table 2

Jurisdiction	Major problem	(% "Yes")
State	Lack of personnel	65%
	Lack of political support	58%
	Inadequate budget	46%
Municipal	Inadequate budget	48%
	Lack of effective legislation	37%
	Untrained personnel	35%

A further question on what Federal assistance the states and cities saw as valuable resulted in a very high response requesting training for personnel, effective noise control methods, and noise control programme guidelines.

The recent shifts in emphasis in the EPA programme have gone a long way to meet these shortcomings. Co-operation with cities and states has been reinforced by the "ECHO" programme (see Section 9) and by seconding "Community Noise Advisors" to towns and cities which do not have their own resources. Another major move to stimulate more activity and awareness at local level has been the production of a "workbook" with the object of assisting local lawmakers to draft regulations which are within national guidelines, but are adapted to the community.

Manpower and budget are the most obvious enforcement limitations, but another which is sometimes overlooked by those high up in the chain of responsibility is training. Noise is a highly technical subject, and an untrained person can bring disrepute on an entire noise programme if a case based on faulty evidence comes to court. Staff must be sufficiently well trained to be able to negotiate and put pressure on offenders to secure voluntary compliance with standards, with the object of out of court settlement where ever possible. When a prosecution is unavoidable, they must be able to convince the court of their competence and the quality of their evidence, even when under attack from a defending lawyer.

The most fundamental question of all, however is that of political support. Budget, manpower and priorities all depend on political decisions, and unless there is continuing support from policy-makers, a noise programme is doomed. It must be clearly stated at national level exactly who is responsible for what, and what general policies are to be implemented, if even the best of noise programmes is not to fail.

9. NOISE ABATEMENT PROGRAMMES: FUTURE DIRECTIONS

Throughout the summary of regulations in this paper, the assumption has been implicit that what is desired is a noise abatement programme - not just laws on the statute book, but a varied set of measures designed to effectively reduce noise pollution, and protect those areas which are still free of major problems. All the evidence clearly shows that no single measure is sufficient: environmental noise is too varied and dispersed for any such limited approach to succeed. In the course of the last 20 years, it has become obvious that, between countries, there are some features which seem to be universal for a successful programme, and the following sections will attempt to elaborate these.

9.1 Objectives

Any noise programme must have clear objectives, and preferably specific objectives, whether the programme is international, national or local in extent. This implies a stated philosophy which does not shirk the difficult decision areas, but defines at least the manner in which decisions are to be made - the "spirit of the laws" should as far as possible be written to ensure a consistent basis on which to resolve conflicts and to reduce the effect that small-scale influences which are not noise-related can have. This is particularly true where land planning is involved.

It has also been clearly demonstrated that no amount of unaided restrictive or punitive regulation will solve the noise problem. There is too much contrary human behaviour involved. Therefore, conditions must be created to encourage people to act in a responsible manner. Such conditions may include economic incentives (charges, compensation), selective restrictions to stimulate the purchase of quiet equipment (e.g. Germany's lawn mower regulation), education etc. To achieve results with such a range of methods, they must be co-ordinated properly, which requires a clearly stated set of objectives to provide a framework for legislation.

9.2 Precision

Precision is a characteristic which may seem to be inevitably required where legislation is concerned. Nonetheless, it has been notably lacking in many noise laws, either for reasons of uncertainty, or deliberately with the intent of allowing some flexibility for individual circumstances to be taken into account. Unfortunately the actual effect of this was to weaken the law to such an extent that it was powerless. The use of "nuisance" or "annoyance" as undefined concepts to be used as criteria has already been discussed, and falls into this category. Another more specific example was the 1964 modification to the United States Federal Airport Act which required that any airport receiving federal aid must take "appropriate action including the adoption of zoning laws .... to the extent reasonable to restrict the use of land adjacent to or in the immediate vicinity of the airport to activities and purposes compatible with normal airport operations".

The imprecision of this amendment was such that almost every case could be treated as an exception, and the law had almost no effect.

While recognising that it is obviously impossible to legislate for every eventuality, it seems that in the past it was the exceptions that were tackled because they permitted apparently easy solutions, while the more systematic problems were conveniently forgotten. Now there is more willingness to grapple with the longer-term problems. The most common (and therefore usually most difficult) areas are tackled directly, and sufficient allowance is left in an overall empowering act to permit regulation of special problems as they arise. The recent laws of both the Netherlands and Germany are good examples of how flexibility can be retained in a law which is precise and comprehensive.

9.3 Division of Responsibility

A noise programme must clearly specify at what level action is to be taken, and where several departments or agencies are involved, their interrelations, areas of responsibility and co-operation must be unambiguous. The normal situation is that departments at national level provide the overall planning, the guidelines, and the regulations for those noise problems which are deemed to be best solved at that level (usually transport systems, and those measures affecting trade such as labelling schemes).

The regional or local authorities are normally responsible for land planning (perhaps under national supervision) and implementation and enforcement of regulations. They also can devise and implement specific local or regional noise abatement programmes ("quiet cities", "noise abatement zones", etc.).

The alternative to a clear definition is that the programme founders in conflicts between authorities, or dies of inaction.

Another necessity if these fates are to be avoided is awareness. This means primarily awareness of the dimensions of the noise problem among the public and particularly among politicians at all levels.

There has in general been little understanding of the facts outside the few in each country who are intimately involved, and this has resulted in a general tendency not to take noise abatement programmes seriously. They almost always are downgraded in priority as soon as they reach into local areas, which is doubly unfortunate since this is where most of the activity in the programme should be.

Thus, one of the first objectives of a national noise programme should be to stimulate awareness of the aims of and the reasons for the programme in order to put pressure on the local authorities for action. Some of the strategies for this are illustrated by recent moves in the United States noise programme.

Now that the specific deadlines in the Noise Control Act have been met, EPA has been able to turn its resources into a broader effort. The relative lull until 1977 in most areas of the noise control effort except direct regulation had the effect of making those areas needing more attention clearer. The survey commissioned by EPA (already referred to in the section on enforcement) clearly showed that the states and local governments have evidently not been truly supporting the noise programme, despite the upsurge in regulation-making that followed the introduction of the Noise Control Act. To assist the overall aims, EPA has announced, with considerable aid from the Quiet Communities Act (1978), a large programme to boost activity at the lower levels. The major features of this programme are increased technical aid, particularly in training programmes, increased information, projects to increase co-operative activity at state and local level (the ECHO programme - Each Community Helps Others) and a model "quiet town" to demonstrate the possibilities of noise regulation and enforcement to other municipalities. In addition, a number of "Community Noise Advisors" have been loaned to various local governments to assist them with noise programmes.

All these actions are designed to stimulate state and municipal governments, and initial results seem to indicate some success.

9.4 Standards

Closely related to the question of precision discussed in paragraph 9.2 is the question of standards. There is now a considerable body of information available to assist in deciding levels for (for example) noise reception standards, but a difficulty has been that local bodies who set such standards had to defend them in court, and found this very difficult in the absence of national approval by some competent body. There is a very good case for setting such standards at national level, or at least defining an approving body which can give the locally set levels a cachet of reliability and authenticity which they can otherwise lack.

Another important aspect of standards is the principle of forward-looking emission levels: that is, emission levels which are set for not only the present, but also more strictly for the future, and which are preannounced. The main aim of emission standards is to stimulate the production of quieter equipment, and this will be far more effective if a manufacturer has a definite limit and a definite date to work towards. It is unreasonable to expect co-operation with regulations which are to some extent unexpected, and industry is far more likely to plan ahead to meet standards if these standards themselves show evidence of forward planning.

This principle is being adopted more and more, particularly for transport. Good examples of its use can be seen in the United States EPA proposed regulations for newly manufactured motor cycles, which specify a current standard, and two future tightenings of levels to become effective in 1982 and 1985. The EEC vehicle noise standards are also forward looking, although over a shorter time span (1980). This timetabling of objectives has another important facet: it allows timetabling of costs, both in the noise programme and for manufacturers. Thus, expenditure can be spread as equitably as possible.

9.5 Feedback

There must be provision (and preferably a requirement) for the noise abatement programme to be assessed for effectiveness. To this end, there should be feedback from local levels to national level so that achievements and difficulties are known, and if necessary, modifications to the system can be made. This feedback requirement can be built into the law in some cases, for example in the Netherlands Noise Abatement Law, where the abatement plans of the local authorities are required to be approved at national level. As well as improving uniformity, this means that the ministry responsible is aware of the actions of all the lower level authorities, and can if necessary stimulate areas which have been neglected.

9.6 Overall Conclusions

All these requirements can be summarised in two words: planning and enforcement. A noise programme should be carefully thought out and have a definite framework, co-ordinating efforts, looking ahead as far as possible, defining objectives, priorities and means of enforcement.

It seems that this desirable situation is only possible when the framework is part of the law - there is no country where a set of scattered regulations can be said to have been truly effective, and in most cases even recognition of this state of affairs is made difficult by the nature of the legislative structure. Because they are scattered, the effectiveness of the laws is extremely difficult to assess.

This accepted, the obvious move is towards comprehensive programmes. The aims of such programmes can be very different from country to country, as a comparison of, for example, the United States Noise Control Act, the Netherlands Noise Abatement Act and the proposed Swiss comprehensive law shows, but the significant fact is that there is a definite trend in the direction of comprehensive programmes. The United States, Germany and Belgium have all had at least partly comprehensive laws for some years, the Netherlands recently introduced a major and innovative law, and France and Switzerland are drafting new laws of this type.

This activity seems to be a vindication of the recommendation of the OECD Ad Hoc Group on Noise Abatement Policies(1) which strongly recommended these moves.

The present climate in noise abatement policy indicates a fundamental acceptance that in the future, the noise environment must be planned, and must not be inefficiently controlled by the unsystematic methods of the past. It is probably also significant that the recent comprehensive laws include land use planning.

Generally straitened economic circumstances and energy limitations have led to careful inspection of the effectiveness and peripheral effects of noise control, and a better understanding of the compromises that must be made. The necessary adaptations can be best made within a comprehensive framework.

Enforcement problems, too, have played their part, and resulted in an appreciation of the value of regulations and measures which are at least to some extent self-enforcing. Such methods as education and labelling schemes to influence markets are more effective than direct control, and require primarily administrative support and implementation. The need for financial resources and for incentive mechanisms also makes a plea for economic instruments such as noise related charges, as previously recommended by OECD(2) and already applied in some countries for aircraft noise or contemplated in a more general sense (the Netherlands). These economic instruments complement regulations rather than replacing them.

It has taken time, and a considerable worsening of the general situation for the weaknesses of the old methods of noise abatement

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1) See Reducing Noise in OECD Countries, op. cit.

2) Ibid.

by regulation to become apparent. Fortunately, experience so far seems to indicate that at least a partial answer to present and future problems lies in the trend towards combined land use planning, education, incentives and direct regulation, within national comprehensive programmes of noise abatement.

LOCAL ACTIONS AND PILOT "QUIET TOWNS"

CONTENTS

1. LOCAL OR NATIONAL ACTION

1.1 Trends in Local Regulation

While noise abatement in ancient times was not considered to be any concern of the national authorities, city authorities were already required to maintain a minimum of public peace and quiet. Specific regulations made their appearance later, as for example in Boston around 1830. With the advent of industrialisation and motorised travel, the problem of noise became so worrying that special departments or commissions were established. Thus in 1930 New York City set up a Commission to investigate the city's "complex noise situation" so as to find ways and means of eliminating unnecessary noise and determine the impact of noise in general on the city's population.(1) This Commission's report stressed even then the high level of traffic noise. In 1948, the National Institute of Municipal Law Officers in the United States issued a guide for local authorities proposing to take noise abatement action, and by 1971 35 per cent of all cities in the United States had adopted this model. The first regulations were vague and of the "unwanted noise must be eliminated" type. After 1952, ceiling levels expressed in dB began to appear in the municipal codes, as for example at the instigation of the Provincial Government of Ontario, Canada.(2)

Round about 1967 the State of California also tackled the problem and local regulatory action then developed quickly throughout the United States, where the number of municipal codes rose from 59 in 1971 to 1,067 in 1977.(3) Recent trends in OECD countries other than those of North America have been relatively slower and have followed differing lines, nor is much information available; widely differing political structures may account for the fact that there has been a considerable amount of local initiative in Germany and Switzerland, while in France local regulatory action has long been taken through the regional health regulations drafted under the supervision of the local representative of central government. Appreciable progress has however been made over the last five years

1) New York City's Approach and Experience, Robert Bennin, Bureau of Noise Abatement, Inter Noise 1974 and Community Noise Regulations: An Overview, Clifford R. Bragdon, Inter Noise 1974.

2) Ontario Model Municipal Noise Control Byelaw, John Manuel, Inter Noise 1976.

3) The Status of Noise Control in the United States: State and Local Governments, Dr. Clifford R. Bragdon, Prepared for ONAC, US EPA, Washington, April 1978.

or so by cities in regard to noise abatement, and nearly all capitals have drafted special noise regulations, while some of them are even beginning to support these regulations by setting up special departments, thus following the alre..dy longstanding example of Greater London.

The amount of action taken locally does not depend on either the size of the municipality or the level of traffic or industrialisation; medium-sized authorities in Switzerland apply noise abatement plans, whereas in the Latin countries even large cities have yet to act; the degree of local awareness and autonomy of the local authorities largely account for the wide variety of situations.

1.2 Government Co-ordination, Encouragement and Control

The development of local regulatory action at the same time as central government action raises the question of whether such action is properly co-ordinated, and invites a comparison of the effectiveness of action at either level for dealing with any given type of problem.

Co-ordination takes the form of control when action is initiated by the local authority and then moves upward to the central government authority. Control is necessarily involved in cases of the approval of municipal regulations, for example when a local authority regulates noise emissions of manufactured products such as vehicles; in other areas of intervention, control depends essentially on the political structure. For instance, the same acceptable levels of noise in the external environment for each district may be required, or, conversely, each local authority may be granted full freedom of action.

The impetus now given by almost all central governments is usually didactic in nature. The essential problem of noise abatement, second to funding of course, is that of technical and legal competence. State intervention is justified by the fact that central governments alone - with the exception of such large cities as London or New York - have the means to enact more effective and precise regulations than those which appeared before 1955. An interesting procedure also made its appearance in Ontario in 1975, Illinois in 1973, and finally in the EPA (United States Environmental Protection Agency): the Government defined a model municipal code, allowing the local authorities to make it more explicit, supplement it and adapt it at will to local conditions.(1) The "model noise control ordinances" and "model municipal noise control byelaw" respectively

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1) Model Municipal Control Byelaw, Ministry of the Environment, Ontario, Canada, Final Report August 1978 and Model Noise Control Ordinance, US EPA, September 1976, Washington, DC.

prepared by the EPA and Ontario's Ministry of the Environment help authorities with the smallest technical staffs to draft effective regulations comprising upper noise limits generally expressed in dBA; the fields of application are not only as in the past nuisance-creating activities but also land use, the management of commercial and private vehicles, air and rail traffic, construction sites, and building codes. These downward-reaching regulations are accompanied by training schemes for local technicians; the model codes comprise technical data and sometimes comprehensive instructions regarding noise abatement.

Under the Quiet Community Act, the EPA has also set up an innovative mutual-help procedure for local authorities: those with noise abatement know-how can lend fully experienced staff to other authorities which propose to take action to improve the noise environment (ECHO program: Each Community Helps Others).(1)

If the technical and funding problems are set aside, the benefits of local action against nuisance-creating activities become more evident: better adaptation to local technical and socio-political conditions, greater motivation of the persons involved, more regular follow-up and management of action programmes, etc.

One considerable drawback has sometimes led to failure: the enactment of stringent rules affecting trade or industry can induce firms to move to more liberal neighbouring districts; such a loss of jobs and tax resources being only acceptable to the mayors of health resorts or other towns whose economy is in fact based on a quiet environment. Inter-municipal difficulties of the same type arise when, for example, public transport companies serve several districts; thus in France quieter buses could not be introduced in Toulouse against the wishes of the surrounding communes.

This type of drawback cannot so much be eliminated by government co-ordination as through the kind of inter-municipal co-operation that has existed since 1974 around Washington D.C. between local governments in several different States. This co-operation has enabled a monitoring campaign and action and training programmes to be launched which could not have been financed by separate authorities.(2)

1.3 The Problem of Funding

The implementation of municipal regulations necessitates a minimum of financing, if only in order to set up specialised departments or agencies. The lack of specialised departments thus nearly always

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1) ECHO, US EPA Brochure and EPA Noise Control Program. Progress to Date, April 1979, US EPA.

2) Metropolitan Washington, Council of Governments. Areawide Environmental Noise Study, Donna McCord Dickman, Inter Noise 1976

results in the poor enforcement of regulations, and it has always been observed that, in the case of the general police forces for example, noise-related matters are neglected in favour of urgent day-to-day work. Apart from operating such specialised departments, local authorities have to plan on sometimes costly action: thus the EPA model municipal codes provide for the purchase of quiet equipment within the limit of a price increase of 25 per cent over and above the cheapest equipment for the same use, while the soundproofing of school buildings, etc. is expensive.

A striking contrast may usually be observed between the ambitions of the approved municipal codes and budget appropriations. The problem of funding is most preoccupying for local authorities, even more than that of staff training, whereas the opposite may be noted for state (provincial) authorities, at least in the United States, as Table 1 shows.(1)

Table 1

UNITED STATES - MAJOR PROBLEMS FACING NOISE CONTROL

		(% "Yes")
State	Lack of personnel	65%
	Lack of political support	58%
	Inadequate budget	46%
Municipal authorities	Inadequate budget	48%
	Lack of effective legislation	37%
	Untrained personnel	35%

Less than 10 per cent of the local authorities in the United States which had issued special municipal noise codes have provided for a special budget, whereas it is estimated that a minimum of 3 cents per capita is needed to achieve any practical results;(1) what is worse, the number of local authorities which do have a special budget dropped from 43 in 1973 to 33 in 1975.

In the Netherlands, the five year programme for noise abatement will necessitate that a staff of 500 persons be allocated to noise abatement in local communities. To this end, 8 million guilders in 1979 and 12 millions in 1980 have been granted to municipalities.

No specific item appears to have been devoted to noise abatement in city budgets in most other countries.(2) Case law in the

1) The Status of Noise Control in the United States, op. cit.

2) An analysis of special funding possibilities for noise abatement relating to the decentralised context of the United States will be found in Noise Abatement: Policy Alternatives for Transportation, National Academy of Sciences, Washington, D.C.

administrative courts is still only in its infancy and the legality of taxes or charges collected by specialised non-governmental agencies is not yet clear. Except in the Netherlands where the Noise Abatement Law stipulates that noise charges, collected at national level, should be reallocated to municipalities to finance noise abatement measures, no country seems to impose special taxes or charges, as on air traffic for example, for use on behalf of local authorities. On the other hand, fines may sometimes be imposed and the hope in some quarters is that these could finance specialised police services. But their imposition stumbles on the general public's ignorance of the meaning of technical acoustic data and they are directed more at the managers of noisy construction sites or factories.

On the whole, local authorities in every country turn mainly to the government to obtain subsidies for noise abatement campaigns, and this usually results in specific local actions rather than any continuing action over time. Such local actions do have the merit, however, of experimentation in an area where almost nothing is known about practical requirements for effectiveness. We shall therefore analyse a series of specific local actions before considering what advantages for noise control can be expected from more widely-based local actions without overburdening the budget.

Annex I contains a descriptive list of specific local noise abatement actions carried out in various countries.

2. LOCAL ACTIONS SPECIFICALLY AIMED AT NOISE ABATEMENT

Roughly speaking, three types of action by local authorities may be distinguished according to whether they are primarily of a regulatory and police-enforced kind, or whether they are primarily participatory or technical. In practice, these various aspects exist side by side, and a participatory experiment may thus lead to greater acceptance of the regulations.

We shall mainly consider the last two types, as the regulations are already described elsewhere and will only be mentioned again in connection with original control tests in certain cities.

2.1 Participatory Actions

2.1.1 Overall Methods of Approach (Case Studies)

The majority of noise sources can be managed more quietly and the general public, as well as trade and industry, can play a considerable role in abating noise without the need for any very substantial outlay of money. At the same time, public awareness can in particular have the effect of mobilising the political or administrative authority for a war against noise, one which sometimes may only be declared by a minority of true believers.

Thus two objectives can already be identified which are not always clearly distinguished in private or public organisations' endeavours to communicate with the general public. Specialised private organisations, under some such title as "The League Against Noise", are sometimes very powerful, as in the Federal Republic of Germany, where they publish an excellent magazine called "Kampf dem Lärm" ("The Fight Against Noise"). They often organise information or public-awareness campaigns through schools, other associations or exhibitions. Rarely, however, have they succeeded in educating the public about noise independently of the local authorities.

In Switzerland, where participation is widely practised, some success has been achieved in Zurich (around the airport), whereas in certain mountain areas the campaign against the intrusion of helicopters has received no support from the rural mountain population.

On the part of local authorities, some large-scale actions may now be noted the most important of which is that at Darlington, near Newcastle, in the United Kingdom. The Darlington experiment followed on the heels of a recommendation by the Noise Advisory Council in 1974.(1) The NAC had realised the need to interest public opinion in noise abatement and to avoid a certain fatalistic attitude. It proposed that a town be chosen where the general public and representatives of the workers' and employers' organisations would be invited to co-operate and examine the practical possibilities of reducing noise annoyance at home, at work and in the street by educational means, publicity and experimental action. Darlington was selected as a test area because marked by the following characteristics:(2)

- a population of 98,000, therefore one sufficiently large, without preventing flexible and fairly prompt action;
- a community independent of any other town, with a sense of its own identity and dignity;
- through-traffic already diverted;
- a town with local newspapers and near a radio station;
- a certain variety of noise problems;
- a co-operative Borough Council, and well-qualified local government personnel.

Six committees were set up by agreement between the Noise Advisory Council and Darlington Borough Council, which demanded considerable activity from its Environmental Health Department, representatives of the NAC and central government departments, teachers

1) Noise in the Next 10 Years, Noise Advisory Council, HMSO London - 1974.

2) See The Problem of Noise and the Quiet Town Experiment, Report of the Noise Seminar, Darlington, 5th-7th September, 1978. Published by Traffic Engineering and Control, London.

(50 schools) and 30 or so local organisations. In addition to a Steering Committee and a Management Committee, four committees dealt with schools, publicity, the industrial and technical sector, and transport.

The leading role was played by the Management Committee, and extensive use was made of the media, pamphlets, about 120 printed leaflets and various slogans. The intention was in fact to avoid the use of regulations and to count on the goodwill of a receptive public.

By means of a survey prior to launching the experiment, the opinions of 600 people were obtained concerning noise in the urban zone.(1) Traffic was mentioned by 87 per cent of those interviewed as the main source of noise in the town. 38 per cent of those in the sample who worked in Darlington said that they found noise at work an "irritant".

An aim of the second survey carried out on completing the experiment was to assess the impact of the promotional campaign. The majority of the people interviewed could recall some particular aspect of the campaign material (mainly visual), but it was still difficult to estimate the real effect on behaviour, the one most often mentioned concerning use of the motor car. The replies relating to effectiveness of the experiment in reducing noise from various sources show that a large majority (70 per cent) thought that the experiment had made no difference to noise conditions in the neighbourhood where they lived, 16 per cent thought conditions were quieter, and 8 per cent noisier. In relation to the town centre, 50 per cent of respondents thought the experiment had made no difference, 39 per cent thought it had improved things, and 4 per cent thought it had made things noisier. Most of those who, in response to a separate question, thought that conditions in the town centre were better (31 per cent of respondents) mentioned that this was "something to do with traffic", i.e. it was a result of a new traffic management scheme introduced during the period of the experiment but independently of it. In response to the same set of questions, 8.5 per cent thought that conditions in their neighbourhood were quieter, 35 per cent noisier and 51 per cent about the same.

The number of complaints about noise made to the Borough Council rose from 170 in 1975 to 356 in 1977, i.e. double the average British rate during that period. This can be attributed to a greater awareness of noise as a problem and to the fact that publicity was being given to the Council's role in noise abatement.

The following figures show the percentages of people who felt Darlington was more noisy or less noisy in 1978 compared with 1976:

1) V.R. Jupp and L. Landon, Noise in Darlington (1976) and People and Noise in Darlington (1978) both published by Newcastle-upon-Tyne Polytechnic.

	1976	1978
Noisy or very noisy	26%	20%
Quiet or very quiet	66%	72%

The survey results are somewhat difficult to interpret, and are not always self-consistent. It must be remembered that the aim of the survey and the experiment was to assess the effectiveness of participation and noise education; if it had been to estimate the reduction in noise, a physical monitoring campaign would have been launched. It must be admitted in this connection that the term "Quiet Town Experiment" was confusing and we understand that the NAC final report is likely to suggest "Quiet Community" for the future.

The increasing number of complaints demonstrates that the public awareness campaign was successful, but it is only in the medium and long term that a change in behaviour can be expected as a result, in particular, of action in the schools. Strictly speaking, the trend of behaviour and opinion in Darlington over a period of at least 10 years should be compared with a similar control city where no specific action had been taken.

On the whole, although it is difficult to assess the operation technically, it may be estimated that for a small government expenditure of £26,000 (£16,000 subsidies to the Council, £10,000 for the two social surveys) the operation was very successful in terms of participation by the general public; this was thanks to flexibility of co-operation between the local authorities and a government agency with no direct regulatory powers, the NAC, whose authority is essentially of a moral kind. The NAC's original aim was achieved almost better than expected as regards the general public and the schools, but the relative failure on the business side, especially in the factories, reflects the difficulty of persuading industrialists to devote time and perhaps money to noise abatement on a voluntary basis.

The interesting idea of using bicycle and motorcycle retailers to arouse the interest of young people could perhaps have been pursued further. Those directly responsible for managing the experiment felt somewhat frustrated in certain areas, for example, enforcement of noise limits for vehicles in use, and enforcement of requirements for party-wall noise attenuation by what they saw as defects in the relevant central government regulations. It was an essential part of the concept of the experiment that it should be conducted within the existing legislative framework, and so one of its incidental benefits was to highlight areas in which that legislation might benefit from re-examination at central government level.

We have selected the following conclusions from existing reports on the operation(1) as useful hints for future tests:

1) The Official Report by the Noise Advisory Council is expected during 1980.

- the term "Quiet Town Experiment" suggests that the aim is to improve the town rather than behaviour, and may be unfortunate, depending on the target in view;
- the presence of radio and local press is very effective;
- too many different pamphlets should be avoided (we would add that certain pamphlets issued at national level could suffice).

The Darlington experiment aroused keen interest in the United Kingdom and has been imitated elsewhere in the world; here again, certain emulators mistook the meaning of "quiet town", as in the case of French projects (e.g. Blois), which are in no way comparable and will be examined in Section 2.3. Only the programme in Allentown, Pennsylvania, may be regarded as a direct offshoot of the Darlington experiment. The choice of Allentown in Spring 1977 by the EPA under the "Quiet Communities Program" was based on criteria similar to those for Darlington; with its 98,000 inhabitants, Allentown had no notable special features and was much like Darlington. One difference of approach should be noted: the approach used by the EPA, which is both a scientific and a regulatory agency, seems rather more authoritative and more inclined towards regulation (penalties) and technical action than towards public involvement and education. This may explain some initial ironic misgivings on the part of politicians and businessmen, who were apt to qualify State proposals which were going to cost time and money as "boondoggling" (i.e. a trivial, useless or wasteful activity). EPA's financial contribution, which was about the same as in Darlington, was used for a large-scale monitoring campaign and a fairly economical survey. A very determined, active technical organiser conducted the entire operation, which was therefore more centralised than in Darlington. Media use was similar although less extensive than in Darlington, but the population was encouraged to engage in quiet behaviour during quiet weekends.

Allentown now has an excellent description of its acoustic environment, not only thanks to the survey but to 20,000 physical noise measurements; at 50 of the locations, measurements were made for 24-hour periods. Time-trend studies now remain to be carried out and especially a follow-up survey. The experience gained in the field has already spread from Allentown to other towns in Pennsylvania.

In France, a significant, purely local experiment which may be mentioned is that conducted in Marseilles during 1975, the first of its kind and enjoying no State financing. The Marseilles approach included all the factors mentioned: a preliminary survey, monitoring campaign, the promotion of awareness through the press, pamphlets, posters and schools. Moreover, the city of Marseilles, which administers a population of 1,000,000, organised its technical services accordingly. This original, thorough-going experiment, however, suffered from a shortage of certain technical and financial resources, and unfortunately no final survey assessed the project's effectiveness. It is interesting to note that, here again, the example set a trend, since the local authorities in Aix then also organised various participation projects, including poster and poetry competitions in the schools, etc., with the help of the "Ligue Méridionale de Lutte contre le Bruit". According to a subsequent survey, the population of Marseilles considered that the most effective action was the monitoring of car exhausts by the police.

2.1.2 Analytical Approaches

A cause for surprise may be the absence of specialised ecological associations in the experiments conducted by English-speaking countries. On the other hand, does the aggressive action taken by such organisations in Federal Germany or Switzerland account for the fact that no operations inspired by the public authorities have been observed in those countries? A new trend may possibly be taking place in Germany, judging by the report of the Working Party on Noise Abatement submitted in June 1978 to the Federal Minister of the Interior.(1) The subgroup responsible for public relations carried out a methodical analysis of the requirements for success. It stressed the need for a clear definition of the possible objectives in any action to motivate, educate or inform the public or the business sector; it emphasized the need to analyse any motivations which could be turned to account. In the matter of objectives, a distinction should be made between reducing noise production by promoting "noise-awareness behaviour", and changing the noise reception area. This change can be brought about either by increasing public awareness, or else by altering attitudes if the aim is to convince the public that it must endure noise for economic reasons. The respective roles of the noise maker and sufferer should also be clearly distinguished. The group sets the following simultaneous targets in any public information and motivation campaign:

- To induce individuals and groups concerned to generate less noise.
- To induce the commercial organisations concerned to introduce some means of noise reduction or soundproofing.
- To induce individuals and groups to accept inevitable noise.

The value of this analysis will be fully apparent, since confusion of the objectives or inversion of the priorities can lead to mediocre if not actually poor results.

1) Projektgruppe Lärmbekämpfung. Abschlussbericht des Arbeitskreises 2, Bundesminister des Innern, Berlin, June 1978.

It will be noted in particular that the third aim, which did not exist in the experiments earlier mentioned can be dangerous if it affords noise makers effective means of psychological action.

The same group defines two requisites for motivating the public:

a) The creation of physical conditions which enable the individual to feel personally concerned by noise; for example, if no quiet products are available, a person will not feel concerned by noise emitted by his own domestic appliances or machinery.
b) The provision of material or moral rewards for quiet behaviour. Consideration might for example be given to financial (tax) benefits or publicity tactics.

A special analysis of the conditions of effectiveness is necessary for each occupational group and each type of noise. The examples of motivation suggested for vehicle users include breaking the association between descriptive terms like "young, dynamic, fast and noisy" in favour of "strong, thoughtful, courteous and quiet". It is important not to give the impression that the most is being asked of those who offer least resistance. Finally, the group thinks that for an operation to be effective, it must comprise a series of mutually supportive actions; the strategy should therefore associate:

- information on the problem of noise;
- education aimed at particular groups;
- self-examination, especially role analysis;
- use of mass advertising media;
- checking the effectiveness of each action.

With regard to the very difficult problem of checking effectiveness, monitoring is unlikely to prove particularly useful. Indirect methods of observation should be adopted such as:

- the receptivity of media regarding a particular type of noise abatement;
- the pressure exerted by public opinion on politicians regarding the enactment of special legislation;
- the tendency to purchase quieter products;
- trends in the number, type and intensity of complaints.

2.1.3 Conclusions

The difference of approach as between experiments in the English-speaking countries and France and the German analysis is very instructive (general and analytical approaches). Some may think in regard to a subject so highly dependent on national cultures and political systems that there is no need to find some middle ground between two different views, while others may feel that any too close analysis aiming at prompt results is either a vain or dangerous exercise, since marked effectiveness might lead too far along the road towards manipulation of public opinion. But in that case should the relative lack of precision of more general actions be preferred?

It seems advisable to find a happy medium where modest conclusions can be drawn from all the experience described above:

- Actions should focus on a type of noise where positive results can be expected from the efforts of the general public and those of the local authority.
- A distinction should be drawn between long-term objectives, such as increasing public awareness, and more specific objectives. The improvement of noise education in schools should probably be left to the relevant institutions.
- During the action undertaken each individual should be taught to distinguish clearly between his role as maker and sufferer of noise.
- A minimum of realistic rewards should be established for the general public.
- A relatively long-term programme, lasting at least some three years, should be planned.
- Methods of checking effectiveness should be devised before the experiment begins.

An experiment aimed solely at the behaviour of the users of mopeds and motorcycles would largely solve one major problem, which does not seem capable of solution through action on the technical side.

2.2 Predominantly Technical Actions (Control and Practical Measures)

Following the enactment of largely incomplete and often poorly enforced legislation, and after experiments in arousing public interest, cases are now appearing which combine the enactment of realistic legislation with police control and technical action.

2.2.1 Organisation of Control

San Diego in California is one of the four cities helped by the EPA under the ECHO Program to provide other local authorities with an example of effective experimentation. In San Diego, the 1973 Noise Control Code was revised in November 1977; it defined all the rules to be observed not only by the public but also by the city authorities. The increased awareness of city officials and co-ordination of the technical services have enabled a series of effective actions to be undertaken. As far as the general public is concerned, particular attention was given to providing clear definitions of the rules governing complaints and offence reporting procedures, the payment of fines and the institution of legal proceedings. Such a precise technical and legal approach makes up for the limited attempt at participation and consultation as compared with the psycho-sociological experiments mentioned earlier. No assessment has been made of the attitude of the public.

A similar approach was adopted in Colorado Springs, Colorado, a fast-growing city where the police could no longer keep pace with people's complaints about noise. An efficient specialised police corps was set up whose members were trained in acoustics; in this city, perhaps even more than elsewhere, conclusions were systematically drawn regarding the difficulty of interesting the general police force in the noise problem: the police training sessions did not succeed in convincing more than 30 per cent of the importance of the problem - how is it possible to motivate a police force which has enough trouble coping with the many acts of physical violence? Another reason led to merging the acoustician with the police officer: after lengthy discussion, the need for highly reliable offence reporting made it necessary to use fairly elaborate equipment: the officer can, for example, record the maximum noise level of a passing vehicle and show the offender the indicator reading. Noisy vehicles - motor cars and motorised two-wheelers - were monitored by a police car equipped with electronic and photographic equipment and a side microphone.(1)

Before passing sentence on an offence, the judge can rely on the best technical evidence, including an extremely detailed questionnaire which the officer reporting the offence must fill in. If the latter is confirmed by the judge, the offender must choose between paying a fine, appealing or repairing the vehicle (usually the exhaust), which is followed by a noise test and a refund out of the fine. The majority of people summonsed in fact went direct to the repairman rather than to the fine-collector and then to the town hall with their noise-control certificate, paying only the regulation balance of the fine ($10). In spite of this unexpected detour, the result desired was obtained.

The problem of young offenders on mopeds and motorcycles is still not adequately solved in spite of discussion meetings between young motorcyclists, complaining householders and motorcycle dealers.

1) San Diego, California, Case History of a Municipal Noise Control Program, US EPA, Washington DC, March 1979 and Vehicular Noise Monitoring from a Microphone Mounted on a Patrol Car, James D. Foch and Mary B. Carlson US EPA, Region VII, Denver, Colorado.

Other problems, especially those concerning industry, have been quite satisfactorily solved. Even dog barking has been reduced by circulating an explanatory, educational pamphlet (to dog owners); an abandoned noisy dog winds up at the Society for the Prevention of Cruelty to Animals and the owner at court.

The cost of the programme was about $60,000 per year, i.e. between 30 and 40¢ per person (0.14 per cent of the city's total budget); in actual fact, there are fairly sharp fluctuations from one year to the next, depending on the purchases of acoustic equipment.

2.2.2 Technical Operations

The predominantly technical programmes found for example, in Oslo (Norway), Auckland (New Zealand) and soon to be adopted in Blois (France) should now be mentioned.

The Norwegian Government published in 1977 a White Paper on noise abatement, and reserved N.Kr.105 million for passive protection along national highways in the period 1978-81. Partly based on this national programme, Oslo City Health Department proposed in 1978 a local programme. The programme, which began to be implemented in 1979, is based on a former noise map of Oslo. In addition to passive measures the Oslo programme discusses and proposes active measures.

In 1980, it is intended to implement a network for heavy vehicles, formed from the most suitable main roads. Police actions are possible to enforce the regulations.

The trial use of traffic lights flashing at night brought the noise level down by 3-4 dB(A), but the experiment had to be dropped because the accident rate was rising.

From the national programme N.Kr.5 million was earmarked for soundproofing roadside buildings in Oslo during 1979. For this first period, the city authorities designated the houses to be protected. House owners can ask for heavier soundproofing than the minimum financed by the programme on condition that they pay the difference.

The Institute of Transport Economics has carried out a study on different protective strategies. The following table demonstrates the value of the mixed strategy, to which the advantages of improved safety and environmental quality should be added. It will be noted that the cost of traffic management in the mixed strategy amounts to only 5 per cent of the cost of investment in soundproofing, etc.

Table 2

COMPARATIVE COST OF TWO DIFFERENT STRATEGIES FOR ACHIEVING AN ACCEPTABLE LEVEL OF INDOOR NOISE

TYPE OF STRATEGY	Cost (Kr. million) for various target levels of indoor noise		
	35 dBA	40 dBA	45 dBA
Strategy (a) Soundproofing and noise barriers	21.1	14.3	5.3
Strategy (b) Combination of soundproofing, noise barriers and traffic control	17.3	10.1	4.8
Savings due to strategy (b) (or a combination)	3.8	4.2	0.5

The action carried out in Grünerløkka, a residential district with a population of 10,000, is characteristic: some traffic lanes were closed to private cars, streets were reserved for buses, and parking was restricted. The total cost of project was N.Kr.206,000. The study also included regulations on heavy vehicles in the district - these have not been implemented, however.

The approach in Oslo may be compared with the action taken by the Bavarian Government, which is considering a vast soundproofing programme for housing in towns with a population of over 45,000. The average cost of soundproofing would be DM.4,200, which is comparable to Oslo, and about DM.61 per capita for the 2,770,000 people living in the towns concerned. This very large-scale action leads to the following question: since central governments cannot organise traffic in the towns and have large budgets, may not these two factors overly induce these authorities to adopt soundproofing policies rather than moderate traffic management policies?

Considering the value of efficient traffic management, it is to be hoped that local responsibilities will be asserted. The case of New Zealand may provide an answer. In 1962, the Government passed the Transport Act, which authorises local authorities to restrict heavy-vehicle traffic in order to protect the environment, while carriers are not allowed to claim any compensation for longer hauls, etc. Within this legislative framework the city of Auckland was able to organise protection for the 10 sq. km. Parkwell residential area between the port and industrial zones. Consultation with the transport industry was effective and the traffic diversion adequately enforced.

The variety of local actions will be further illustrated by one last case, that of Blois, France. For the last two years, a large-scale monitoring campaign has enabled both daytime and night-time noise maps to be plotted for Blois. The city authorities have planned a three-year programme starting in January 1979 which combines a public awareness campaign, the monitoring of sources, town planning and a series of specific studies. The executive arm will consist of a noise commissioner who will also be able to deploy an anti-noise police squad. The following special actions are planned:

- opening a restful park with a daytime Leq of less than 50 dBA;
- improvement of the present bus fleet by installing engine claddings designed by a car manufacturer with the help of the Institut de Recherche des Transports;
- provision of an area reserved for noisy recreational activities.

2.3 Conclusion Concerning Specific Actions

The present non-exhaustive review is sufficient to show the wide variety of possible specific approaches and actions a city can take. The difficulty of defining a municipal policy is twofold: the most important problems have to be isolated from the disparate mass of noise conditions in a city and those issues which can be solved more efficiently by the city authorities than by the central Government should be dealt with first. The evidence shows that the management of heavy traffic, including buses, the organisation of noisy community recreational activities and the monitoring of two-wheeled motorised vehicles, while difficult, are particularly advisable areas of local-authority action.

It must be repeated that any methods of arousing or educating the public will be ineffective unless supported by legislation and technology, but, on the other hand, if the latter are not understood by that public, they may be rejected. In many countries, the example comes from above and it is as much necessary to alert, educate and co-ordinate city officials as the man in the street. The city services can directly improve the noise environment through careful management of the factors listed in Table 3. Sensitiveness of city officials to the problem is very important; we saw in the case of Oslo and Auckland that actions relating to traffic but not specifically to noise, can, if noise abatement becomes an added aim, bring about much greater improvements than specific *ad hoc* actions.

TABLE 3

AREAS OF ACTION FOR A CITY AUTHORITY WISHING TO REDUCE NOISE

Noise. City responsibility	Possible influence depends on countries	No influence
I. City or contractual services(1) - Collection of household waste - Incineration plant - Sewerage treatment station - Public transport vehicle (sometimes depending on a group of local authorities) - Local road-mending or -building sites - Firemen - Public parks and gardens - Road sweeping. Tree pruning	State of private vehicles and machinery on public property	Rail traffic Definition of new private vehicle noise limits Definition of manufactured products (in the United States, EPA pre-emption)
II. City regulations - Delivery times and conditions - Markets. Fairs. Fun fairs - Construction sites - Cinemas, theatres, etc. - Bars - Dances, concerts - Outdoor loudspeakers, sirens, bells, music for advertising purposes - Amusement park vehicles and equipment	Military installations. Parade grounds. Shooting ranges	International airports
III. Town planning. Traffic. Zoning and building permits - Siting of industrial zones - Siting of noisy recreational activities - Diversion of heavy traffic - Industrial building permits, etc. - Pedestrian zones, traffic management	Working hours Animals (dogs?)	
IV. Institutions under local responsibility - State, nursery and other schools - Sports grounds, swimming pools - Ambulances - Hospitals (some)	State higher education Private education Hospitals Low-cost rented housing	

(1) US EPA - MNCO. Quietest products to be used by city services provided their cost does not exceed 125 per cent of the equivalent cheapest product.

2.4 Specific Action Flow Chart

To analyse the movement in time of the cases mentioned above, it is possible, in spite of their variety, to distinguish three stages: origin, action and conclusion, in accordance with the following flow chart:

Origin	Action	Conclusion
Complaints or Government encouragement Sometimes local initiative	Monitoring campaign, Source inventory, Surveys (sometimes before, sometimes after)	Technical action plan, Services organisation
	Participation Education	Noise abatement code, Police checks

What is nearly always missing is an assessment of the results of action in physical terms.

Annex I contains an analytical table of the cases studied.

3. LOCAL ACTIONS NOT SPECIFICALLY AIMED AT NOISE ABATEMENT

3.1 Effectiveness of Non-specific Actions

Motor vehicle traffic is by far the nuisance most often mentioned in surveys covering the physical environment; and efficient town planning could considerably reduce nuisance from a good many sources of noise produced by industry, transport or leisure activities. There is therefore significant scope for noise abatement measures at the local level under the heading of highway management and town planning. Such actions cannot be regarded as specifically aimed at the problem of noise since they encompass a great many aspects of urban life. To overlook them would however be a serious mistake on the part of environmental authorities, especially as actions specifically directed at noise abatement do not always meet expectations.

We shall not consider local town-planning actions proper, as these are either fragmentary and still neglect noise or else concern new towns, which are not relevant to our present purpose.

On the other hand, interesting forms of action to reorganise local traffic have been undertaken in various cities. In Darlington itself, the reorganisation of traffic, quite independently of the experiment, was responsible for an improvement clearly perceived by the population (see Section 2.1.1).

Transport or traffic plans on the scale of a town or metropolitan area will be distinguished from the detailed organisation of traffic in residential districts.

3.2 Traffic Plans

3.2.1 Improvement of Urban Sectors

Traffic improvement operations which may be regarded as significant have to do with goods vehicles, speed limits, traffic light regulation, traffic restrictions and the promotion of public transport. As a rule traffic experts have not yet paid enough attention to environmental impacts, since a prevailing major concern is to reduce journey times and delays at traffic lights. Many people thought that by improving traffic flows the noise environment would naturally benefit. This is not necessarily true, as quite often full use of the road network by one-way streets leads rather to a general spreading of noise unaccompanied by any appreciable reduction of loudness in the busiest areas. The average situation has improved to a certain extent, but there has been a deterioration in areas which earlier were relatively spared. This brings us back to the problem of the noise-exposure indicator.

However, even before 1970, certain urban district improvement projects took the noise environment into account. Such was the case, for example, in two sectors of Greater London, Barnsbury (London, Islington) and Kensington.(1) The process comprised, in chronological order, the diversion of through traffic, improvement of bus traffic, car parks near bus stops and the closing of certain streets to cars. This approach is interesting because it is so comprehensive. In addition, the Barnsbury scheme included a goods depot and pedestrian ways between the car parks and the shopping centre. Although no series of noise measurements are available, this type of action usually has the effect of reducing noise practically everywhere, with a probably very slight rise on roads bearing the brunt of through-traffic diversion, which were already very busy before reorganisation.

As in London, Gideonsberg, a semi-central district of Västerås (Sweden, with a population of 100,000) saw the opening in 1966 of a section of ring road to round off a network round the district. In October 1968, six streets inside the district were isolated by blocks of concrete. In 1969, residents in the centre, and even shopkeepers, were highly pleased, but ring-road traffic had gone up appreciably.

3.2.2 Traffic Cells

The system of cells foreshadowed much more extensive measures on a city-wide scale, such as, for example, in Gothenburg, Sweden, followed by Groningen, Netherlands. In August 1970, the centre of Gothenburg was subdivided into five cells which could only be entered

1) "Urban Transport and Environment" Water Bor, JSV, Vol. 15, No. 1, March 1971.

by pedestrians and public or emergency vehicles; all traffic through or between the five cells was transferred outside to the ring road.(1) Traffic in the closed streets in the city centre fell by 70 per cent, while the total number of vehicle-kilometres, including through traffic, rose by only 7 per cent. The reduction in the number of accidents per year was also very significant. Since 1970, this operation has been a continuing success. Access to the city centre has not deteriorated, while the cell system has been extended and will be extended still further. The public was receptive to these widely publicised measures; it was also noted that communication with the public worked better by circulating pamphlets than through an exhibition which few people came to see.

The cell principle has been applied more recently in Groningen in the Netherlands (population 160,000). The traffic system was changed on 18th September, 1977, when the city was divided into four sectors and through-traffic diverted to the ring roads, whereas previously 40 per cent of the vehicle-kilometres travelled in the city centre did not have the centre as their destination. The operation's aims were defined as follows by the city authorities:(2)

a) to distribute space more fairly between cars, pedestrians and two-wheeled traffic;
b) to reduce noise wherever it was excessive;
c) to bring pollution down to a low level.

It will be noted that environmental targets ranked high on the list; the Government shouldered 80 per cent of the cost of the road alterations for two-wheeled traffic and public transport, since the local authority's programme was attuned to central government objectives of promoting public transport and improving safety. The work is estimated to have cost a total of Fl.14 million ($7 million) and comprised:

- installing a freight distribution centre outside the city to reduce heavy vehicle traffic in the centre;
- converting part of the main road into a bus station;
- reserving two streets for pedestrians;
- making considerable provision for cyclists.

The results included, first, a rather small modal shift. Between 1977 and 1978, the Leq noise level fell by 2.1 dBA, rose by 1.8 dBA on the ring road and dropped by 1.7 on the access roads, but bus noise, unfortunately, prevented any greater emission reductions in the centre. The noise level in the Grote Markt, which is now a pedestrian zone, dropped by 12.5 dBA.

1) See also Urban Transport and the Environment, OECD/ECMT, 1979.
2) Ibid.

To sum up, the Groningen experiment is an environmentally satisfactory one, in spite of the small modal shift; the decline of shopping activity in the centre is perhaps temporary and in any case cannot necessarily be attributed to the reorganisation of traffic.

3.2.3 Large Metropolitan Areas and Goods Transport

The example provided by Gothenburg and Groningen cannot be extended to the case of conurbations with populations of one million or more; through traffic in such conurbations in any event becomes a secondary consideration. So far, these metropolitan areas have few overall plans which include improvement of the noise environment. A case in point is Brussels, where the traffic plans do not take account of noise and pollution disamenities.(1) This reserve on the part of large cities may be explained in the case of Belgium by the emphasis laid on the prime necessity of vehicle improvement at a time when the traffic management authorities already have their hands full in dealing with congestion, accidents and, lately motor-fuel savings. For cities like New York and London, improvements have been continued district by district.

One case, that of Osaka City (population 2,770,000) may however be mentioned.(2) Various scenarios concerning traffic trends and organisation were analysed and led to the conclusion that the number of vehicle-kilometres travelled in the city would be between 22 and 28 million by 1990; the city authorities then decided to set the upper limit at 22 million vehicle-kilometres, in particular by promoting public transport (including limousine taxis taking nine passengers) and reorganising goods transport. This has been the subject of a complicated reorganisation comprising in particular the relocation of most transport firms in two distribution centres in the suburbs; the speed limit for heavy vehicles was reduced from 50/60 km/h to 40 km/h. No assessment has been made of the noise environment, but it is probable that the reduction in the number of vehicle-kilometres will not produce any appreciable improvement for the city area as a whole. On the other hand, the improved management of goods transport may be responsible for some substantial progress, considering how much heavy vehicles are responsible, day and night, for the noise impact on outlying residential districts of very large cities.

Side by side with the goods transport plans mentioned above, the problem of vehicles delivering goods in city centres should also be considered for smaller towns as well as the major cities. Various studies and tests have shown that a city authority wishing to improve private motor car traffic flows can do better than merely shift

1) Urban Transport and the Environment, op. cit.
2) Ibid.

delivery times to the morning or night hours. Small deliveries should be combined and transhipment and distribution centres organised at suitable sites. A study in Columbus, Ohio, has shown that the number of delivery vehicles entering the shopping district could be reduced from 660 to 70 by providing a single distribution terminal. Various experiments in the United Kingdom have resulted in a 50 to 85 per cent reduction where delivery vehicle-kilometres are concerned.

It is possible in theory to set out one or two principles for reducing inner city vehicle-kilometres to a minimum:(1)

a) a distribution centre serving a (resident or business) population evenly spread out in a circle reduces traffic to a minimum if it is in the centre of the zone;
b) for city areas with a population of over one million, various types of centre can be provided down the scale from city to to suburb to neighbourhood;
c) an ideal way of reducing all noisy traffic to a minimum consists in locating a city distribution centre near a service ring road some two-thirds to three-quarters of the distance from the centre to the city limits.

The development plans for cities such as Hamburg and Copenhagen do not include ring roads but axial forms of growth with a succession of urban centres, completed by a district centre to counteract the centripetal tendency of radial towns. Measures to restrict heavy-vehicle traffic at special times, particularly at night, will not be overlooked either; many cities in Federal Germany, Switzerland, the Netherlands, etc., apply them effectively.(2) The organisation of goods transport often clashes with the commercial requirements of firms, which want to retain their contact with the customer and to keep an eye on the goods during transport. Considering that it is possible to combine such varied targets as energy conservation and improvement of the noise and visual environments, reducing chemical pollution, etc., by rationalising goods transport, conceivably one special means whereby city authorities can establish contact is through consultation with haulage and retail firms.

1) Systèmes de distribution urbaine de marchandises (Urban goods distribution systems), IRT Bulletin No. 5, January 1974.

2) See for example "Lärmminderung durch Beschränkung des Strassenverkehrs", Volker Jokiel, VDI, Kampf dem Lärm 25, 80-92 (1978).

3.3 Individual Measures in Residential Districts

3.3.1 "Quiet please, residential area!"

It is essential to stress the highly important role which city authorities can play by laying down detailed regulations governing traffic in residential areas and the allocation of space between motor cars, two-wheeled vehicles and pedestrians. Traffic signs and signals, road markings and traffic lanes marked out simply by painted lines or kerbs can be very effective in promoting car and pedestrian safety and in reducing noise.

There is no scope in the present report for analysing what is being done in this connection throughout the world. Regrettably, however, reviews usually speak of pedestrian streets alone, which ultimately must be regarded as an extreme, not very widespread case.

Small-scale replanning measures in urban centres have been much studied, particularly with reference to pedestrian streets. In spite of their general interest, they play only a small part in reducing noise where dwellings are concerned. Less study has been devoted to residential districts.

The most common environmental improvement in residential areas where pedestrians, cars and two-wheeled traffic have to go is obtained by imposing speed limits. Obviously, this slowing down adds to safety, quietness and motor-fuel savings. When it is claimed that bringing speed limits down to less than 60 km/h is valueless for noise and energy purposes because of the use made of the gearbox, it is forgotten that such a lowering further reduces acceleration levels.

We need not refer to the considerable work done in the British, Scandinavian and French new towns and elsewhere.

3.3.2 Practical Measures in Residential Districts

In September 1976 the Netherlands defined the concept of "residential zone" by a Ministerial Order.(1) Scandinavia has demonstrated the importance of public involvement for promoting the success of small-scale replanning measures, which are usually tested provisionally for a year before being made permanent.

In the Federal Republic of Germany, at the instigation of the Ministry of Transport, the ADAC (Allgemeiner Deutscher Automobil Club) surveyed 403 towns and districts and prepared a carefully documented brochure.(2) The effect of various types of measures to

1) Woonerf (Wohndorf): Eine andere Art von Einrichten der Wohnumgebung und die dort geltenden neuen Veherhrsanordnungen, Royal Touring Club of the Netherlands, April 1977.

2) Sicherheit für den Fussgänger II - Verkehrsberuhigung Schlussfolgerungen aus dem Städtewettbewerb, ADAC, Bundesminister für Verkehr, 1977.

regulate traffic speed was carefully investigated, and it was noted, for example, that it was possible to lower speeds by about 10 km/h, i.e. from an average speed of 48 km/h to 38 km/h, by making slight changes to traffic lanes and reducing their width.

Such measures to reduce vehicle speeds have certain advantages in promoting safety and the re-allocation of space between pedestrian, two-wheeled and other traffic. They also eliminate traffic taking back-street routes through residential districts in order to avoid congested main roads. In terms of noise, substantial benefits can be expected owing to the reduced volume of through traffic, hence reduced noise peaks, and the lesser abruptness and lower level of such peaks. It is regrettable, however, that none of the studies presented were carried out at night, when lighting is a very effective means of action. The ADAC does of course admit that these are only palliative measures, and that vehicles should above all be soundproofed and engines cladded.

The analysis thus suggests the following measures:

- Putting up traffic signs in residential zones;
- A speed limit (30 km/h);
- Reducing the number of other traffic signs as far as possible, especially priority signs, since they tend to speed up the traffic; retaining only priority from the right in all cases;
- Eliminating through traffic by slowing down vehicles, lengthening routes, etc.;
- Organising parking facilities so as to improve visibility and reduce speed (parking alternating from side to side, etc.);
- Withdrawing public areas from general traffic and marking them out for pedestrians, etc.

Table 4 sums up the effectiveness of measures applied according to the partial aims in view.(1)

These measures can only be applied, of course, to roads carrying little traffic, where according to experts the maximum rush-hour flow can be set at between 200 and 400 vehicles per hour.

The effectiveness of these measures for noise abatement should be analysed with regard to certain points such as the use of paving, the provision of paths for motorised two-wheeled traffic and operation at night; the promotion of such small-scale replanning to reduce noise in residential districts can however largely be expected without the noise abatement authorities being particularly involved. What is regarded as calling for greater attention is the overall organisation of transport on the scale of a whole city.

1) Sicherheit für den Fussgänger, op. cit.

TABLE 4

Measure \ Partial aim		To avoid through-traffic	To reduce speed	To improve visibility	To promote residential areas	To provide more space for pedestrians, children, etc.	To reduce noise (1)
Transport system	- Dead-end streets	••	•			•	•
	- Winding streets	•	•				•
	- One-way streets	•					
Traffic flow	- Organisation of parking facilities		••	••			
	- Narrower traffic lanes		••				•
Treatment of the ground	- Paving	•	•		••	••	??
	- Partial paving		•		••	•	?
	- Traffic islands				••	••	
	- Other ground markings		•				
Traffic signs	- Residential zone		•				•
	- 30 km/h		••				•
	- Priority						
	- Other		•				•
Lighting ?							
"Silent policemen" (speed control bumps)		•	••				•

(1) This column does not appear in the reference.

4. CONCLUSIONS AND PROPOSALS

The variety of actions that can be taken locally to abate noise is considerable, but their effectiveness is seldom evaluated. Specific local actions, especially those calling for participation by the general public, have gone through the exploratory stage and should now be followed by others which do not overambitiously seek to alter behaviour. The training of children and young people should really be taken over by appropriate educational institutions, since on this score the city authorities can neither keep up the continuous effort which is essentially needed nor count on the necessary technical expertise.(1) As for action aimed at the general public, the many different forms of communication used presents a difficult choice; if future action is to be economical, then exhibitions and talks would appear to be less effective than the radio or newspapers; pamphlets and printed leaflets may be few in number but very widely circulated; in the case of posters, the information content is small and they must necessarily suggest that people turn to another more detailed form of information; quiet days or weekends would seem to be of value. This leaves the question of motivation and rewards: competitions, free publicity, tax reliefs?(2)

If less ambitious aims have to be adopted concerning the behaviour of the general public, some forms of participation can nevertheless be counted on when preparing official regulations for publication and especially enforcement. Special noise abatement codes are often ineffective for lack of funds, qualified personnel and public and general police motivation. Control is one of the most difficult problems, and a combination of measures ought to be used for adequately enforcing the regulations:

- Information and public relations.
- Appointment of a special executive and co-ordination between city services with regard to noise abatement.
- Training of a very small but special police squad. Experience has shown that the general police may not be sufficiently motivated to clamp down on offences against the noise code. What must still be determined is the size of population warranting the services of a special police officer.
- Adequate measurement instrumentation.

The co-ordination of city services is all the more important as actions not specifically directed at noise abatement, such as traffic management, town planning, building and the management of city maintenance services, also have a strong impact on the noise environment. Is it possible to arouse the interest of the general public when the city employees have not first been convinced?

1) See also Background Report No. 7, Education and Information.

2) Ibid.

Short of action concerned with noise abatement alone, many other kinds of action might be taken which could both conserve energy and reduce the noise impact: quiet leisure activities, use of bicycles, organisation of goods transport, promotion of quiet public transport. Others might combine pleasanter working conditions for building and construction site workers with improving the quality of the environment.

With regard to private trade and industry, experiments carried out in fairly small communities have proved rather disappointing; those with a population under 200,000 do not have the same resources for education and regulation as are available to government and trade associations. A great many aspects of working life, such as noise at the workplace, are covered by government regulations so that there is only a narrow margin left for consultation and agreement between city authorities and trade and industry. In large cities, on the other hand, while the scope for action is much greater, the powers which certain sectors of business will always enjoy can only be counter-balanced by government.

If guidelines for individual local actions were to be suggested, the following might be considered:

1st suggestion. For a medium-sized town, consultation with the 16-35 age group on specific subjects: two-wheeled motor vehicles, public places, etc. There is little likelihood of a confusion of roles, since that of the noise producer predominates and very natural motivations may be found. Communication may be established in many ways: through cafés, bicycle and motor-cycle dealers, etc., newspapers, "quiet Sundays". The object would in particular be the hitherto unsolved problem of reducing the noise made by two-wheeled vehicles. As there is a risk of segregating the population, the age bracket must be broad. Perhaps quiet recreational sites and quiet businesses could be rewarded through town publicity?

2nd suggestion. For a large conurbation: consultation with goods carriers, co-ordination between services, appointment of a special executive. The principal target of consultation with the general public would be the commercial sector, which could serve as intermediaries while still being concerned themselves. Might rewards be in tax form, or through town publicity?

3rd suggestion. For metropolitan areas, education, information and participation of government officials. How can each help in his own sector? Could some form of competition be used and prizes awarded?

4th suggestion. For a neighbourhood, the answer may be a survey in depth and the search for solutions - during meetings, debates regarding small-scale adjustments covering traffic, special-vehicle passengers, refuse collection trucks, road-repair and gardening activities.

5th suggestion. For a small- or medium-sized town: consultation with the general public on the subject of quiet recreational activities combined with quiet weekends; discussion of such substitutes for present noisy activities as bicycles, etc., and manual lawnmowers (for small gardens).

Such actions will always call for a high degree of motivation and a great deal of time on the part of the local officials in charge. Government financial aid alone would not therefore suffice.

ANNEX 1

SPECIFIC NOISE ABATEMENT ACTIONS

TOWN	DARLINGTON, U.K.	ALLENTOWN, PENNSYLVANIA, U.S.A.	MARSEILLES, FRANCE	BLOIS, FRANCE	AUCKLAND, NEW ZEALAND	OSLO, NORWAY	SAN DIEGO CALIFORNIA, U.S.A.	COLORADO SPRINGS COLORADO, U.S.A.
POPULATION	95,000	108,000	1,000,000	50,000				197,000
- Origin of the operation								
. Date	20.09.76	September 1977	May 1975		22.09.79	1976	November 1977	
. Government impetus	NAC	EPA Quiet Communities Program	-	Comité Bruit Vibrations PARIS		White paper and government financing	ECHO Program	
. Complaints	-	-	-	-	Strong local complaints			Complaints
. Surveys	-	-	-	-	-			
. Local initiative	-	-	City authority initiative	Local technical proposal				
- Special Executive	4 local committees	2 full-time officials	Special organisational chart.	Deputy Mayor	Deputy Mayor	City Health Department	Administrator	Administrator loaned by BOULDER, in the Health Protection Service
. Co-ordination of services	-	-		Structure planned			Education and co-ordination of services	
. Special police	-	Noise control officer						Technician and police officer combined (2 officers)
- Funding	£50,000 from London + officials' time	$60,000 from the ONAC + fines	?	Frs. 500,000 to 1,000,000 (50% government)	-	Cost-effectiveness analysis		$60,000 per year
- Stages of action								
. Preliminary survey	600 people	YES } Draft report in June 1979	YES	NO	Special among lorry drivers	YES, noise map	Noise map	
. Monitoring, Inventory of sources		YES } 12,000 monitoring points		500 points + Noise map (day, night)				
. Training scheme	YES, many claimed		YES	Information for heavy vehicle drivers				Training for the police
. Police control	-	YES	YES	-			YES	Unsuccessful until the police received special noise training and some were assigned full-time to noise work.
. Definition of technical action	YES	YES	YES	YES, planned	YES, management of heavy traffic	YES, traffic management, soundproofing	YES, full	
. Follow-up survey	YES, 600 people	-	YES, for checking results	-	-	Survey planned in 1980		
. Issue of code and control	-	May 1979	-	Regulations planned Public awareness campaign planned	Heavy vehicle traffic regulations	YES (fines, court rulings)		
- Public relations, participation								Education of public, but little interest shown by the latter. Use of newspapers Various prospectuses (including one on dog barking)
. Radio, TV	YES	YES	-	-	-			
. Newspapers	YES	YES	YES	-	-			
. Posters	YES	?	Small posters	-	-			
. Window stickers, emblems	YES	-	YES + leaflets	-	-			
. Printed pamphlets	120	-	-	-	-			
. Lectures	YES	-	YES, 5	-	-			
. Exhibitions	YES - BUS + FIXED	-	-	-	-			
. Retailers	YES, of two-wheeled vehicles, etc.	-	-	-	-			
. Quiet days	NO	Quiet weekends	-	-	-			
. Postmark slogan	-	-	YES	-	-			
. School action	Considerable: poetry, poster competitions, etc.	-	-	-	-			
. Giant sound-level meters	-	-	-	Giant sound-level meter planned in city centre	-			
- Summary Report	YES, June 1979	March 1980	-	September 1979			March 1979	
- Special features	Song	Similar to Darlington, but 6 months later and more technical	Encouragement to use soundproofed equipment. Gift for newlyweds.		Good contacts with road hauliers	Heavy vehicle regulations. Road network for heavy vehicles	Good study of rules, complaints, official reports, court procedure	Need for expensive equipment for valid reports. Specially equipped vehicle

NOISE CHARGES

CONTENTS

1. INTRODUCTION

A noise abatement strategy includes many elements and is subject to many constraints. The elements include in particular measures designed to reduce noise at the source, or to reduce the transmission of noise by sound-insulation of the receiving environment, and measures aimed at regulating and influencing behaviour.(1) The constraints are mainly of a historical, technical and economic kind: historically the development of industrial societies has led to a heavy legacy of noise, since the quality of the noise environment has steadily deteriorated and may well become even worse unless stringent measures are taken.(2) From a technological standpoint, the promotion of effective methods to reduce noise is urgently needed. Lastly, adequate and sustained financing of policies is required.

A number of fundamental questions therefore arise in connection with noise abatement policies:

i) How can the accumulated deterioration of the noise environment be made up?

ii) How can the various factors of noise abatement be effectively integrated to form a real anti-noise strategy?

iii) How can the effectiveness of policies be improved, especially as regards the actual enforcement of decisions?

iv) How can strategies be adapted and be made to evolve over time, particularly with regard to international and national standards?

v) How can such policies be financed?

While it is true that the regulatory approach, both in terms of planning and implementation, is designed to answer these questions, cannot more be done to complement regulations by incentive and financial mechanisms? Such is the aim of introducing noise emission charges.

The idea of applying charges has made considerable headway in recent years. Some countries are planning to use them for motor vehicles, and several others already impose charges on aircraft noise.

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1) See Background Report No. 3, Regulating for Noise Abatement.

2) See Background Report No. 1, The Present and Future State of the Noise Environment, and The State of the Environment, OECD 1979.

2. MOTOR VEHICLE NOISE CHARGES

Noise charges for motor vehicles should meet the incentive, integration and financial needs mentioned in the introduction.

2.1 The Incentive Function

Noise is reduced at the source mainly by setting noise emission standards. To the extent that these are strictly and fully applied, such a practice plays an important part in noise abatement policies, but is this enough? Analysis shows that in the absence of complementary mechanisms the system of emission standards has serious defects, mainly on account of its rigid nature.

It is thus a well-known fact that the setting of noise emission standards for motor vehicles is a cumbersome, slow and complicated process, due in particular to real or alleged technological difficulties argued by manufacturers and to commercial constraints, especially at international level. The outcome as a rule is that the standard, achieved following arduous negotiations, will be a compromise and reflect available or known noise abatement technology, one of average quality if not the lowest common denominator. For this reason, sophisticated technologies have little chance of being developed or even brought to light. As noted in the Report by the Ad Hoc Group on Noise Abatement Policies, "The setting of the standard and the fixing of the date of enforcement requires often very lengthy and difficult negotiations, especially with regard to the question that noise reductions have to be considered technically and economically feasible. Experience shows that it is difficult to induce industry to make greater efforts with regard to the development and use of environmentally acceptable products. It can be concluded that standards, although essential, should be complemented by incentive mechanisms".(1)

Clearly, therefore, amendment of the standards, and their strengthening over time will be a lengthy, often uncertain process. Much time elapses before standards are altered, and the period between two changes may be as long as ten years.

From the manufacturer's standpoint, the standard represents a goal in itself, one which nothing prompts him to exceed. It is in the nature of a concession granted by the authorities and an inducement to maintain the status quo.

To a certain extent, international constraints may also slow reinforcement of the standards. Thus the setting of uniform emission levels through international agreements in order to preclude non-tariff trade barriers may prevent countries which so desire from

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1) Reducing Noise in OECD Countries, OECD 1978, p. 87.

further reducing these levels, at least by regulation. Other methods must therefore be found, and if standards cannot be set, incentives may be used.

The standard hence constitutes a useful stage of noise control strategy as well as a curb if there are no suitable mechanisms for amending it over time.

But noise levels must be steadily and significantly lowered to check degradation of the noise environment and if possible improve it. Recourse to incentive mechanisms is accordingly desirable.

To impose a charge on noise emitted by motor vehicles, including private cars, lorries and motorcycles, is one method: to have to pay for emitting noise is an incentive to reduce noise.

An incentive for whom? Two economic transactors are here involved, the vehicle manufacturer and the user.

As defined by the OECD we know that the Polluter-Pays Principle does not call for identification of the "polluter". Actually the authorities must select the point of impact where the charge (or regulation) will be most effective. In regard to motor vehicle traffic two problems arise: (i) pollution by motor vehicles is due to both the manufacturer and the user; (ii) the pollution sources are mobile. Moreover, if the aim is to reduce noise emission at source, the question is whether it is proposed to emphasize reduction at the source on the part of the manufacturer, or the reduction of noise emission by changing user behaviour (both steps in any event being interdependent).

Action in regard to the manufacturer has a twofold advantage; first, it affects the economic transactor who has the real technological and economic capacity to reduce the noise levels of the vehicles he produces, and secondly, the charge is imposed on a "stationary" transactor who can be easily identified and controlled.

What will happen if the manufacturer has to pay a charge depending on the noise level of each vehicle which is sold? He will try to reduce the emission levels or else merely try to pass on the charge into the vehicle's selling price. In the first case, the rate of the charge must be high enough to make it more profitable to reduce the noise level than to pay the charge. In the second case, the increased selling price will induce potential buyers to choose relatively cheaper vehicles.(1) Here again the manufacturer will be induced to improve the acoustic performance of his vehicles in order to retain his share of the market.

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1) And less noisy vehicles, if noise is a factor making for a difference in price between two types of otherwise comparable vehicle. The extent to which selling prices will be affected by charges is obviously dependent on the market structure.

The drawback of a charge imposed on the manufacturer is that no direct link is established with the actual noise impact of the vehicle, which depends on how it is used. A charge might hence conceivably be imposed on the vehicle user, where the advantages and drawbacks of payment by the manufacturer are exactly reversed: the advantage would thus consist in linking the charge to emissions and ultimately to the real impact of noise (depending on the rate and places of use, etc.). The drawback is the greater complexity of such a system: to tax millions of mobile sources is of course no easy task. Nor does the user have the technological or economic capacity to change the noise characteristics of his vehicle, while on the other hand driver behaviour does have a decisive effect on the noise which is emitted. Simplified systems might however be devised for assessing the potential impact of vehicle noise (see below) with payment of an annual charge. The user would then be induced to purchase a quieter vehicle in order to pay a lower charge, which again will have an incentive effect on the manufacturer.

Whatever methods are used for collecting the charge, the advantages are thus the following:

- An incentive for the manufacturer to make use of the best technologies for reducing noise in the short term, and to develop new technologies in the long term.
- Greater flexibility to the extent that the manufacturer has freedom of choice: no particular technology is imposed, and he may either decide to alter his models, increase the production of one with respect to another, etc.
- Economy, since each manufacturer will be induced to develop a technology costing less than payment of a charge. Noise will hence be reduced at least cost to the community.
- A dynamic and progressive approach, resulting from a regular, sustained incentive to reduce noise levels.

Another advantage of such a charge, moreover, is that financial resources are provided.

2.2 A Mechanism for Integrating Policy and Providing Finance

Noise abatement measures should not be aimed solely at reducing noise at the source. As stated in the Introduction, loudness of reception depends not only on action at the emission stage but also on action with regard to transmission paths, the receiving environment etc. So why not use the funds collected by means of a noise charge to finance these actions?

A successful noise abatement strategy requires that actions be integrated and co-ordinated.(1) Experience in water management shows that the redistributive charge is a suitable integrating mechanism.

1) See Background Report No. 3 Regulating for Noise Abatement.

All the measures referred to (soundproofing of housing, noise barriers, etc.) are generally very costly, and the proceeds from the charges would be a useful source of finance.

As will also be seen for aircraft noise, it will be some time before noise standards can appreciably improve the noise environment, and some forecasts envisage a delay of ten to fifteen years. Hence it is here that the especially difficult problem of making good the accumulated deterioration and of financing transitional measures to protect the most exposed populations arises; moreover in some cases certain persons and groups must be compensated when no satisfactory protective measures can be taken. Some regulations provide expressly for compensation mechanisms of this kind.(1) Clearly a charge would help to finance such mechanisms for compensation purposes, and it could also contribute to the financing of research and development where noise abatement technologies are concerned.

Lastly, it may be noted that the financing and incentive roles are complementary and in practice can be combined; the closer the relationship between the charge paid and the noise emitted, the stronger the incentive, whatever the rate may be.

2.3 Calculating and Implementing the Charges

Although at present there is no case of charges being applied to motor vehicles, numerous analyses have been made and several countries are studying the feasibility of such charges.(2) The new Noise Nuisance Act in the Netherlands (March 1979) expressly lays down that such charges shall be applied.(3) It may therefore be useful to describe briefly the main conclusions of these studies and projects.

2.3.1 A system based on estimated noise nuisance

A system has been suggested(4) which bases the charge on noise levels measured under test conditions, mileage and the zone in which the vehicle is registered. It will be briefly described hereunder as an example, as it highlights the main elements to be taken into account for calculating such a charge. The basis of assessment is determined as follows:

Basis (A.Z.K.)
where: A = the annoyance score
Z = the zone rating
K = the mileage (in kilometres) per annum

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1) See Background Report No. 6, Compensation for Damage due to Noise

2) See in particular Reducing Noise in OECD Countries op.cit., and Noise Charges, OECD 1976

3) See Noise Charges in the Netherlands, OECD 1977

4) Ibid.

Determination of the annoyance score is based on empirical evidence, indicating that annoyance doubles with each 10 dB noise increase.(1) Zone rating is introduced on the assumption that as a rule the noise impact of vehicles owned by the urban residents will be greater than that of vehicles owned by rural or semi-rural residents. Thus, for example, a rural area would attract a weight of 0.5, a semi-rural zone one of 1.0 and an urban area one of 2.0. This might be a reasonable assumption in the case of various types of private car, light vehicles, small vans, mopeds and light motorcycles, the use of which will largely depend on the owner's residence; but becomes more questionable in the case of heavy commercial vehicles and the heavier types of private car used mainly for business purposes. This calls for a more sophisticated system of zone rating which may complicate the charge system considerably.

The application of a mileage coefficient is necessary for relating the charge to actual use of the vehicle. While this requires a periodical check of the vehicle and perhaps a few additional measures to counter opportunities of fraud, on the other hand it is more equitable than a system whereby use is estimated, for example, on the basis of statistics of average mileage per vehicle category. The actual choice should therefore be made in respect of both equity and the cost of implementing such a system.

By multiplying the annoyance score (A) with the zone rating (Z) and yearly mileage in kilometres (K), a total noise rating (TNR) per vehicle will be obtained. Thus:

$TNR = KZA$

The charge per vehicle will then be:

$C = bKZA$, where b is the basis of assessment

The rate can be determined either in terms of the total revenue needed for applying a redistributive charge or the estimated cost of an incentive charge to promote noise abatement. Taking for example a private car registered in an urban zone, with a relatively low noise level of 70 dBA and a recorded annual mileage of 10,000 km, we get a total noise rating of 10,000 x 20 x 2 = 400,000. For a truck registered in the same zone with a yearly mileage of 30,000 km and a noise level of 90 dBA, the number of taxable noise units would

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1) In the following examples, it is assumed that at 50 dBA Leq, the annoyance score is zero. Hence the annoyance score increases in the following way:

Noise level dBA Leq	Annoyance score
60	10
70	20
80	40
90	80

amount to 4.8 million, or 12 times the previous figure mentioned. Should the truck be registered in a semi-rural zone the charge would be halved. This latter example again shows that the zone ratings must be very carefully applied, since a truck with a yearly mileage of 30,000 km can hardly be expected to be used mainly in one zone alone.

This scheme, presented for illustrative purposes points out, in particular, that the noisiest vehicles should be more heavily charged. In fact, priority should be given to noise abatement of heavy vehicles and motorcycles; hence, one could envisage, at least as a first step, levying noise charges on these two categories of vehicles only. This would have the advantage of simplifying the implementation of charges while concentrating on the noisiest vehicles.

2.3.2 The Charge System Under Consideration in the Netherlands

As already indicated, the new Dutch Noise Nuisance Act (March 1979) provides for the introduction of charges on the noise emission of motor vehicles (and aircraft: see below). The method of calculating these charges has not yet been determined and several systems are under consideration.(1)

The Act specifies that the charge must be based on noise emission levels and/or noise duration.

The noise duration factor might be allowed for, although very roughly, by means of a surtax on petrol. It is proposed to introduce such a charge on a preliminary basis: the rate would be moderate and it would be for a four-year period starting in 1980. It would be used to finance the initial cost of implementing the Noise Act, namely administrative costs and R & D expenditure to the extent of some Fl.40 million per year.

Emission levels would be taken into account by means of a charge based on noise levels measured under standard test conditions (ISO Test) and paid by the vehicle owner or buyer. The rate would be higher than for the surtax on petrol and would be used to finance an extensive noise abatement programme (noise barriers, soundproofing, etc.) costing some Fl.135 million (1976) per year, or Fl.149 million (1978). The charge would be steeply progressive and be doubled for each increment of 3 dBA. It would be applied in the mid-1980s, after testing the surtax on petrol.

Clearly only a charge based on noise levels would have an incentive effect, particularly in view of its steep progression. It is not, however, based on a calculation of impact.

1) See Noise Charges in the Netherlands, OECD, 1977

3. AIRCRAFT NOISE CHARGES

3.1 An Incentive and Financing Requirement

Aircraft noise can be tackled by means of two complementary strategies: reduction at the source and protective measures around airports.

3.1.1 Reduction at source

Aircraft noise is reduced at source mainly by using noise standards laid down by the International Civil Aviation Organisation (ICAO).

The existing regulations have a number of shortcomings:

(i) Although ICAO standards represent a significant step forward, their full impact will not be felt for some years. In fact, the noise limits apply only to types of aircraft designed after 1st January, 1969 and to types of aircraft designed before this date but manufactured after 1st March, 1972 (or 1st January, 1976 according to the type of engine). Aircraft already flying before the publication of the first noise standards in 1971(1), and those designed before 1969 and manufactured before 1972 (or 1976 according to the type of engine) are exempted. It is estimated that some 2,500 to 3,000 aircraft do not conform to the noise standards (excluding aircraft owned by East European airlines).

(ii) Since the operational life of a commercial aircraft is 15 to 20 years, the number of old, noisy aircraft is not expected to fall significantly until after 1980. In view of the number of movements made by the noisiest aircraft, little significant reduction of annoyance caused to people living near airports can be estimated before 1990.

(iii) It should also be noted that some consider the ICAO standards insufficient to protect the health and welfare of the public. In fact, these standards do not define noise levels acceptable to the public but the lowest noise levels estimated technically feasible and economically reasonable for aircraft manufacturers. Moreover, the annoyance created in communities around airports is not only a function of the noise of individual aircraft but also of the number of movements; ICAO noise standards apply only to the first element and not to the second. Even if all aircraft had a noise certification, a noise problem could arise due to the intensity of air traffic.

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1) Standards referred to as "Annex 16" of the ICAO Convention. For further details, see Reducing Noise in OECD Countries, op. cit. page 82.

Recourse to charges on aircraft noise as a <u>complement</u> to existing regulations should therefore result in the following advantages:

(i) The charge, if set at a sufficiently incentive level, could encourage airlines to retrofit aircraft that are not certified by the ICAO. This operation is technically feasible for 90 per cent of existing aircraft.

(ii) Similarly, airlines would be encouraged to renew their fleet of aircraft more promptly and to purchase quieter aircraft.

(iii) The charge would constitute a permanent incentive towards developing quieter aircraft.

(iv) At operational level, airlines would be induced to use the quietest type of aircraft on short, busy routes involving large numbers of landings and take-offs, and the noisiest type on the longest routes, where the number of movements is smaller.

3.1.2 <u>Local noise abatement</u>

To abate local noise, i.e. around airports, various methods can be used, as by soundproofing the most exposed dwellings or purchasing them and rehousing the local inhabitants, acquiring land through recourse to zoning procedures, etc., while the possibility of paying compensation to those most exposed to noise should be borne in mind. Such measures are generally very costly, and consideration could be given to financing them by means of noise charges which would be levied by the airports.

Charges would have the particular advantage of facilitating and speeding such operations, which in many cases are urgently called for.

In most cases, as it happens, it is this redistributive approach which is adopted.

3.2 <u>Existing Charge Systems</u>

Since 1973 <u>France</u> has levied a special tax to finance up to two-thirds of the cost of soundproofing public and private buildings or of purchasing property exposed to excessive noise levels. This system is used at the two Paris airports (Orly and Roissy-Charles de Gaulle). Strictly speaking, however, it is not a charge on noise, since the amount bears no relation to noise emissions and a tax per passenger carried is merely involved (one franc for domestic flights and three francs for international flights).

Between 1973 and 1979, some Frs.160 million were thus able to be allocated to the soundproofing of classrooms and hospital rooms and to the purchasing of dwellings.

The introduction of a real noise-related charge for aircraft has been proposed but has yet to be approved.(1)

In Japan, a "special landing charge" for the purpose of financing noise-abatement operations has been levied since September 1975.

This charge is computed as follows:

(Maximum weight of aircraft in tonnes x 580)

$$+ \left(\frac{\text{EPNdB take-off value} + \text{EPNdB landing value}}{2} - 83\right) \times 3,260 \text{ yen}$$

In 1979, the charges by type of aircraft were as follows:

Type of aircraft	Charge	
	Yen	US$
B.747.SR	215,420	1,034
DC.8	196,680	944
L.1011	169,100	812
B.727	101,240	487
DC.9	69,280	333

The charge is paid by the airlines, and part is shared among the passengers by including the following flat rate amounts in the price of tickets (for domestic flights only):

	Yen	US$
Adult	600	3
Child	300	1.5
Handicapped person	450	2.25

In fiscal year 1978 the revenue so obtained amounted to ¥.19,013 million ($95 million).

Another approach currently used in Germany and the United Kingdom consists in granting rebates on normal airport charges instead of levying charges in the strict sense.

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1) The basis for the charge would be the noise emission in EPNdB as measured under the ICAO Annex 16, noise certification procedure and called "characteristic noise" (CN) compared with the maximum noise level authorised under Annex 16, called "reference noise" (RN):

Aircraft would thus be classified in five categories:

Category I if CN is greater than RN;
Category II if CN is equal to or lower than RN by a maximum of 9 EPNdB;
Category III if CN is lower than RN by no less than 9 EPNdB and no more than 18 EPNdB;
Category IV if CN is lower than RN by no less than 18 EPNdB and no more than 27 EPNdB;
Category V if CN is lower than RN by more than 27 EPNdB.

The charge (t) would be calculated by applying a rate of:

Category I	t	Francs per ton of maximum take-off weight
Category II	1/2 t	" " " " " " "
Category III	1/4 t	" " " " " " "
Category IV	1/8 t	" " " " " " "
Category V	0 t	" " " " " " "

In Germany, a rebate of 5 per cent has been granted since 1st April, 1976 for aircraft complying with ICAO standards. Since November 1978 the rebate has been 11 per cent. The revenue from the supplement levied on non certified aircraft is used to finance compensation in the most exposed zones.

In the United Kingdom, Manchester Airport has been using a system of rebates since 1st April, 1975: one of 10 per cent on landing charges (plus an additional rebate of 20 per cent on the "surcharges" for international flights).

The rebate applies to aircraft which have been noise-certificated to the ICAO standards or the American "FAR 36" standards, and is granted for aircraft which do not exceed the following noise levels:

Aircraft type	Take-off levels (PndB)
Boeing 747	100
DC10, Tristar	98
Airbus 300 B and hush-kitted Boeing 727	97
Hush-kitted Boeing 737, DC9 Fokker 28, Falcon 20, Hush-kitted H.S. 125	96

In order to benefit from the rebate the airlines must file a special application and show evidence that the noise levels of their aircraft do not exceed prescribed levels. Thirty-two airlines have asked to participate in this system, and the amount of rebates as a percentage of total landing charges collected has risen from 0.77 per cent in 1975/76 to 1.4 per cent in 1977/78.

Since 1st April, 1979 a comparable system has been introduced at the three London airports (Heathrow, Gatwick, Stansted), where the rebate is 15 per cent. The rebate applies to noise certificated aircraft.

In the Netherlands the Aviation Act stipulates that aircraft noise charges shall be implemented. A system is at present being worked out. It would be based on aircraft noise emission (not the impact). The charge would double for each 3 x 3 dBA increase of the noise level as measured according to FAR 36 standard measurement (three measuring points - approach, take-off, sideline). The rate would be redistributive, i.e. used to finance local noise protection measures.

3.3 Proposed Systems

Although the idea of penalising the noisiest aircraft is gaining favour, the above examples show that existing systems are still somewhat simplistic. The connection between the basis of the charge and the actual noise levels is fairly loose, while no reference is made to the noise's real impact. The rates seem fairly arbitrary, in that no explicit relationship with a specific funding scheme and a fortiori no calculated incentive function exist.

Studies carried out at the OECD and elsewhere, however, show that it would be possible to introduce a system of aircraft noise charges based on the potential noise impact of each type of aircraft without requiring unduly complicated calculations. It is along these lines, moreover, that the Netherlands would seem to be working. In this regard the OECD Ad Hoc Group on Noise Abatement Policies has recommended that such charges be linked to a "standardised impact under usual operating conditions".(1)

The noise impact of aircraft can in fact be easily evaluated owing to the following factors:

- the impact is located in clearly defined zones (airports);
- the knowledge of the noise level of each type of aircraft is precise;
- the knowledge of the corresponding "noise footprint", i.e. the ground area affected by the noise load, is also precise;
- annoyance can also be measured: it is now possible to ascertain the percentage of people highly annoyed in relation to each noise level.

As regards the rates, those of a redistributive charge are easy to calculate: it suffices to know the cost of programmes to be financed by the charge for protection against noise in the vicinity of airports. Calculation of an incentive rate, i.e. one inducing airlines to take appropriate noise abatement measures, is much more difficult. Trial calculations(2) show that account must be taken of:

- capital costs and any losses in revenue (when aircraft to be modified are grounded) and changes in operating costs and productivity;
- the number of airports levying noise charges and the relative rates of such charges;
- the annual number of landings;
- the aircraft's remaining operational life.

The undertaking is therefore complex but feasible. No doubt the greatest obstacle lies in evaluating the above-mentioned variables.

Trial calculations show that very high rates would be required if they are to serve as an incentive to retrofit or replace aircraft, which is hardly surprising in view of the fact that the average cost of hush-kitting an existing aircraft is some $1.4 million.(3) Yet

1) Reducing Noise in OECD Countries, op. cit., page 76.

2) See: Charging for Noise, OECD, 1976.

3) This is the average cost in 1979 US$ of the "SAM" (Sound Absorption Material) method. The cost varies according to the type of aircraft. See Background Report No. 8, The Cost of Noise Abatement.

an incentive effect would not necessarily be precluded by lower rates, for example redistributive rates, as indicated in the report by the above-mentioned Ad Hoc Group:

"The existence of a charge, even at a lower level than that required to induce retrofit or replacement, will nevertheless be a factor to be taken into account to prompt airlines to take action in this direction. Also charges will be a constant stimulus to the research and development of quieter engines. Even if charges are not high enough to represent alone a reason to modify or replace a noisy aircraft, the mere fact that airlines know that the less noise they make, the less charge they pay, constitutes a factor to be taken into account (this holds particularly true if the charge cannot be passed on to the passengers)."(1)

4. CONCLUSION

The idea of directly or indirectly charging for the emission of noise has made considerable headway in recent years. As regards aircraft noise some systems are already being applied, while others are in process of being worked out. The efficiency of existing systems could be improved by more closely linking them with the impact of the noise emitted.

Where land-transport noise is concerned, we are still in the research stage, even if such research is now well advanced. While several countries are considering some form of charge on motor vehicle noise, no specific system has as yet been introduced.

As pointed out in the Introduction, the noise environment continues to deteriorate.(2) This trend can only be reversed by energetic policies in which economic incentives have an important role to play: on this account the OECD Council has recommended that Member countries "support this dynamic approach to noise abatement by using, as appropriate, economic incentives. These incentives could consist of noise-related charges for certain noise-producing equipment. When this is not in conflict with the national fiscal system, the resulting proceeds should be devoted to the financing and promotion of noise abatement measures".(3)

1) Reducing Noise in OECD Countries, op. cit., page 81.

2) See Background Report No. 1, The Present and Future State of the Noise Environment.

3) Recommendation of the Council on Noise Abatement Policies /C(78)73(Final)/, 12th July, 1978.

BACKGROUND REPORT NUMBER 6

COMPENSATION FOR DAMAGE DUE TO NOISE

CONTENTS

1. THE ROLE OF COMPENSATION

Compensation (or redress) for damage(1) may be defined as payment, in cash or in kind, designed to restore as far as possible a person to his initial level of welfare as before the occurrence of the damage.

The need to compensate for damage is felt with particular acuteness in the case of the environment, whether in the event of accidental pollution (discharge of chemicals, oil spills), or more simply when under certain conditions no effective preventive measures can be taken. Such a situation often applies with regard to noise: noisy city streets lined with houses, built-up areas around airports, dwellings near noisy industrial plants, etc.

Unpleasant, even intolerable, conditions arise not infrequently in such cases, either because no satisfactory means of prevention are available, or because the effects of preventive measures (reducing the emission levels of vehicles) will only make themselves fully felt after some considerable time: it will be remembered that it takes ten to fifteen years for motor vehicles and some twenty years for aircraft to be replaced. To this must be added that the effect of reduction at the source may be slowed or counter-balanced by increases in car numbers or traffic. At all events, forecasts of noise exposure indicate a permanent risk of deterioration as regards quality of the noise environment, nor can any significant improvement be expected for some time.

Thus while prevention must remain the rule, the fact remains that compensatory measures have to be taken, whether on a transitional basis or as a last resort.

Hence damage compensation must not be the foundation of noise abatement policies, but should be regarded as a useful and often necessary accompaniment.

It should moreover be noted that compensation may act as an incentive towards better prevention. The prospect of having to pay compensation may induce those responsible (for instance a road-making authority) to take measures which will minimise the impact of noise. This is in line with the idea of charges,(2) since compensation and charges are closely related concepts.

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1) The term "compensation" is used mainly by economists. In legal terms "redress" means restoring the victim to his original position, i.e. disappearance of the damage suffered.

2) See Background Report No. 5, Noise Charges.

Once the need for compensation is recognised, an important question arises: can this need be adequately met? In other words, do "noise victims" have the requisite facilities for asserting their claim to redress?

This question may first be answered by saying that the general principles of law recognise that any victim of damage has a right of redress; to obtain redress implies court proceedings. The next question, therefore, is whether in regard to the environment in general and noise in particular such arrangements are suitable for ensuring effective damage compensation. In fact, there are several reasons why such general arrangements may not always be well suited for dealing with the particular problem of noise.

It is common knowledge that court action is a slow, costly, uncertain process which is hesitatingly undertaken without reasonable chances of success; while well suited to such situations as private nuisance and conflicts among individuals(1) which remain exceptional, court action is less easy in more usual, widespread traffic-noise conditions marking a conflict between some individual or group of individuals and, for example, a public authority responsible for the existence of a road. The problem then takes on an altogether different dimension, since here conflicting private interests are replaced by conflicting private and public interests; moreover such conflicts are no longer of an unusual, sporadic kind, and lasting, widespread annoyance (noise from roads and airports) is involved.

At this level the noise victim may encounter serious obstacles in asserting his rights: thus how can the person liable(2) or even the source of the noise be ascertained? In other words, who should be sued? The airlines or the airport authority? The road-building authority or the drivers of motor vehicles?

The result of the foregoing factors is a lack of balance between the "polluter" and the "victim", the former usually being a powerful, well-organised public or private body, and the latter an isolated individual.

The situation is all the more delicate as the position of the polluter may be quite legal: true, a road may be noisy, but lawfully so, since it was built in accordance with the relevant laws and regulations in force;(3) while an airport may also be noisy, it will have

1) The specific aim of private law is in fact to meet this kind of situation.

2) The problem of determining liability is often met by applying the no-fault (strict liability) principle, where the person inflicting damage is held responsible by reason of its mere existence, whether or not any fault is involved.

3) Except, of course, in cases where such legal provisions have been violated.

been legally established and the aircraft comply with the requisite standards. In other words, the situation is one of "lawful pollution", i.e. damage has been caused by perfectly legal activities. This does not mean that the victims lack any right of recourse: as a rule administrative authorisations (building licences, emission standards, etc.) are granted "without prejudice to the rights of third parties". But under these conditions it may prove extremely complicated to assert such rights.

For these reasons the need has developed to strengthen the victim's position by setting up machinery designed to compensate for noise damage, which in certain conditions would guarantee prompt, equitable payment. This is what a number of countries have done, either by means of special legislation (e.g. the Land Compensation Act in the United Kingdom), by including special provisions in noise legislation (Germany, the Netherlands), or by instituting specific machinery, in particular to deal with airport noise (France, Japan).

Under these arrangements compensation may take several forms, which will be described below.

2. FORMS OF COMPENSATION

Compensation may be granted in kind and/or in cash, a particularly important feature in the case of noise.

2.1 Compensation in Kind

Compensation in kind is a method of effectively and directly restoring victims or the victims' property to their original state by providing a good or service (redress). In most cases this will involve the soundproofing of living accommodation, e.g. by installing double glazing or double windows.

This practice is fairly widespread in relation to both road traffic and aircraft. In fact, noise insulation provisions can be part of noise control regulations. The following examples illustrate this point.

2.1.1 Road Traffic

In the United Kingdom, the Noise Insulation Regulations made under the Land Compensation Act 1973 provide that, where dwellings are or will within 15 years be subjected to increased traffic noise from a new or improved highway of at least 1dB(A) resulting in an end noise level of 68 dB(A) or above on the L10 (18 hour) index,(1)

1) Measurements over 18 daytime hours on the L10 index (noise level exceeded for 10 per cent of the time), i.e. around 65 dBA on the Leq scale.

a duty or power arises for the highway authority to provide insulation at its expense.(1)

Also under the Noise Insulation Regulations buildings may be soundproofed where works for the construction of a highway or additional carriageway or the alteration of a highway cause or are expected to cause noise at a level which, in the opinion of the appropriate highway authority, seriously affects or will seriously affect for a substantial period of time enjoyment of an eligible building adjacent to the site, and where no entitlement arises for traffic noise insulation. With regard to traffic noise insulation, it has been estimated that some 30,000 dwellings along major roads may benefit from these provisions at an average cost of £600-700 per dwelling; a similar number of dwellings are affected along secondary roads. In all, a potential outlay of £36-42 million may be involved ($65-76 million).

In Germany, the Air Traffic Noise Control Act of 1971 and the 1974 Pollution Act provide for the payment of insulation expenses for buildings exposed to sound levels exceeding the prescribed limits. The Bill on noise from road traffic and from railways will fix sound limits calling for the insulation of buildings in cases where no satisfactory preventive measures can be taken. Several municipalities have undertaken soundproofing programmes. For example, from 1974 to 1979 the City of Munich spent DM.20 million ($9 million) representing 50 per cent of soundproofing expenses (the other 50 per cent being borne by the owners).

In the Netherlands, the Noise Nuisance Act of March, 1979 provides that above a noise level of 50 dBA (Leq) at the front of dwellings, protective measures must be taken to ensure that the sound level within dwellings does not exceed 35 to 55 dBA (level defined according to the situation: buildings existing or to be constructed, "rehabilitation areas", etc.). The cost of these soundproofing measures is to be borne by the municipalities and be financed by means of charges payable on motor-vehicle noise.(2) The annual rehabilitation cost for dwellings exposed to sound levels of 65 dBA or over

1) The highway authority has a duty to provide noise insulation where the increase in noise is due to traffic on a new highway or additional carriageway opened after 16th October, 1972, and a power to provide insulation is conferred upon them where the increase is due to traffic on a new highway or additional carriageway opened between 17th October, 1969 and 16th October, 1972, or to traffic on an altered highway opened at any time. Noise insulation is provided for windows and doors of living rooms and bedrooms exposed to the prescribed levels of noise. For a more detailed study of the Land Compensation Act see Reducing Noise in OECD Countries, OECD, 1978.

2) See Background Report No. 5, Noise Charges.

was alone estimated at Fl.170 million (1976) over about 10 years (205 million at 1978 prices, i.e. 85 million 1978 dollars), three-quarters of which was for insulation costs alone; 326,000 dwellings are affected in this way.(1)

In France there is no Act expressly providing for the sound-proofing of dwellings exposed to excessive sound levels. However, provision is often made for sound insulation measures by the public authorities where frontage levels exceed 65 dBA (Leq). It is estimated that 4.6 million dwellings are exposed to such levels.

In the United States, States are, under specified conditions, permitted to use Federal Highway funds for acoustical treatment of severely impacted buildings.

2.1.2 Air Traffic

The practice of providing compensation in the form of sound-proofing is also extensively used in the vicinity of major airports. It is warranted by the fact that gradual replacement of the noisiest aircraft takes some time and will not be fully effective until the end of the 1980s. Meanwhile people living nearby continue to suffer from excessive sound levels, particularly since the benefits of noise abatement at source are offset or reduced by the rapid increase in air traffic. Compensatory measures are thus needed.

In the United Kingdom, a first system of financing the insulation of dwellings around London Heathrow Airport operated from 1966 to 1972: the British Airport Authority was required to pay 50 per cent (60 per cent from 1968) of insulation expenses for dwellings situated within the 55 NNI (Noise and Number Index) zone, i.e. about 77 dBA Leq-24h. From 1972 to 1977 a new system was introduced for Heathrow with a similar one from 1973 at Gatwick establishing zones entitled to 100 per cent and 75 per cent (85 per cent from 1975) payment of costs incurred (for persons resident on 1st January, 1966 in the case of Heathrow and on 1st January, 1973 in the case of Gatwick).

In 1980, a single compensation zone has been defined covering dwellings which, in spite of the progressive replacement of older noisy aircraft by newer and quieter ones, will in the long term still be subjected to excessive sound levels, particularly at night. In all, £4.25 million ($7.65 million) has been spent and a further outlay of £19 million ($34.2 million - April 1978 prices) is estimated over the coming years.

In Germany, the Air Traffic Noise Control Act of 1971 provides for measures to soundproof dwellings in the vicinity of more than 40 civil and military airports. From 1974 to 1978 DM.12.7 million ($5.7 million) were spent on civil airports and DM.7.7 million ($3.4 million) on military airports (in the first case expenses were

1) See also Background Report No. 8, The Costs of Noise Abatement.

borne by the airport authorities and airlines, and in the second case by the public authorities).

In the Netherlands the aircraft noise charges to be shortly introduced will be used to pay for the soundproofing of the most exposed dwellings. Some 20,000 dwellings close to Amsterdam-Schiphol Airport will be affected.

In Japan the Aircraft Noise Abatement Act provides for financial assistance with the soundproofing of dwellings and public buildings. In fiscal year 1979 (starting 1st April) Yen.50.6 billion ($253 million) was allocated to dwellings and Yen.9.9 billion ($49 million) to public buildings (schools, hospitals, etc.)

Thus, noise insulation provisions exist in many countries. These are mainly used to cope with the most difficult situations where source abatement or other means are not likely to bring about significant improvements, at least in the short or medium term. Soundproofing of buildings is not a panacea as it provides only reduction of indoor noise levels while the outdoor environment remains noisy; also, these reductions are effective only when windows are closed which is an unwelcome constraint. On the other hand, it might be, in certain cases, a cost effective solution where only a limited number of buildings are concerned: for instance, when a noisy factory is surrounded by a limited number of houses, it might be less costly to insulate these houses than to abate the factory noise.

2.2 Compensation in Cash

This second type of compensation involves a cash payment to the "victim" to compensate wholly or in part for the damage suffered.(1) The payment is therefore the monetary equivalent of the damage and may, for example, cover:

- the fall in the value of property situated within the area affected by noise;
- the fact that housing has been rendered totally unsuitable for use as accommodation;
- loss of amenity and medical expenses.

In the first case the amount of compensation will be equal to the loss in value on the real-estate market.

In the second, the dwellings concerned may be purchased to enable their inhabitants to find other accommodation. This acquisition may in some cases be accompanied by the payment of a moving allowance.

1) Although the provision of financial assistance for soundproofing takes the form of a cash payment, it nevertheless counts as compensation in kind since it must be used for the purpose specified.

The third case raises more sensitive problems of assessment, which will have to be resolved either by the courts or with reference to pre-established rules.(1)

Cash compensation may also be paid to supplement compensation in kind where the latter is deemed inadequate: thus the soundproofing of dwellings may be regarded as only a partial remedy, since it requires windows to be kept closed and since areas outside the building (gardens, terraces, etc.) cannot be used.

Although less widely used than compensation in kind, cash compensation is used to some extent in the case of noise, and a few examples are given below.

2.2.1 Surface Transport

In the United Kingdom the Land Compensation Act referred to above provides that any dwelling the value of which falls due to noise from public works such as roads and airports, gives a right to compensation.(2)

The depreciation in value is calculated with reference to the market price one year after the works are put into service. Where dwellings are soundproofed, the corresponding increase in value is taken into account. This will give the net depreciation. The number of applications for compensation has so far proved to be lower than expected. From 1973 to 1978 15,800 applications were received, 6,200 of which were dealt with while the rest are still pending, i.e. a total cost of £2.8 million ($5 million) and £450 to £900 ($816 to $1,633) per case. Owing to growing public awareness of the law, the number of applications is expected to increase over the coming years.

In Germany, the 1971 Act referred to above also provides for possible compensation for depreciation in the value of property in cases of noise due to public works related to airports.

In Japan, problems caused by the Shinkansen railway have been dealt with in two ways:

- Rehousing of people living along the railway line where sound levels exceed 85 dBA and thus make any soundproofing ineffective; in fiscal year 1978 the cost of such operations amounted to Yen.757 million, i.e. $3.7 million.
- Acquisition of land where buildings have been demolished (Yen.488 million, i.e. $2.4 million in fiscal year 1978).

1) Some hold that loss of amenity is reflected in the fall in property value (see Background Report No. 2, Part II, on the Social Cost of Noise).

2) Such compensation is available for depreciation due to noise, vibration, odours, smoke and the discharge of solid or liquid substances. Loss in value caused by other factors such as the visual impact of a road or aversion to its presence is not subject to compensation, although these factors could have a substantial impact on house prices.

2.2.2 Air Traffic

In the case of airport noise monetary compensation often takes the form of the acquisition of properties exposed to excessive noise.

Japan's Aircraft Noise Abatement Act provides for financial assistance in rehousing families exposed to noise levels of over 90 on the WECPNL index (i.e. around 77 dBA-Leq). In fiscal year 1979, Yen.12.7 billion was spent in this way ($63 million).

In France, the Paris Airport Authority has since 1973 undertaken the soundproofing of the most exposed public buildings (notably schools and hospitals) and the acquisition of housing situated in zone A (around 73 dBA Leq-24h); it is estimated that at such noise levels sound insulation is not a satisfactory solution. From 1973 to 1978, Frs.160 million were spent in this way ($33 million). The necessary finance is raised by taxes on noise levied at Orly and Charles de Gaulle airports.(1)

In the United States, Los Angeles Airport has acquired nearly 3,000 dwellings and a considerable amount of land for a total outlay of $300 million, including $131 million on land acquisition (1972-1976). By the end of 1977 total expenditure on land acquisition by American airports amounted to $266 million.

In general, when referring to the costs of such operations, it is necessary to calculate a net figure having regard to the potential resale price of the land or its use value for non-residential purposes.

2.3 Compensation for Past Damage or Purchase of an "Easement"

Just as it may be total or partial, compensation may relate to damage which occurred in the past and/or is likely to occur in the future.

Compensation for past damage is by its very nature temporary, in that the occurrence of further damage will give a renewed right to compensation. This is the traditional case of a claim to the courts for compensation for disturbance of possession. The important factor here is that, should the cause of the damage not disappear, the victim may renew his claim. It is clear that this type of compensation is ill-suited to road traffic in urban areas or to air traffic which constitute permanent causes of damage.

In such cases compensation may take the form of the purchase of an easement, i.e. a once-and-for-all payment of compensation deemed to provide equitable redress for past and future damage.(2)

1) See Background Report No. 5, Noise Charges

2) The purchase of an easement is only appropriate in cases of "lawful" noise, i.e. where, in spite of compliance with the law, noise is nevertheless excessive (see section 1). The purchase of an easement is inapplicable to cases of "unlawful" noise (private nuisance, etc.).

The purchase of an easement must be used with discretion and reserved strictly for cases where not only is any preventive measure but also any other type of compensation unfeasible. The purchase of an easement may thus be regarded as the purchase of a right to pollute: for example, the right to create noise by constructing a road may be "purchased" from the inhabitants of a certain area. But before going to this extreme, other solutions should be considered; such as, rerouting the road or, where this is impossible, purchasing the dwelling and rehousing the inhabitants. Only where nothing else can be done and where construction of the road is an absolute necessity should the purchase of an easement be considered. This is a good example of the conflict between the public interest, which requires the construction of the road, and the private interests of those who will have to suffer the impacts of the road.

A distinction should also be made between cases involving existing infrastructure and new construction. In the latter case the range of options is wider and recourse to the purchase of an easement should more easily be avoided.

Finally it should be noted that the sound insulation of buildings is a type of purchase of an easement (though partial), since the persons concerned remain where they are in return for payment for such insulation.

The purchase of an easement is an easier solution for the public authorities since it takes the form of a single, definitive payment. The United Kingdom Land Compensation Act thus specifies that compensation payments are made in final settlement. Otherwise the possibility endures of applying to the courts for compensation until such time as the cause of damage disappears.

3. CONCLUSION

In planning and implementing noise abatement policies two essential questions with regard to damage compensation arise:

i) What should be the role of compensation in such policies?
ii) If the principle of compensation is accepted, how should it be applied?

3.1 The Role of Compensation

Deciding the role which compensation can play in noise abatement policies is an extremely sensitive problem which to some extent will determine the nature and scope of the policies themselves. Depending on the part played by compensation, the relative scope of action to reduce noise at source and more particularly of "correction" or "rehabilitation" may thus vary considerably. In the extreme case any resort to compensation may be rejected and everyone guaranteed freedom from excessive noise together with all the constraints and costs which this may imply (rehousing of people affected, rerouting of roads, etc.).

It is therefore important to determine the part to be played by compensation, having regard to the political and economic implications.

3.2 The Organisation and Financing of Compensation

If it is accepted that compensation is a "necessary evil" insofar as existing and foreseeable sound levels mean that large groups of the population will continue to be exposed to excessive sound levels without, save in the long term, any real possibility of improvement, the problem then arises of how compensation is to be organised and financed.

It may be decided to leave the civil and administrative courts to deal with claims for compensation within the framework of traditional procedures applicable to cases of "private nuisance". This amounts to a case-by-case policy, which is in effect no compensation policy at all. The argument proposed in this report tends instead to show that a need exists for specific arrangements for the organisation and financing of compensation.

3.2.1 Organisation

By virtue of the general principle of law whereby all damage gives rise to a right to redress, every individual has the possibility of bringing legal proceedings where he feels he has suffered abnormal and excessive damage, for example, due to the proximity of a highway or airport. Instances of this are quite common, particularly in the case of those living near airports (e.g. Los Angeles and Paris-Orly Airports).

It is not always easy, however, for an individual to assert his rights: legal procedures are slow and costly and often prove ill-suited to environmental disamenities: the chain of causality is difficult to establish and the burden of proof weighs heavily on the plaintiff, outmatched by a powerful, organised "polluter" (public authority, airport authority, industry, etc.).

Improvement of the legal position of the "victim" therefore calls for specific compensation systems by means of specific legislation or regulations. This is already seen in various environmental fields, such as marine pollution (United States, Canada, Finland) and air pollution (Japan, the Netherlands). In relation to noise a number of existing systems have been referred to above, such as the Land Compensation Act in the United Kingdom, noise legislation in Germany, and various systems for compensating those living near airports in different countries. What is more, these systems fall within the general framework of recognition of the right to a non-polluted environment, as proclaimed by Article 1 of the Stockholm Declaration

(1972) and, in some countries, embodied in national legislation or even in constitutions.

The organisation of compensation requires machinery to provide speedy and equitable redress for damage suffered. It has to determine what sort of damage will give rise to a right to compensation (depreciation in the value of property, disturbance of possession, etc.); who will have the right to take action (tenants, owners, public and private buildings, etc.); it has to fix noise limits giving a right to compensation (noise reception standards); to define the circumstances (public works, airports, new projects or extension of existing facilities, etc.); and to lay down rules for assessing compensation.(1)

3.2.2 Finance

Arrangements to finance compensation can greatly facilitate the operation of compensation systems. The creation of compensation funds financed by means of charges is sometimes resorted to, as in the case of aircraft noise (France, Japan, the Netherlands), part of the proceeds being allocated for the compensation of nearby residents. Such systems of finance can also have an incentive effect, in the same way as noise charges;(2) they are moreover a guarantee against the possible insolvency of the polluter.

The organisation and financing of compensation should however never lead to it becoming a major tool of noise abatement policy. As was said in the introduction, prevention should remain the rule and compensation the exception. Arrangements for compensation should be used to safeguard the rights of "noise victims" in cases where no satisfactory preventive measures are available; it is a matter of ensuring fair treatment for all.

1) For a detailed survey see Reducing Noise in OECD Countries op. cit, Chapter 3, paragraph III.

2) See Background Report No. 5, Noise Charges.

BACKGROUND REPORT NUMBER 7

EDUCATION AND INFORMATION

CONTENTS

1. INTRODUCTION

Environmental noise can be divided into two categories. The first is that which is due to sources whose noise emission can only be reduced by major design modification or by alterations to their use which entail substantial economic consequences.(1) In this category comes noise from air traffic, highways and major industrial plants. The second category is of noise which can or could have been prevented or reduced with negligible economic effect. In this category comes noise from machines and installations whose designers or planners gave little or no thought to noise control; noise directly caused by individual members of the public, with or without the aid of machines; and noise caused by lack of maintenance of silencing equipment. It is the second category which is the subject of this report.

2. SCOPE FOR REDUCING NOISE BY EDUCATION AND PUBLICITY

Education and information can influence noise levels in the following instances:

(i) When the action creating the noise is unnecessary. This includes noise from use of machines or equipment by members of the public in an unnecessary or inconsiderate manner. Common examples are the driving of motor-vehicles in a noisy manner, or deliberately increasing the noise emission of a vehicle by altering its exhaust system. Another widespread problem is disturbance of neighbours by noise from amplified music.

(ii) When the designer or manufacturer of a machine can incorporate low-noise features, either at minimum cost, or at a cost which will be recouped in increased sales through consumer demand for quieter products.

(iii) When the planner of a development can make decisions concerning the location or construction of buildings, roads and other features which reduce the incidence of noise nuisance problems.

(iv) When the operator of a factory or industrial installation can foresee noise complaints and has enough knowledge to institute simple noise control techniques.

(v) When the contractor and employees on a construction site are aware enough of noise nuisance to maintain and operate the construction plant in the quietest possible condition.

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1) See Background Report No. 8, The Costs of Noise Abatement.

In determining the effectiveness of measures to reduce noise, one must consider the aspects of environmental noise which could be affected. In general, environmental noise consists of a background level, over which is superimposed a pattern of peaks due to sources such as individual vehicles, aircraft, voices and miscellaneous sources. In most localities, the background noise level is caused by road traffic, and low-cost measures are incapable of making a significant impact on noise from this source. In some areas the background level is due to industry, where there are several hundreds of individual sources of noise distributed about factories in an industrial area, none of which individually emits a high level of noise, but which collectively combine to cause a steady noise throughout the district. Once again, low-cost measures can make little impact.

However, in many cases the background level is of much less importance than the superimposed peaks. Many complex noise indices which have been introduced in an attempt to quantify the annoyance value of a variable noise place great weight on the variability of the noise.

The low-cost measures discussed in this report will tend to show their effect in terms of reducing peaks rather than reducing the overall sound level, and it is therefore a complex matter to measure the effects physically. Since, in environmental noise, one's concern is exclusively the subjective response of people, the best measure of success is the social survey rather than the sound level survey.

3. APPLICATIONS OF EDUCATION AND PUBLICITY

The means of bringing about the noise reductions described above are basically of four types: the use of low-cost noise control equipment; the stimulation of consumer demand for quiet products; educating the public to consider the effects of their activities on others; educating designers, planners and industrialists in applied acoustics.

3.1 Low-Cost Noise Control Equipment

There are some instances where useful reductions in noise can be achieved by means of noise control equipment of minimum net cost. A prime example would be the fitting of stainless steel exhaust systems as original equipment on new cars. The cost of the system itself is approximately double that of a mild steel system, but the lifetime is more than twice that of a mild steel system so that the net cost is negative. Noise due to defective exhaust systems has little effect on the overall ambient noise levels in cities and near highways, but individual vehicles are capable of causing widespread annoyance. Some countries have enforcement procedures which minimise the incidence of vehicle owners operating their vehicles with defective exhaust systems, but in many cases it is possible for drivers to escape controls for long periods.

Another example, also in the automotive field, is the fitting of silencers to the air-release valves of the braking systems of heavy vehicles. Peak sound levels of over 100 dB(A) are often received by pedestrians alongside heavy vehicles stopping and starting in congested traffic. The experience of one haulage fleet operator in the United Kingdom was that at a capital cost of only a few pounds per vehicle, and to no measurable mechanical disadvantage, a reduction of up to 20 dB(A) in the level of noise from this source could be achieved.

Many machines, for instance those powered by small single-cylindered petrol engines such as lawn mowers and chain saws, are fitted with inefficient exhaust silencers due to ignorance of the technical basis of silencer design by the manufacturers. The cost of developing and fitting efficient silencers would be small in terms of marginal product cost.

The problem, however, is not so much the cost of noise reduction in these cases as the motivation of the manufacturers of the machines to use the noise control measures described. The motivation has to be either legislation, which is not discussed in this report, consumer demand or a sense of goodwill towards those who are affected by the noise of the product concerned.

3.2 Stimulation of Consumer Demand for Low-Noise Products

The money spent on noise reduction is often regarded as a cost which produces no financial return. It has proved difficult to establish a cost-benefit approach to noise, and although there may well be hidden returns in the form of lower absenteeism from work and reduced demand on health services, the prospect of financial return is rarely the motive for reducing noise.

By contrast, where consumer demand for products is influenced by noise level, money spent on achieving lower noise levels, which in turn produce higher levels of sales may be considered by manufacturers as a positive investment.

Until the public is sufficiently educated to take a more altruistic attitude than is at present evident, the sources of noise whose sales are likely to be affected by noise level are confined to machines whose noise effects the user to a significant extent. The largest categories are those of domestic appliances, garden machinery and do-it-yourself equipment.

The users of machines are seldom as annoyed by the noise as their neighbours, and the neighbours have no direct influence on the user's purchasing policy. It is by no means demonstrated that, except in such areas as the interior noise levels of motor cars, noise level significantly affects the choice of product where the purchaser is also the operator of the machine. The situation is quite different where hearing hazard is involved, and it may be that labelling as a noise control measure is effective only in this area.

Legislation on noise labelling has existed in various countries for some years, an early example being the United States Noise Control Act of 1972 - an enabling instrument that requires regulations to be issued. However little or no experience of the effects has been obtained, since, with the exception of hearing protectors in the United States, the powers conferred by such legislation have yet to be put into effect. As a less arduous way of achieving the goals of labelling, voluntary labelling is encouraged in the United States, to the extent that it meets the EPA's specifications concerning the type of information shown on the label and the format used. In most countries suppliers of industrial equipment are increasingly required to supply noise specifications by prospective purchasers.

The Swiss noise abatement society has had a noise labelling system since 1968. Noise levels of certain equipment are measured by the technical institute set up for the purpose, and the number of products tested increases each year. The system appears to have only a moderate impact; some manufacturers use the labels as selling points, but the majority show little interest.

Many labelling schemes have been introduced in France (e.g. the Acotherm label for windows and acoustics labels for buildings which have existed since 1972) but the multiplicity of different schemes results in some confusion which offsets their effectiveness.

Several national consumer organisations publish comparative noise level data about consumer products along with other test results, an example being the magazine "Which" of the Consumers' Association of the United Kingdom.

Government as a consumer can also help to stimulate the production of quieter products through its procurement policies. The United States Government Services Agency has successfully used this approach, which is now being pursued on a wider scale through the efforts of an interagency committee.

3.3 Educating the Public

People tend to be concerned about noise only when they are suffering it themselves. This is an age in which many seemingly innocuous substances, activities and lifestyles are being regularly denounced by the scientific community as harmful. The public in general does respond to publicity when informed in a convincing manner that doing or omitting to do something is harmful to themselves; the levelling off of tobacco consumption and the popularity of jogging are examples of public response. These are, however, cases in which the person's concern is his own welfare. Public response to problems affecting others is rather less apparent.

Pollution, and annoyance by noise in particular, except in the case of hearing hazard, generally affects others to a much greater extent than it affects the polluter. Where the polluter can control his noise output, his attitude will be determined primarily by his altruistic sense, and secondarily by fear of the law and the effect on his financial situation.

3.4 Publicity

The approach to the problem of non-hazardous noise is clouded by the poor definition of its effects. Direct effects of noise on health are very difficult to determine. Public response to noise is partially determined by a person's awareness of noise as a social problem, and his or her state of mind towards it. Part of the increase in annoyance by noise recorded in many countries over the past 25 years may be due to a greater awareness of the existence of the noise or to higher expectations with regard to environmental quality as well as to the increase in the level of noise. Consequently, any publicity campaign intended to encourage people to reduce the creation of noise, may also increase the number of complaints about existing noise.

Publicity can take the form of conventional campaigns involving advertising on television, radio and in the press, but a campaign of this kind large enough to have a significant effect can be expensive. Furthermore, it may not be particularly effective, since it is difficult not to create the impression that officialdom is once again telling the populace what to do, and thereby induce a certain amount of adverse reaction.

Some of the most effective publicity has been achieved by means of the indirect public relations approach rather than by advertising. Noise abatement societies in some countries have official recognition and are financially supported by their governments. For example, the Netherlands Association Against Noise (NSG), a private organisation, is supported by the Ministry of Health and Hygiene. The NSG carried out a public relations campaign intended, over a period of years, to contribute to a change in public attitude to noise. This was very successful in terms of coverage, in that 69 per cent of persons interviewed had read, seen or heard something about nuisance due to noise, but whether they had in any way changed their attitudes is difficult to determine.

The United Kingdom Noise Advisory Council has turned away from the idea of direct publicity of the kind undertaken by the NSG, but has attracted local interest by means of a travelling exhibition in the form of a "Noise Caravan". This is a mobile audio-visual display designed to convey some basic information about noise, to explain the powers of local government authorities and what the public can do to help themselves. The numbers of people reached by a single caravan are necessarily small. The Council also publishes a number of leaflets, including "Bothered by Noise? How the Law Can Help You".

The United States Environmental Protection Agency has established under contract the National Information Centre for Quiet (NICQ) as a national clearinghouse for the collection and dissemination of public education/information materials on noise, its effects, and methods used to quieten the environment.

3.5 Education in Schools

If the attitude of the public is to change in the long term the most effective means of bringing about a change is by incorporating into educational systems modules relating to acoustics and noise control. Traditionally, the only coverage of the subject in school curricula has been the treatment of sound as one of the trio of "Heat, Light and Sound". Treatment of the subject of sound has been of a very fundamental and abstract nature. One of the features of the noise problem is the widespread ignorance of very basic principles which could so easily be greatly reduced by inclusion of noise as part of basic syllabuses.

In response to the Quiet Communities Act of 1978, a noise module has been developed by the United States EPA to be used in junior and senior high schools as part of the science curriculum, which is currently being pilot-tested. A noise module has also been designed to be used by the International Union of Operating Engineers (heavy equipment operators) in their apprenticeship training programme, and is currently being tested in three major union training centres.

It is the education of children at quite a young age which offers the most promising long-term solution to the problem of anti-social noise. In the United Kingdom, the Noise Advisory Council, during the Darlington Quiet Town Experiment, produced jointly with the Advisory Centre for Education a noise project pack for use in schools. The intention was that schoolchildren should be given an interest in the subject by encouraging them to take part in such practical work as measuring noise in the town and conducting simple social surveys.

In Switzerland the police courses on road traffic given in primary schools draw the children's attention to the need not to make noise. Also, the Swiss Institute for Research into the Built Environment prepares school courses on environmental protection which includes noise abatement. In France the government intends to distribute through the national educational service booklets specially designed to educate children about noise. It is also concentrating in particular on persuading young motor-cyclists to respect the peace and quiet of others.

It is at the school level that education of this kind can be most effective. In most OECD countries universities and technical colleges run acoustics courses, but these courses are attended only by those wishing to acquire some specialised knowledge.

As far as adults are concerned, many noise annoyance problems start with thoughtlessness, but degenerate into antagonistic relationships between noise maker and sufferer. This is because the sufferer often responds to noise with anger, and the noise maker reacts to anger in a defensive manner. Although it would be no easier to achieve than to educate the noise maker into not causing annoyance, great benefits would ensue from educating the noise sufferer in the art of complaining in a courteous manner. The use of specially appointed and trained noise wardens, such as the United States Environmental Protection Agency's programme to train qualified older Americans to become focal points for handling noise complaints in their own communities may prove especially valuable.

3.6 Educating Designers, Planners and Industrialists

In many countries, ignorance of even basic noise control among engineers and designers is so widespread that even the introduction of the sort of noise modules described above for use in schools would, in the long term, achieve a substantial improvement in the present standard of knowledge. Engineers and planners faced with noise problems can turn to a number of professional sources of assistance in the form of consultancy services. However, as money spent on the solution of noise problems is usually regarded as devoid of any financial return, there is often reluctance to incur fees except in the case of major projects. Many noise nuisance problems around factories are caused by relatively small sources such as fans, and some basic knowledge of acoustics by plant engineers would enable them to prevent or reduce the noise.

Those who are aware of a need to acquire some specialised knowledge of noise control have in most OECD countries a reasonably good choice of courses of varying length and depth. However, the demand for such courses is very much a function of the weight of legislation or the pressure of environmental action bearing upon the industry concerned. In the absence of such pressures, it is unlikely that the personnel concerned would have the motivation to attend such courses. In the longer term, this lack of specialised knowledge could be overcome by including the study of acoustics and noise related matters in the higher-education syllabus for trainee engineers, planners etc.

The greatest short-term benefit that can be obtained in this area is provided not so much by provision of training courses as by more widespread means of conveying basic essentials in easily comprehensible form. This is done by articles in the technical press and low-cost publications aimed at a practical level. Most of the publications of this kind at present produced by government and other agencies not aimed at the general public tend to be somewhat specialised and do not cover the kind of broad, basic noise control principles required in a simple manner.

It is most unfortunate that the decibel scale appears so difficult a concept to the layman, since training material often begins by attempting to elucidate it and succeeds in persuading the student that the subject as a whole is equally difficult. At the fundamental level it would be desirable to avoid making the subject seem any more complex than it is, and concentrate on practical details, at least at the outset.

There is a tendency in industrial organisations to concentrate on giving noise training to a few specific personnel, on the grounds that any noise questions may be referred to them. This does not solve the fundamental problem of noise-producing errors being made in the ordinary day-to-day running of a factory. The resulting noise is often due to failure to foresee a noise problem, and therefore even if a noise specialist exists within the firm there would be a similar failure to consult him or her.

4. CONCLUSIONS

Despite the widespread scale of the noise problem, those directly disturbed by noise at any time are in the minority, and the majority who are not disturbed tend not to care about those who are. Many of those responsible for making noise, even if they are aware of the problem, still cause noise problems through ignorance and designers frequently fail to think about noise at all in the early stages when noise control might cost little or nothing.

The education problem is of two kinds: how to induce a greater sense of altruism in people, and how to achieve a widespread knowledge of basic noise control techniques.

Many existing anti-noise campaigns may be at fault in appearing to concentrate on a need for generally low noise levels, which people do not necessarily want, and failing to transmit the message that people should think of others and avoid annoying them by noise. The public themselves have little or no power to control overall noise levels, whereas the power to reduce nuisance is predominantly in the hands of individuals.

A campaign which is too general in its call for quiet is liable to create the impression that its sponsors are slightly eccentric.

Publicity material should concentrate on the problem that at some time afflicts everyone with normal hearing - noise annoyance.

Nationwide publicity campaigns are not always low-cost options. Publicity can best take the form of the application and distribution of well produced literature, and maximum use of the press and other news media.

One of the most promising courses of action is the teaching of noise control in schools. This should involve not only making people aware of the noise problem but also giving them a basic understanding of the fundamentals of acoustics and noise control.

There is a need for the better dissemination of the basics of noise control engineering to all those concerned with engineering, design and planning, rather than to leave training to a selected number of would-be noise specialists within an organisation.

Noise labelling, at least until such time as the public attitude has changed, is of limited potential except where the purchaser is directly affected by the noise emitted by the product. The type of noise problems discussed in this report tend to involve disturbance of others, and this tends to limit the effect of labelling except for the more considerate members of the public. The influence of labelling on encouraging the public to choose quieter products should be further investigated. It should take its place alongside education as a useful part of an overall scheme.

In the short term, the greatest benefit would ensue from an improvement in communications between individual noise makers and noise sufferers. Too many cases of noise annoyance which could easily be solved in the early stages degenerate rapidly into antagonism.

If a greater sense of altruism could be induced in the population, noise would not be the only problem overcome.

BACKGROUND REPORT NUMBER 8

THE COSTS OF NOISE ABATEMENT

CONTENTS

1. INTRODUCTION

The mechanisms by which noise nuisance can be abated are many. The most obvious method is to abate the noise at source. This means in effect searching for the source of the noise emission and then using various methods for reducing that noise. The methods may include "retrofit" - use of noise suppression technology on existing installations, machinery, vehicles, aircraft, etc. They may also include restrictions on the level of activity of the noise-generating source, including limitation or prohibition of night flights by aircraft, and even actual reductions in the level of industrial and other outputs. Also, new installations or equipment may be designed so as to reduce noise.

The second approach is to prevent the noise from reaching the receiving environment - i.e. from being transmitted from source to receiver. We may distinguish here between methods designed to provide insulation in the receiver's environment, and methods designed to screen the sufferer from the noise source - i.e. placing some barrier between the source and the receiving environment. An example of the former is the double-glazing of windows. An example of the latter is the erection of sound barriers between, say, a road and a residential area. Note too that land use falls into the category of abatement through the use of the transmission environment, since it uses distance and the location of activities as a means of reducing the final noise impact on the receiving environment.

The following schema categorises these means:

NOISE SOURCE	⟶	TRANSMISSION ENVIRONMENT	⟶	RECEIVING ENVIRONMENT
(Abatement = retrofit, use of new technology, activity reduction)		(Abatement = screens, land-use management, tunnels, below-surface roads)		(Abatement = insulation, layout of buildings and use of rooms)

All these abatement measures have costs. These are self-evident in the cases of retrofit, sinking roads below the surface, barriers and so on. It is less obvious that restricting levels of activity will have costs. For the firm, any restriction on output will result in forgone profits and these define the proper costs of abatement if that option is used. New technology will have an additional cost if it is introduced earlier than would otherwise be the case. Where existing machinery, aircraft, vehicles, etc. are being retired anyway the abatement cost could in certain cases be negligible or zero in the sense that it is already "designed into" the new technology.

Note too that source abatement can be achieved by other means than purely technological changes. These include traffic and road policy in general - e.g. the use of by-passes to avoid town traffic; the diversion of road or even air traffic to rail through deliberate economic incentives; traffic restraint through increases in fuel taxes; speed limits and so on. Insofar as any such policy adds costs to the operators of vehicles and aircraft, or imposes costs on retail/wholesale distributors and consumers, then these abatement measures also have costs. In the event, however, such measures tend to aim at a "package" of benefits - reduced noise, improved safety, preservation of town buildings, reduced congestion, and so on. If noise reduction is only one of the benefits of such a package, it becomes essential to allocate the costs of the measures taken across all the benefits gained. No single benefit is therefore free, but neither can it be costed as if it bore the entire cost of the policy. This is a classic problem of joint costs: there is no ready answer to the question of how to allocate these costs to the various individual benefits. Nonetheless, such wider-ranging methods often constitute the appropriate mix of policy instruments for noise abatement.

Finally, account must be taken of the fact that, because of the lack of consistent and comparable data, it is often difficult to get a consistent and uniform view of abatement cost: data presented in this brief overview are those which appear to be the most consistent and significant at this general level of analysis, even if diverging views could be expressed on some specific points of detail.(1) Also, comparisons are often difficult due to the differing noise measurement methods used in the cases studied. The cost-effectiveness of the abatement measures is also difficult to assess and compare as there is no single measure of annoyance which applies to all situations. The purpose of this note is to indicate orders of magnitude and not to give a final and precise answer to the question of what noise abatement costs are.

2. ROAD TRAFFIC

The main emphasis of a programme of road traffic noise abatement should be on the reduction of noise at source. But a number of other complementary actions must be taken such as land use, erecting noise barriers and insulating houses. We will first consider possible reductions with regard to the main noise sources.

1) For more detailed information see The Cost of Noise Abatement, (in Part III).

2.1 Quietening Vehicles

2.1.1 Lorries

With the possible exception of motorcycles, when poorly maintained and inconsiderately used, lorries are the noisiest vehicles on the roads and are often cited as the main contributor to annoyance.

Previous EEC regulations limited the heaviest lorries to a maximum noise level of 91 dBA;(1) this has been changed to 88 dBA in 1980. In Switzerland, the present limit is 88 dBA and will be 86 dBA in 1982. In Japan the 1979 standard is 86 dBA. In the United States the present required level is 83 dBA (80 dBA in 1982); i.e. about 89 dBA (and 86 dBA) according to European standards.(2)

Most of the research on lorry noise abatement shows that noise levels of 80 to 81 dBA (ISO test conditions) are achievable, i.e. a reduction of about 10 dBA.(3)

United States data suggest that such noise reductions could be achieved at the following cost for an achieved noise level of 81 dBA:

TABLE 1

SUMMARY OF THE COST OF ACHIEVING AN 81 dBA NOISE LEVEL FOR LORRIES (USA)(4)

Type of Lorry	Average price of vehicle 1973 $	Capital abatement cost in 1973 $	Abatement cost as a % of total price
Medium (petrol)	5,836	665	11.4
Heavy (petrol)	11,613	815	7.0
Medium (diesel)	7,360	1,624	22.1
Heavy (diesel)	25,608	1,454	5.7

These figures are applicable to the United States situation and might not reflect the European one. Provisional United Kingdom data suggest that a 38 ton lorry could be produced to meet an 80 dBA level at an extra cost of about 10 per cent of the capital cost. The gain is therefore about a 10 dBA reduction. Other European data suggest price increases of up to 3 per cent to meet 86 dBA for a large lorry and 84 dBA for a medium-sized lorry.

1) As measured under ISO test conditions.

2) To compare with European legislation, account must be taken of the fact that United States measures are made at a distance of 50 feet (= 15 metres) instead of 25 feet (7.5 metres) under ISO test conditions. Thus, as a rough estimate, 5 to 6 dBA must be added to compare with European standards.

3) "American Quiet Truck Programme" and "British Quiet Heavy Lorry Project".

4) These figures are not totally agreed by some manufacturers but can be used as an order of magnitude.

Account must be taken of the fact that fuel saving can be simultaneously achieved through the use of more efficient fans, fan clutches and exhaust gas seals. On the basis of the above-mentioned American data, the net result, taking into account all costs and benefits, would be as follows (additional cost or benefit, in percentage of the vehicle price, American data):

Medium (petrol):	6.9 per cent	
Heavy (petrol*):	1.4 per cent	(benefit)
Medium (diesel):	34 per cent	
Heavy (diesel):	5 per cent	

(* Note that few petrol-driven heavy lorries exist in Europe.)

There may also be a slight additional cost, in the form of reduced revenue arising from a small reduction in payload which is not allowed for in the above figures.

Finally, it should be noted that the scope for retrofitting existing lorries is very limited; retrofitting does not appear to be a cost-effective solution.

2.1.2 Buses

Present noise levels of buses currently range between 77 and 91 dBA (ISO test). EEC 1979 limits were 89 dBA for buses of more than 3.5 tonnes but less than 200 hp. DIN, and 91 dBA for heavy buses (more than 200 hp. DIN); limits for the former have been reduced to 82 dBA from 1980, and limits for heavy buses will be reduced to 85 dBA in 1982. In the United States the proposed limits are 89 dBA initially, reducing to 83 dBA after several years.(1)

As in the case of lorries, experience proves that a 10 dBA reduction is currently achievable, which means that buses emitting between 77 and 80 dBA can be manufactured. The quietest models so far in operation (77 dBA) bear an additional capital cost of 7 per cent - 8 per cent; 80 dBA buses can be produced at an additional capital cost, varying between 2.5 per cent and 5 per cent according to estimates.

The extra weight of a quietened bus gives rise to an extra fuel consumption of the order of 3 per cent.

Contrary to the case of lorries, certain buses can be easily retrofitted to achieve 80 - 82 dBA levels: in the Netherlands, the capital cost is estimated to be about 7.5 per cent.

2.1.3 Motorcycles

Mopeds (i.e. motorcycles of less than 50cc) are already relatively quiet when produced; the problem is to ensure that they are well maintained and not modified by users.

1) These figures include 6 dBA additions to compare with ISO measures.

In contrast, larger motorcycles are a significant cause of nuisance: a 91 dBA noise level (ISO test) is a common figure; thus, motorcycles have noise levels similar to heavy trucks. New EEC standards are 80 to 86 dBA - according to cylinder capacity - for motorcycles of more than 50cc;(1) United States proposed limits are comparable; the Swiss standard is 85 dBA. In Japan the current standard for larger motorcycles is 81 dBA (ISO test).

Tentative American figures suggest the following picture if compliance with an 81 dBA (ISO test) standard is to be secured. For motorcycles of less than 100cc, price increases of about 10 per cent would result (cost changes are systematically 2 - 3 per cent less because of the spreading of retailers' margins); for 100 - 169cc the price increase would be 22 per cent and similar increases (24 and 22 per cent) would be required for machines up to 750cc. For the very large machines, over 750cc, the increase would be about 13 per cent.

Clearly all these increases are significant and could be expected to affect the market for motorcycles. On the other hand, the high degree of annoyance attached to motorcycles by the general public may well warrant such changes.

2.1.4 Motor Cars

Almost all motor cars comply with the previous 82 dBA EEC limit and about 80 per cent(2) with the 80 dBA limit applied since 1st April, 1980 (and already enforced in Switzerland). This does not mean that such compliance completely eliminates noise nuisance due to motor cars; further reductions are needed.

One can estimate that the extra capital cost to achieve noise levels of 78 - 80 dBA has been about 1 per cent for each dBA reduced.

These reductions relate to total vehicle noise but are achieved purely by changes in power train noise, leaving rolling noise unaffected. Rolling noise does not make a significant contribution to total vehicle noise in the conditions of the ISO test but at higher speeds it becomes very important; in particular, road surfaces contribute significantly to rolling noise and action is possible here. Above all, the removal of "pavé" surfaces would contribute to such reductions. Again, however, the choice of road surface cannot be dictated by noise considerations alone - safety for braking and skidding must also be considered.

1) Note that Motorcycles are tested in second gear which gives about 6 dBA more than under a test in third gear.

2) According to Dutch and Swedish surveys.

TABLE 2

SUMMARY OF COSTS OF QUIETENING MOTOR VEHICLES
(orders of magnitude)

Type of vehicle	Existing noise levels dBA (ISO test)	Achievable noise levels (dBA)	Capital cost (in %)
Heavy lorries	86 - 91	80 - 81	6 to 20%
Buses	77 - 91	77 - 80	2.5 to 8%
Motorcycles	80 - 91	78 - 84	10 to 24%
Motor cars	74 - 82	70 - 80	Approx. 1% per dBA for the first 4-5 dBA reduction.

2.2 Other Abatement Measures

2.2.1 Speed Limits and Traffic Management

Speed limits, if observed, would have a direct effect on reducing noise in that the noise emitted by a vehicle varies with the logarithm of its speed. A Swiss expert committee has estimated that a reduction in authorised speed from 100 to 80 km/h would bring a reduction in noise levels of 2 to 3 dBA. Both the direct and indirect effect would be greater if more stringent limits were applied to lorries than to cars, since the difference in noise emitted at any given speed between a lorry and a car is of the order of 10 dBA.

Although it may rarely be the case that noise reduction alone would justify the imposition of speed limits outside towns, it would reinforce the other arguments for such a measure. Following the oil crisis of 1973, many countries imposed speed limits outside built-up areas in order to save fuel. This also led to a reduction in accidents, both through a decline in traffic volumes, which of course had other causes as well, also related to the oil crisis, and through a direct increase in safety due to lower speeds. No studies of the value of these benefits, or of the disbenefits arising from longer journey times, are available.

However, speed limits are an effective noise reduction factor only in non-urban traffic conditions, i.e. where rolling noise usually predominates. For urban traffic where speeds are already low, speed limits do not contribute significantly to noise reduction; in particular, because of gear changing, lower vehicle speeds do not result in lower engine speed.

The most wide-ranging policy which would have the effect of reducing traffic noise would of course involve the redesign and rerouting of roads away from towns; the reservation of special roads within towns for lorries if they are obliged to operate through towns;

traffic restraints; encouragement of diversion of freight to rail, and so on. All policies of this nature have their costs. Clearly, to assess any policy requires a full cost-benefit assessment. Thus, a policy of diverting traffic from road to rail would require an analysis of increased operating costs (traffic would have been diverted already if it were cheaper to do so); the level of noise reductions; improved safety and so on. In some cases the main costs may consist of enforcement, for example where the town is small and the lorry is simply passing through it to save time. The costs are then the added time by using some other route (if it exists), and the costs of enforcement. The benefits are the environmental gains within the town.

Many other urban options exist, such as zoning of areas for pedestrian use only. These are now fairly common in Europe. City centre noise is reduced, but the main gains are frequently in safety, even in zones where bus and taxi use is permitted in the otherwise pedestrianised area. Again the costs occur in respect of any delays to diverted traffic and care must be taken to see that the diverted traffic does not simply create the same amount of noise nuisance elsewhere.

Clearly the costs and benefits of such schemes will vary widely from town to town and should be calculated afresh on each occasion. Nevertheless, the success of pedestrianisation schemes in many towns in different countries suggests that they should often be an element in an urban noise abatement strategy.

2.2.2 Noise Barriers

Barriers have a role to play in respect of urban and interurban motorways and major roads; but it is less clear that they can be used elsewhere without being distinctly unaesthetic, or, in the case of earth mounds, unworkable. Noise reduction varies with the distances involved but a minimum of 5 dBA reduction can be expected in the protected zone, up to 10 - 15 dBA in some cases. Earth mounds can, however, be a convenient way of disposing of soil from roadworks so that the actual cost is reduced to whatever is necessary to make the mound look attractive (sowing with grass, planting trees) and this, in any event, becomes a joint cost (note that the cost is highly dependent on the price of land).

For other barriers, such as walls, United Kingdom cost estimates suggest about $80 per metre (1978 prices) for a 1.4 metre high wall with a guardrail. For a 2.2 metre high wall the cost rises to $260 per metre. This can be compared to Dutch data for aluminium and wood screens where the price per metre for a two metre high screen indicates about $300 per metre for aluminium and $200 per metre for a wood screen. Swedish data on steel and plastic screens (3.5 metres high) or other metals with plastic covering suggests $300-500 per metre with the added benefit that some of the screens are specifically designed to be sound absorbing so as to avoid the possible problem, in some circumstances, of the noise being simply reflected to the opposite side of the road.

Concrete screens in France appear to range from about $400 to $700 per metre according to the absorbing properties, but for very much higher screen heights (3.5 - 6 metres). United States estimates range from $276 per metre for a 4 metre high timber barrier to $82 for a 2 metre high concrete barrier.

2.2.3 Insulation of Buildings

Although insulation of buildings is in a sense the least satisfactory method of dealing with noise, there are circumstances in which it is the only possible method. In particular, it is the only way of bringing relief to many of the people exposed to the most severe noise levels when they are at home, which is a task deserving priority within noise abatement programmes. For protection against road traffic noise it is normally necessary to insulate windows only. The effectiveness of the various options varies greatly: compared to a standard window giving a 20 - 23 dBA insulation, thick 8 to 10mm glass would provide 30 dBA insulation and a double window about 40 dBA insulation. Cost would vary according to these various options and other joint costs such as ventilation. Also, insulating new buildings at the construction stage is much less costly than insulating existing ones.

Cost comparisons are therefore difficult and one can only give orders of magnitude (cost per square metre in 1978 dollars).

In Switzerland a 35 - 40 dBA insulation would cost about $250; a 30 dBA insulation (thick glass) would cost between $200 and $300 (France and Germany). Double windows are more expensive and cost about $600, and more if ventilation is added.

In terms of cost per dwelling, French evidence indicates that the insulation of a three-room flat would cost about 2,700 1978 dollars; for a five-room flat the cost would be $3,300. A programme for insulating 2,300 flats in the Lyon suburbs (France) will cost Frs.40 million ($8.5 million), that is, an average cost of $3,700 per flat.

2.3 Some Global Estimates of the Cost of Traffic Noise Abatement

In a few countries, global estimates have been made of the actual or potential cost of traffic noise abatement at national level. In fact this information is rather scanty and relates mostly to house insulation and road construction; it is however interesting to summarise some of these estimates.

For the Netherlands it is estimated that 326,000 dwellings are exposed to traffic noise of 65 dBA and more. Insulating these dwellings in order to provide an indoor level of 45 dBA Leq would cost between Fl.1.25 and 1.6 billion (1976 price level, i.e. 0.68 to 0.87 billion 1978 dollars). This cost would be incurred if no other source abatement measures were taken. If spread over a 10 year period this would mean an annual expense of about Fl.170 million at 1975 prices (i.e. Fl.205 million at 1978 prices).(1)

For Germany, estimates have been made of the noise protection cost that would be necessary to comply with the standards proposed in the new draft law on noise. According to these estimates the building of new roads would bear an additional cost of 5 to 13 per cent according to policy options.(2) It is, however, estimated that beyond the benefits in terms of better noise climate, other benefits will accrue from house insulation, in particular in terms of savings in heating cost. For motor cars, the increased capital cost will be about 4 per cent and the running cost 5 per cent to 7 per cent. For lorries the capital cost is estimated at 10 per cent and an additional transport cost of 3 per cent to 5 per cent is expected.(3) But benefits in terms of fuel savings should also be taken into account.

In Japan, 3 per cent of the five year programme for road construction (1978-1982) is allocated to environmental improvement, 40 per cent of which is directly related to noise abatement (barriers and building insulation).(4)

In France, the cost of reducing noise emission levels of all vehicles is estimated at Frs.29.2 billion (1977) over a 10 year period. If one takes an averaged yearly cost of 2.9 billion per year, this means about 5.5 per cent of the value added by the motor industry in 1977: 81 per cent of this cost relates to motor cars, 14 per cent to lorries, 1 per cent to buses and 3 per cent to other heavy vehicles. Insulating all dwellings (i.e. 4.6 million dwellings) exposed to a noise level of 65 dBA (Leq) or more would cost Frs.40 billion (1977); if spread over a 10 year period this would be 3 per cent of the construction sector output in 1976. Finally, protection measures along urban motorways (barriers, earth mounds, etc.) are estimated to cost Frs.5.3 billion (0.4 per cent of 1976 construction sector output.(5)

1) Source: Ministry of Environment and Public Health: Financial Implications of Policy Standards for the Abatement of Road Traffic Noise, December 1976 - and J.A. Suurland Noise Charges in the Netherlands, OECD, 1976.

2) Averaged figures - derived from W. Kentner: Das Verkehrslärmschutzgesetz und seine wirtschaftlichen Folgen - Umwelt, June, 1978.

3) W. Kentner, op.cit.

4) Source: information provided to the Secretariat.

5) Estimates done by Institut de Recherche des Transports: J. Lambert: Essai d'évaluation du coût global d'insonorisation des logements exposés à des niveaux de bruit excessifs, 1979.

3. AIRCRAFT

For aircraft noise abatement, six options are available: (a) quietening the engines ("retrofit"); (b) replacement of engines; (c) early retirement of aircraft in favour of noise-certified craft; (d) flight procedure and operational changes; (e) airport-based measures (such as land-use planning); (f) insulation of the receiving environment, e.g. insulation of houses.

Options (a), (b) and (c) constitute the major measures for noise abatement at source - note that all available options can be combined. Some engines might be retrofitted, a number of other aircraft can be replaced, while airport measures and noise insulation can be simultaneously implemented where airport noise levels remain too high despite noise reduction at the source.

3.1 Retrofit and Engine Replacement(1)

With the exception of the new "quieter" aircraft(2), virtually all aircraft are capable of being quietened to some extent. The older, noisy aircraft fall into two categories:

(a) 4-engined aircraft such as B-707, B-720, DC-8 and VC-10. These have the highest single event noise levels. Many are powered by the JT3D engine.

(b) 2- and 3-engined aircraft such as the DC-9, B-727, B-737 and BAC-111. Although these have single event noise levels that are substantially below those of the 4-engined aircraft, they are short-haul aircraft and therefore take off and land more frequently. Many are powered by the JT8D engine.

Retrofit measures may consist of nacelle retrofit with some sound absorption material (SAM) or introducing a new front fan with higher by-pass capability (REFAN). Refan technologies are extremely expensive and little attention is now paid to them as serious options for source abatement. Other retrofit options (SAM) are still considered to a certain extent although early retirement of craft in favour of new, less noisy craft seems to be preferred. However, since it is difficult to assess the costs of early replacement (although it would appear the exercises are being done), the costs of SAM retrofit provide some benchmark to work with. Generally speaking it appears that retrofit is not a cost effective solution in terms of noise reduction.

1) The information which is synthesized here is mainly derived from studies of the European Civil Aviation Conference (ECAC: Technical information on retrofit, Doc. No. 13, September 1977) and various studies for the United States (FAA, EPA), the Netherlands and the United Kingdom. For details see Part III.

2) Such as DC-10, DC9-80, L1011, Airbus, B-747 (2nd generation), which are much less noisy than older aircraft.

Allowing for the fact that payloads are reduced, fuel consumption increased and that there will be some out-of-service time, the total cost of SAM retrofit would appear to be some $1 million per aircraft, on average (derived from European Civil Aviation Conference estimates). Obviously, costs vary with type of aircraft: with B-707 for example, having a total cost of $2.77 million compared to $1.59 million for a DC-8 and $0.37 million for a B-727 (see Table 3). These are 1975 dollar prices, so that for 1979 prices one should allow for cost increases and for revaluation at 1979 prices. Some American studies indicate a 7 per cent per annum rise in costs. Allowing for this would suggest that the $1 million per aircraft average would rise to $1.3 million at 1978 prices and further conversion to 1979 prices raises it to some $1.4 million. As percentages of aircraft prices, and using the 1975 price data, SAM modification of a B-707 would amount to some 10 - 20 per cent of price (the range reflecting the fact that cost varies with the numbers modified). For a B-727, the cost would appear to be of the order of 4 per cent.

The effectiveness of SAM retrofit varies greatly between types of aircraft. From Table 3 it can be seen that for two- and three-engined aircraft only 2- 3 EPNdB(1) average reduction can be achieved. Gains are much more significant for four-engined aircraft (5 to 9 EPNdB) but with a wide range of cost. The cost and effectiveness of SAM retrofit are summarised in Table 3.

To meet the noise standards of the International Civil Aviation Organisation (ICAO),(2) would imply the retrofitting of about 700 aircraft in Europe(3) and 1,200 in the United States (in the absence of jet engine replacement and early retirement of aircraft).

It should be borne in mind that the attainment of these noise limits is no guarantee of the eradication of noise nuisance in the vicinity of airports, although it could certainly represent a substantial reduction in community noise loads, but this is highly dependent on the growth of traffic volume that might partly or totally offset the noise emission reduction.

In terms of noise impact reduction, assuming that all subsonic jets would comply with the relevant ICAO noise standards over the

1) Effective Perceived Noise decibel = special unit for aircraft noise measurement. To get the approximate corresponding level expressed in decibels A (dBA) one can subtract 13 - 15 units from the numerical value in EPNdB. For example the noise level of a Boeing 707 of 111 EPNdB equals approximately 111 - 13 = 98 dBA.

2) Presented in the ICAO "Annex 16" Chapter 2 (3rd Edition - July 1978). These standards are also embodied in the United States Federal Aviation Agency standards (FAR. 36) with some slight differences.

3) i.e. Member countries of ECAC (European Civil Aviation Conference). This covers roughly all OECD European countries.

TABLE 3

SUMMARY OF COST AND EFFECTIVENESS OF SAM RETROFIT (ECAC AND USA)

Type of Aircraft	Number (1975)			Present noise level EPNdB*	Feasible noise reduction EPNdB*	Average total cost per aircraft $M. 1975**	Average total cost per EPNdB $M. 1975***
	ECAC	USA	Total				
2 engines							
DC-9	188	} 448	} 688	} 100	3	0.44	0.15
B-737	52				2	0.54	0.27
BAC-111	82		82	102	3	0.74	0.25
Caravelle (10 and 12)	30		30	101	2	0.19	0.09
Mercure	10		10	101	n.a.	0.17	
3 engines							
B-727	79	454	533	102	3	0.37	0.12
Trident	41		41	106	2	1.87	0.93
4 engines							
DC-8	79	} 270	430	} 110	8	1.59	0.20
B-707	81				9	2.77	0.31
Super VC-10	11		11	110	5	3.47	0.69
B-747	4	45	49	110	6	1.101	0.18

*) average value of the 3 ICAO measuring points.

**) derived from ECAC data.

***) rounded figures.

period 1980-1985 the population affected in the 35 NNI contour (roughly equivalent to Leq60)(1) would be reduced by:

20% (142,000 people) for all French airports

48% (681,400 people) for Heathrow (London) airport

24% (14,930 people) for Schiphol (Amsterdam) airport

(These estimates, made by ECAC, relate to the year of maximum benefits.)

This would be achieved at a cost of some $800 million in 1979 prices for the ECAC aircraft alone plus the cost of retrofitting non ECAC aircraft using ECAC airports. It is estimated that if no retrofit policy is implemented the "natural" replacement of old aircraft by new quieter ones would bring about the same benefit during the period 1985-1990. Thus the benefit of retrofit would be some six additional years of reduced noise (depending on traffic growth assumptions).

No detailed cost data appears to be available on engine replacement and it is understood that, in some cases, the cost could be prohibitive: of the order of 50 per cent of the cost of the aircraft itself. There are, however, important programmes of engine replacement on DC-8 aircraft. The cost is estimated at $9 million per aircraft.(2) Six airlines have decided to re-engine their DC-8s; substantial fuel savings are also expected through this operation.

To conclude on retrofit, it would appear that, if applied to all aircraft, this would constitute a relatively expensive solution. But it does not mean that retrofit should be rejected altogether. Taking into account the age and type of use some aircraft might be cost effectively retrofitted while others could be replaced (see below). In fact retrofitting JT8D powered aircraft (B-727, B-737) is still considered as a cost effective solution. Moreover, account should be taken of the increased fuel efficiency of new technology engines. No doubt this will constitute a driving force in decision making.

3.2 Early Retirement of Aircraft

If old, noisy aircraft were replaced by the new technology aircraft, community noise exposure would be reduced in two ways:

a) The single event noise levels of the replacement aircraft would be lower than those of the older aircraft, even with SAM retrofit.

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1) To compare with other noise indices, it can be roughly estimated that: 35 NNI (United Kingdom) = 91.5 CNR (United States) = 73.5 N (France) = 38.5 ke (Netherlands).

2) Flight International - 9th June, 1979 and 15th September, 1979.

b) The number of aircraft movements would be reduced or would grow more slowly since the airlines are likely to take the opportunity of introducing aircraft with a larger number of seats than the aircraft that they replace.

The cost of replacing an aircraft will, of course, depend upon the age of that aircraft and its remaining lifetime. Any cost calculations are therefore likely to be sensitive to the various interpretations that may be put on the remaining lifetime. Some airlines may appreciate the opportunity of accelerating the retirement of old aircraft whereas others, operating in different markets, may wish to extend the lifetime for as long as possible.

American data(1) suggest some combination of replacement and retrofit is called for, with JT-3D (B-707, B-720, DC-8) aircraft being replaced by craft with quieter engines but which also have improved fuel efficiency. JT-8D aircraft (B-727, B-737) on the other hand would be retrofitted. The gain in fuel efficiency (due to replacement) is even thought to generate an actual net financial benefit in such a policy. In terms of noise it is estimated that such a policy would, by 1995, reduce the population affected by noise levels of above 30 NEF(2) by some 40 per cent compared to the "no action" case. Clearly, if such gains can be secured at no cost one would expect at least the replacement part of the programme to be undertaken, without the provision of any incentives. The retrofit of the JT-8D craft would however require some incentive since, clearly, the net financial benefits would be higher still if these were not retrofitted. No hard evidence appears to be available to suggest what such a "mixed" policy would achieve in Europe.(3)

3.3 Flight Procedures and Operational Changes

Other measures relating to procedure and operational practice have all been argued to have small cost. Reduced thrust take-off reduces side-line noise. Maximum angle climb outs and power cutback techniques reduce noise in either the immediate or outlying vicinity of the airport, with no apparent cost and even financial benefits. This appears also to be true for maintaining higher altitudes than hitherto before intercepting the glide slope. Two segment approaches are not considered further since they have been judged unsafe by the United States Federal Aviation Agency. It seems clear, however, that changes in operating practice, subject to safety considerations, can reduce noise and even secure financial benefits.

1) FAR part 36 compliance Regulation: Final Environmental Impact Statement - FAA, October 1976.

2) "Noise Exposure Forecast" (30 NEF = 65 Ldn = 32 NNI)

3) Subject to the results of a recent ECAC study, not yet available.

3.4 Airport Measures

Airport measures may also be used. Noisy aircraft can be kept to runways where they cause least noise nuisance. Minimum noise routes can also be sought. In both cases costs are incurred in terms of increased diversion (except when noise preferred runways are also operationally preferable). For preferential runway treatment, one estimate suggests about $15 - 20 per movement (1979 prices) and for minimum noise routes about $17 - 20 per movement.

Curfews can also be used, given that night-time noise is the source of the greatest annoyance. The cost here will obviously be the cost of diverting to other airports if they will accept night-time flights, or rescheduling craft to daytime flights or cancelling the flights altogether. It has been suggested that a 10 p.m. to 7 a.m. national curfew in the United States would cost some $140 million at 1979 prices assuming a 10 per cent reduction in flight activity. The benefit would appear to be a reduction of about 60 per cent in the area affected by any NEF level.

Overall, then, it seems clear that careful attention to operational practice could secure noise benefits at small or negative cost. Airport practice could secure further gains but there may be costs involved that would be regarded as unacceptable, e.g. the effect of night curfews on mail delivery and so on. On the other hand, night curfews have been argued to secure very significant reductions in noise exposure. Attention seems best focused on some mix of retrofit and early retirement. It is vitally important to look at the mixes of policy and secure the least cost option once an environmental noise standard is determined.

3.5 Insulation of Buildings

Insulation is not an entirely satisfactory method of protecting the community against noise, since outdoor noise remains. But it might be an indispensable measure when other measures for reducing noise provide results which are insufficient or will take effect only after a long time lag. It has also the advantage of a feasible combination with thermal insulation (for energy conservation purposes). Insulation has in any case had to be adopted at many of the major airports. The main factors affecting cost are similar to those for insulation against road traffic noise, but the following factors also have to be taken into account:

a) aircraft noise is overhead, and therefore roof insulation is also required;
b) insulation against aircraft noise often needs to be greater than insulation against traffic noise because of the non-continuous (episodic) nature of the noise.

In order to derive a cost per house, the window costs for road traffic noise should be used, to which should be added the costs of insulating overhead. These costs have been estimated to be £40 - 180 per square metre ($80 - 360, 1978) depending upon the areas of attic floor and the number of layers of plaster board used.

For buildings other than houses there is very little data available. Table 4 summarises some recent data prepared by FAA on the costs of soundproofing public buildings near airports.

It is however important to stress the fact that the best way to abate aircraft noise is to promote the acquisition of less noisy aircraft. In fact, the noise certification levels of Chapter 3 of ICAO Annex 16 are markedly lower than those of Chapter 2. Aircraft complying with both of those Chapters are noise certificated. However only aircarft complying with Chapter 3 standards can bring about a significant improvement in the acoustical environment.

TABLE 4

COSTS OF SOUNDPROOFING PUBLIC BUILDINGS AGAINST AIRCRAFT NOISE (1977 DOLLARS)

	\$ per m^2 of floor area	\$ per building
United States (estimates)	approx. 65	180,000(1)
Germany (actual)	approx. 65	
Canada (actual)		200,000
Japan		160,000

Note: 1) Schools - $5,030 per room for 10 dB(A) reduction
$5,750 per room for 20 dB(A) reduction

Hospitals - $2,630 per room for 10 dB(A) reduction
$3,050 per room for 20 dB(A) reduction

4. INDUSTRIAL NOISE

Since industrial noise sources are usually stationary, sensible land-use planning can help avoid many potential community noise problems. Where industrial noise is a problem the most appropriate method of abatement is at source. When this is prohibitively expensive, or technically infeasible, protection is necessary in the form of barriers or insulation.

4.1 Land-Use Planning

Industrial plants that are capable of causing a community noise problem can usually be identified at the planning stage (e.g. plants that are open, rather than enclosed, such as refineries, chemical plants, steel works, sawmills, etc.). The problem can be reduced by preventing the plant from being built on a particular piece of land, or by not allowing noise-sensitive buildings such as housing from being built nearby.

The cost implications for industry could include such items as:

- increased transport costs;
- higher land prices elsewhere;
- difficulties in obtaining labour elsewhere.

These are likely to be very dependent upon the local circumstances and therefore any cost conclusions that might be drawn are of limited value. Furthermore, no examples of well-documented cost data have been produced.

4.2 Abatement at Source

In practice, abatement at source usually means incorporating noise control at the design stage of a new plant, or the more expensive introduction of changes to an existing plant. In contrast to aircraft noise abatement, premature retirement is only rarely contemplated as a solution to industrial noise problems and the costs are almost always limited to capital costs, although there are occasional increases in fuel consumption.

It is necessary to consider source abatement costs at the plant level. But this poses data problems because no two plants are the same. Each is a unique combination of different types of noise sources (furnaces, fans, motors, compressors, piping, etc.).

It has been suggested that a relationship may exist between abatement cost (expressed as a percentage of fixed assets) and the reduction in community noise level that is achieved. An attempt to establish such a relationship tentatively estimated 0.15 to 0.20 per cent per dB(A).(1)

However, the use of such a relationship neglects the fact that differences are likely to exist between industries, and perhaps between plant types in any one industry. Furthermore it is a widely held view that it is cheaper to incorporate noise control at the design stage than to introduce changes to an existing plant. Also it is often stated that each additional dB(A) saved tends to cost more than the previous one, and therefore at any existing plant the cost may depend upon the extent to which noise abatement measures have already been taken.

In a 1976-77 study for the Netherlands, it was assumed that the cost of quietening noisy plants, in order to achieve a night-time community noise level of less than 45 dB(A), would be as follows:

Plant Type	Cost (as % of fixed assets)
Metal Industries	2.0%
Chemical/Petroleum	1.5%
Others (some exceptions)	1.0%

1) Metra, 1976.

These percentages were applied only to plants that were known to be causing a community noise problem. Thus they should not be applied elsewhere (e.g. for other countries) without first taking into account the fact that not all plants will need to be quietened.

4.3 Noise Barriers

For maximum effectiveness this form of protection needs to be introduced as near to the equipment as possible. Thus in practice they are likely to be erected by the plant operator on his own land. Examples include the use in Japan of walls around large sources of noise such as furnaces. Costs are similar to those recorded in the case of road traffic noise, but the efficiency might be greater.

4.4 Insulation of Buildings

The costs of insulation against industrial noise are similar to those for insulation against road traffic noise.

4.5 Comparison of Alternative Abatement Methods

Very little information exists on how the various abatement methods compare, in terms of cost or effectiveness, in a given set of circumstances.

Research in the Netherlands indicates that, on average, abatement at source is about ten times as expensive as house insulation, although the latter is of course a much less satisfactory solution from the point of view of the people troubled by noise.

4.6 Some Global Estimates of the Cost of Industrial Noise Abatement

For the Netherlands, to achieve a community noise level of 55 dBA Leq during day time, 50 dBA Leq during evenings and 45 dBA Leq at night would cost Fl.880 million (1976) for all industries (475 million 1978 dollars), i.e. about 2.3 per cent of the gross asset formation of industry. This is considered as an upper limit, i.e. with no transition period (so called "overnight" conversion cost) and no house insulation. Insulating houses on sites where only a few houses are affected, instead of source reduction, would decrease the cost to Fl.600 million with negligible house insulation cost.(1).

In Sweden source reduction cost is estimated at S.Kr.500 million (1977), i.e. about 125 million 1978 dollars. (0.8 per cent of industry gross asset formation).

1) METRA (1977): Cost implications of proposed industrial noise legislation and economic appraisal, and Ministry of Public Health and Environment: Financial consequences of policy measures in connection with zoning systems round industrial sites (March 1978).

As a percentage of total pollution control investment by industry, noise control investment accounts for 4 per cent in Austria, (1970-1980);(1) 3.4 per cent (1974) and 9.4 per cent (1979) in Germany;(2) and 7.6 per cent in Japan.(3)

5. CONCLUSIONS AND POLICY IMPLICATIONS

Anyone seeking to identify generally applicable conclusions from the existing studies of noise abatement costs would be undertaking a hazardous and questionable exercise. As noted, the data are often not comparable or are incomplete. The very first conclusion that emerges, therefore, is that substantially increased research on noise abatement costs is needed to help policy making. The principles on which that research is undertaken should also ensure that all costs are taken into account, not just the capital costs of abatement.

However, this brief survey has indicated some areas where policy might usefully be directed. For aircraft, abatement costs are fairly standard by country and it seems clear that we know the costs of retrofit with some accuracy. The costs of early retirement require detailed information of fleet structure and its age distribution. Given this it seems that retrofit alone is not a cost-effective solution. As suggested in this overview, some combination of retrofit and replacement may be optimal. The noise gains then need to be compared to what noise levels will be in the event that "natural" reductions of noise come about as certificated aircraft are introduced, bearing in mind that increased movements can readily offset gains from certification.

The situation with respect to traffic noise seems complicated in one of the areas that matters most - lorry noise. There are disputes about the cost of abating such noise at source, but, apart from medium diesel lorries, it appears to be the case that an 80/81 dBA level (ISO test) could be achieved for lorries for price increases of 5 - 10 per cent. It may, however, be cheaper to consider the re-routing of lorries away from towns, or confining them to special routes within town initially as a substitute measure and then as an additional measure. The essential benefit here is not just reduced noise but also the extra safety and environmental benefits that would accrue.

Slightly lower cost increases would seem to apply to buses to meet the same standard and it is worth emphasising that 10 dBA reductions are highly significant and currently feasible. Additional capital costs range between 2.5 and 8 per cent.

1) Source: OECD Environmental Expenditure Data Bank.

2) Ibid, quoted from a study done by the Battelle Institute.

3) Figures provided to OECD, quoted from the Japan Development Bank.

Motorcycle cost increases appear to be far more substantial in terms of the percentage change on the original price (in particular for larger motorcycles). Nonetheless, motorcycle noise is singled out by the public as a source of particular nuisance and the price changes must be considered in the light of this public reaction.

Motor car noise can be reduced by 2 to 7 dBA according to model with what appear to be "acceptable" cost increases of about 1 per cent per dBA (for the first 4-5 dBA).

On vehicles in general, then, the social case in favour of noise reductions at source appears powerful. This said, due consideration must be given to "mixing" source reduction with the use of barriers, screens and household and public insulation. For existing towns it would appear expensive to double-glaze especially if the windows are to have ventilation, but this might be an indispensible measure when no other satisfactory measures of noise abatement exist or when such measures are in prospect only in the longer term. For newer houses there seems to be a fairly clear case for making insulation part of building regulations, especially when it is borne in mind that costs are lower and that insulation also saves energy and acts as a theft deterrent. Cost effectiveness studies should indicate the best solutions.

How far wider policies of altering transport policy in general can be used is a matter for case-by-case study by Member governments. In the longer run it would seem more sensible to design for reduced environmental interference than to "patch up" a system that is designed for maximum economic benefit but not maximum social benefit.

NOISE ABATEMENT IN THE CONTEXT OF ENERGY CONSERVATION AND OTHER POLICY OBJECTIVES

CONTENTS

1. INTRODUCTION

1.1 The Purposes of this Report

In this report, it will be possible to discuss only one relationship between noise reduction and other policy objectives. That is the relationship between noise reduction and energy conservation. Even this discussion is only a preliminary attempt. The energy crisis is continuing to grow in the light of events of recent years, and the need to study dislocations in other policy caused by energy conservation will become more pressing. Specific research is needed immediately on the question of the relationship between noise reduction and energy conservation.

A secondary objective of this report will be the identification of other policy objectives which may affect or be affected by noise reduction efforts.

1.2 The Relationship Between Noise Reduction and Other Policy Objectives

In general there is no one relationship between noise reduction and another given policy objective. The reason is that noise reduction to a given level may be achieved by numerous combinations of measures - source, path, and receiver controls; or from a different perspective, combinations of planning and design measures applicable to new plant, equipment and facilities, and operational measures applicable to existing noise sources and problems. Each combination of measures may have different side effects on other policy objectives like energy conservation.

Therefore, the complete analysis of the interplay of noise reduction and another policy objective requires the analysis of the effects of all individual noise reduction measures that might be included in an overall noise reduction strategy. The results of this analysis could then become the basis for the selection of a noise reduction strategy which would optimize simultaneously noise reduction and one or more other desirable social goals.

2. NOISE REDUCTION AND ENERGY CONSERVATION

2.1 Introduction

There is likely to be an underlying compatibility between the goals of noise reduction and energy conservation. This is all the more important since energy conservation is a major policy objective. It is fortunate for the protection of the noise environment that, in the long run, the increasing scarcity of petroleum may induce a more limited use of the internal combustion engine (ICE). Since the ICE is the root cause of much of the noise problem, the overall impact of energy conservation on noise reduction is likely to be favourable. The foreseeable alternatives to the ICE are all quieter or present more manageable noise problems because many of them focus on stationary rather than mobile equipment. Examples include substitution of electricity - whether produced by solar, wind power, coal or nuclear facilities - for petroleum in the energy mix. New technologies for energy production may produce noise problems, but a preliminary survey(1) shows that they may not be as severe as the ones presently caused by the continued growth of ICE noise sources.

The following sections will examine the energy-related concomitants of various noise reduction measures.

2.2 Road Traffic Noise

It has been clear for some time that, in any scheme either to save energy in the field of transport or to reduce noise, road traffic must be a prime target.

Road vehicles have been conclusively shown in many surveys and measurements to be by far the most wide-spread source of noise, and to annoy a very large number of people. Consequently, measures to reduce noise from motor cars, lorries and motorcycles have received much attention in recent years, and source noise reduction in this area has become an important feature of the noise campaigns in most OECD countries. Transport consumes 20 per cent of total energy consumption in Europe, 15 per cent in Japan and 33 per cent in the United States. And road transport accounts for 80 per cent of the energy consumed for transport. According to a study by the Battelle Institute, urban motor car traffic accounts for 34 per cent of road transport, and motor car traffic outside urban areas accounts for 28 per cent.(2)

2.2.1 Noise Reduction at the Source

Present vehicles. Because of the very wide range of types of vehicles and modes of use, the noise problems are very different according to cases, and few general guidelines can be laid down. The situation is further complicated by the increase in efficiency of petrol engines.

1) D.N. Keast, Bolt, Beranek, and Newman, Inc., Noise Control Needs in the Developing Energy Technologies, Report No. COO-4387-1 prepared for U.S. Department of Energy, March, 1978. Noise-related problems associated with new energy technologies that were identified by the author include: draft fans for large boilers, wind-driven turbine generators, free-steam venting at geothermal energy sources.

2) Battelle Institute, Les économies d'énergie possibles dans les transports, 1977.

For conventional types of internal combustion engine, the trade-offs between noise, energy consumption and air pollution are relatively well known. As a general rule, differential taxation in Europe on the basis of engine size (cylindric capacity) and relatively high fuel costs have encouraged high rotating-speed engines of small size which are fairly efficient, but usually quite noisy.

The current position can be improved both in terms of energy consumption and noise abatement without revolutionary changes, as work by a few car manufacturers has shown. Renault, for example, has shown that by increasing engine capacity from 850 to 1100cc and reducing maximum engine speed from 5000 to 4000 rpm, noise could be reduced by 4 dB for the same power output, with the expected saving in fuel consumption, and low exhaust emission values. The only negative feature of this approach is the slightly heavier engine that results, using more raw materials.

The typical North American vehicle of ten years ago shows the opposite extreme: very large engines which are much quieter at normal driving speeds, but with high fuel consumption caused in part by the great vehicle weight. Thus for light vehicles (normally driven by petrol engines) energy, noise and air pollution requirements can be reconciled to some degree. If, however, an extreme value of any of these characteristics is demanded, the others may worsen. Thus, if energy considerations are paramount, noise may increase slightly.

For example, in proposed noise regulations for newly-manufactured buses and motorcycles, energy consumption consequences were calculated. In 1977 it was estimated in the United States that compliance with noise regulations for buses /i.e. reducing their noise from present levels to 83 dBA(1) by 1985/ would also involve a fuel penalty of up to 3 per cent.(2) The added weight of noise reduction materials would be the cause of the increase in fuel consumption. Added weight would also affect the fuel consumption of motorcycles as a result of meeting their noise regulations. Estimates in 1977 indicated that in the United States reducing motorcycle noise from present levels down to 86 dBA(1) by 1981 would slightly increase fuel consumption depending on the type of the vehicle.(3) It should be noted however that in relation to a country's total fuel consumption, the fuel consumed by motorcycles is almost negligeable whereas the

1) At 7.50 metres (European measurement procedure).

2) Proposed Bus Noise Emission Regulation (EPA 550/9-77-201), U.S. Environmental Protection Agency, Office of Noise Abatement and Control, August, 1977.

3) Proposed Motorcycle Noise Emission Regulations (EPA 550/9-77-203), U.S. Environmental Protection Agency, Office of Noise Abatement and Control, November, 1977.

noise they produce constitutes in many cases a major source of annoyance. Therefore a slight increase in motorcycle fuel consumption would be hardly noticeable whereas a reduction of the noise produced by motorcycles would be very welcome.

Classically, diesel engines are noisier than the equivalent petrol engine, but more energy efficient. Since in the past they have been used primarily in heavy vehicles (but now also more and more in light vehicles), the weight penalties of noise reduction measures are not as critical as for cars, and substantial reductions can be achieved, as has been demonstrated by "quiet truck" projects in several countries. While the increased weight of a quiet engine results in a slight fuel consumption increase, more efficient fans and fan clutches, mufflers and exhaust gas seals are both fuel saving and noise reduction measures, and tend to cancel this adverse effect. The present fuel shortage and cost situation is likely to increase demand for these techniques on fuel economy grounds, with a corresponding improvement in noise performance regardless of regulations. Another commonly used technique used with diesel engines is turbocharging, which improves both fuel economy and noise.

As examples of the sort of projects that are under way in some countries which attempt to reconcile the various factors, it is useful to look at some work which is being done in the Netherlands. The firm of DAF Trucks, Eindhoven, is currently doing research which, by making fundamental changes to a diesel engine, is aimed at reducing both the noise emission and the exhaust gas emission. The research will lead to the construction of two prototypes, one with minimum noise production and the other with an optimum exhaust gas composition from the viewpoint of environmental health. The ultimate production model may be a compromise between these two prototypes, and it is expected that the fuel consumption will be less than that of present diesels.

Besides design work on engines, another major area of vehicle noise reduction is that of screening. As far as is known, shielding an engine for noise reduction results in no change in the character of air pollution, and marginal increases in fuel consumption and exhaust levels due to the increased weight of the vehicle, as mentioned previously. A similar situation applies to silencers. The slight increased fuel usage which may be caused by a silencer should be small if the silencer is carefully designed, and exhaust systems designed for noise can be combined with exhaust gas treatment provisions to reduce air pollution. In addition a proper vehicle design may be advantageous both for the cooling of the engine and for its noise emission (good aerodynamic and air intake design).

In addition to better design of new vehicles, attention has been given to retrofitting in-use vehicles for use of other fuel, for petrol conservation purposes. Most of these [Liquified Petroleum Gas (LPG), compressed natural gas, alcohol/petrol mixtures] are relatively non-polluting as well as efficient. For example, the Research Institute for Road Vehicles at Delft in the Netherlands (TNO), is engaged on a trial with a number of buses whose diesel engine has been converted for the use of LPG as fuel. Such buses have been operational for some time in municipal transport in the city of Vienna. Experience there indicates that, in comparison with the diesel bus, the LPG bus offers considerable advantages from the viewpoint of environmental health. Both the noise emission and the exhaust gas emission of the LPG bus are considerably lower than those of the diesel bus.

"New technology" vehicles. Electric vehicles have been used in several countries for limited uses for many years. Their advantages from the noise point of view are obvious, but in terms of overall energy consumption it is doubtful if they are more efficient than internal combustion engines. They are also almost totally non-polluting, which has obvious attractions, in particular for urban areas, but will probably not become more generally used until the promised developments in storage batteries are fully viable, or until pressure on fossil fuel use makes their other disadvantages less important.

New fossil fuel engines under development include the Stirling engine and the stratified charge engine. The first, while it has very good noise and fuel consumption performance, will probably not come into widespread use because of its very high manufacturing costs, both in terms of material and energy use. The stratified charge engine is under intensive development primarily because it is very efficient in terms of energy consumption.

2.2.2 Operational Noise Reduction Measures

Traffic speed restrictions are an example of a noise reduction strategy that has predominantly positive effects on other important considerations. Increased fuel economy and road safety are well known results of reduced speed, provided traffic flows freely. In "stop and start" traffic, fuel consumption, noise and accidents increase, so care should be taken not to slow the traffic so much it clogs, negating the benefits.

Control of traffic volume is an important factor in noise from motor vehicles, and the noise factor is sometimes used as a reason for increased use of public transport, but a 50 per cent reduction in traffic volume is required for a mere 3 dB reduction in noise, so once again the energy argument dominates - such a 50 per cent reduction would greatly reduce total fuel consumption (and probably air pollution, particularly if electric transport is used).

Rerouting of traffic, especially lorries, is a third operational approach. In three Dutch towns, Rijswijk, Eindhoven and Groningen, research is being done into the environmental effects of traffic measures.

In the demonstration projects involving rearrangement of urban areas, environmental health is one of the five qualitative aspects for which indicators are collected in the form of a pre- and a post-change investigation; with these indicators the effects of the re-arrangement can be quantified. The rearrangement is directed towards improvement of the residential and human environment by changing traffic circulation in the experimental areas. Changes in the traffic situation in the various option areas may affect the environmental aspects connected with motorised traffic. The energy and noise consequences of rerouting depend on the particular situation. On the one hand, longer routes may increase fuel consumption. On the other hand, if the longer route contains fewer stops or changes in speed, a decrease in fuel costs per mile may offset the fuel consumption effect of the longer route.

2.3 Railway Noise Reduction

Railway noise is one of the few areas where the situation with regard to energy, noise and air pollution is fairly clear. A British study(1) has shown that a massive shift from road freight vehicles to rail would make a slight improvement in road noise at the expense of an even smaller increase in rail noise. Such a change in noise level, it was decided, would not be sufficient on its own to justify the upheaval caused. If however, rail noise is not considered in isolation, the electrification of rail networks is clearly desirable from many points of view: electric trains are more energy-efficient, less dependent upon oil supply, non-polluting and even in cases where they may not be significantly quieter (e.g. at high speed) they have been shown to be less annoying than diesel trains. A recent British study(2) showed for example that a diesel train at 52 dBA and an (overhead) electric train at 62 dBA were equally annoying, even after allowance had been made for such factors as reaction to smoke and odour, traffic mix and others. The decision is made even easier by comparison of costs. Electric trains are cheaper to run overall, and in particular have much lower maintenance costs. The current trend towards high speed trains may also help to the extent that technology and maintenance are necessarily at a higher level on these trains. For railways, then, the situation is clear: electrification is desirable from many angles, and there is no serious conflict of noise with other requirements.

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1) U.K. Noise Advisory Council, Noise Implications of Transfer of Freight from Road to Rail.

2) Information communicated by the Institute of Sound and Vibration Research, Southampton University.

2.4 Air Transport Noise Reduction

The introduction of wide-bodied jets in the early 70s was accompanied by the introduction of the "high bypass-ratio" type of turbofan engine which has resulted in dramatic reduction in noise levels of commercial aircraft. One of the principal reasons for the development of such engines was their improved fuel consumption, as well as lower pollution levels (except for NO_x) as an incidental benefit, and work is continuing to improve these engines further. The situation with older aircraft is a case where the arguments for both energy conservation and noise point strongly in the same direction. The earlier aircraft such as 707, DC8, Caravelle and others are very noisy and inefficient by comparison with modern turbofan-driven aircraft. The arguments for either retrofit of new-type engines, or rapid replacement of the aircraft, are strong.

The situation for new aircraft seems to show that fuel consumption and pollution levels are likely to improve, and this would not be at the expense of noise levels. Replacement of older planes will be strongly dependent on the economic situation seen by the airlines, and present energy costs may well assist in speeding this process.

2.5 Other Noise Sources

Industrial noise can be considered with respect to energy in two senses: the production of energy, and the energy consuming production of other goods.

In the first case, energy production is either fairly quiet, or noisy only for the immediate surroundings (electric generation for example), or in isolated areas, such as oil production flares, etc. The major conflicts between energy production and the environment are thus not in the field of noise, but rather air or water pollution. While of course there are individual exceptions, there seems little need to consider policy aspects of noise in energy production.

For energy consuming industry, on the other hand, there is generally little conflict between noise reduction and other non-financial restraints. Historically, old plants can be energy inefficient, polluting and noisy, for the simple reason that these factors were not considered as design constraints. New plant is not necessarily any better, but in most cases there is potential for energy saving, pollution reduction <u>and</u> noise reduction where the problem is considered from the beginning in a comprehensive way.

While some modern factories have made notable improvements in all these areas, in most cases the point at which conflicts between these objectives start to occur may not have been approached, and there remains plenty of room for further improvements to be made before compromise is necessary.

2.6 Building Design

The major connection between energy conservation and noise control of this type is the relationship between acoustic and thermal insulation in buildings. Some, but not all, of the desirable characteristics for both are very similar: double window glazing, lack of leaks, and insulated wall structure.

While procedures for funding both "weatherisation" and "soundproofing" exist in many countries in some form, these do not seem to have been co-ordinated, except in the United States, and in the Netherlands where joint programmes have been started. However, these programmes are still in the demonstration stage. Preliminary United States research suggests that sealing of air leaks in the building envelope for noise control also yields an estimated 15 to 20 per cent saving in the annual heating/cooling energy requirement for the building.(1)

It may be that there is a case for increasing availability of funds for acoustic insulation on the basis that this can also be energy saving (whereas thermal insulation alone is not necessarily a protection against noise). Of course, the details of optimum thermal insulation can be different from those required for acoustical insulation. For example, a material with open pores may be excellent as a heat barrier and also efficient as an acoustical absorbant; on the other hand, a material such as light concrete would provide some thermal insulation while its effect on noise transmission would be negligible. At any rate, the thermal bonus gained from acoustic insulation may help justify provision of acoustic insulation in borderline cases, and certainly the combination of the two requirements can help raise building standards.

2.7 Urban and Land Use Planning

The interrelationship between noise reduction and energy conservation depends on the specific planning feature that is considered. Several examples illustrate this fact.

Urban planning is moving towards greater emphasis on public transport. Most immediately attractive for urban areas is a return to the trolley bus, light rail vehicles, buses and underground railways. Improvements in technology have made these options increasingly interesting as energy costs have risen and pressure for a shift to public transport grows. At present, for example, the Netherlands is studying electric vehicles, trolley buses and a diesel electric bus

1) D.N. Keast, Bolt, Beranek, and Newman, Inc., Energy Conservation and Noise Control in Residences (draft), prepared for the U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Washington, D.C., August, 1978.

which is said to be quieter for city use than conventional diesel, and more efficient. If a side effect of improved public transport is a reduction in use of private vehicles in the urban environment, a net noise reduction should result.

Another commonly used planning technique is zoning and geographical isolation. For example, a technique to reduce airport noise annoyance is isolation: the airport is placed away from residential areas. Particularly where protected zones are used as part of the land planning around the airport (as in Canada for example), this can result in substantial use of productive agricultural land, or scarce natural woodland needed for recreation. It also implies longer commuting distance and consequently more fuel consumption on ground transportation between the city and the airport. Since in most countries major projects like airports are subjected to environmental impact assessment, there seems little need to further emphasize this point, but it does represent the major drawback of the "isolation" technique.

3. OTHER POLICY OBJECTIVES

The purpose of this section is to identify other possible policy objectives the achievement of which may be interrelated with environmental noise reduction. The following have been identified. They are listed in no particular order.

3.1 Control of Air Pollution

In United States environmental impact statements, the possibility has been raised that confining roads within noise barriers or cuttings will increase the air pollution over the roads.(1) However, this effect apparently has not yet been investigated thoroughly.

3.2 Road Safety

The interaction between tyres and road surface is the principal causative factor in vehicle noise propagation at higher speeds, and any changes for noise reasons must be linked first with safety considerations. Several studies on tire noise have come to conflicting conclusions on this subject, which certainly needs more study. There is a trend towards the belief that it is possible to build roads with lower noise properties and high wet braking co-efficients, but possibly only with the use of slightly more expensive road

1) Route 66 from Capitol Beltway (I-495) to the Potomac River, Final Supplemental Environmental/Section 4(f) Statement, August, 1976.

materials.(1) The general problem is very complex, involving wear of both the tyres and the road and many other closely interrelated factors. High speed noise caused by this mechanism may however become less of a problem if strict speed limits are introduced for energy-saving reasons, since it is strongly speed-related.

3.3 Visual Aesthetics

Noise barriers or screens are increasingly used to protect residential areas adjacent to motorways from traffic noise. Such barriers may be visually intrusive unless carefully constructed, either from the point of view of a driver, or from that of an onlooker. In some countries the government has devoted extra effort to promoting the availability of numerous aesthetically-pleasing barrier design alternatives.(2) Review of local public reaction in the press confirms that visual aesthetics can be one factor in local acceptance of new barrier projects.(3)

3.4 Adequate Growth of Transportation

This policy goal has often been seen as incompatible with protection of the population against noise. Classic examples are the construction of a new road through heavily developed urban areas, and frequent public opposition to proposed sites for new airports. This subject is such an inherent part of the context of noise abatement and control that it is implicitly addressed in several other reports for the Conference.

3.5 Adequate Urban Planning

Although the goals of noise reduction and optimal urban planning are compatible, they are not identical. The point has been made that a new town optimally designed for quiet would probably be less than optimal from the standpoint of other urban indicators.

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1) International Tire Noise Conference, August 28-31, 1979, Stockholm: Abstracts of Papers:

   W. Liedl and D. Denker, The Influence of the Road and Tread Pattern on the Tire Noise and Skid Resistance (page 7); N.A. Nilsson, Possible Methods for Reducing External Tire Noise (page 20).

2) U.S. Department of Transportation, FHWA, Highway Noise Barrier Selection and Construction Experiences, a State of the Art Report, 1975.

   U.S. Department of Transportation, FHWA, A Guide to Visual Quality in Noise Barrier Design, December 1976.

3) "Thumbs Down on Noise Barriers", West Hartford (Conn.) News, June 29, 1978.

   S. Conway, "Beltway Noise Persists", The Washington Post, May 4, 1979.

4. CONCLUSIONS

The first obvious conclusion is that noise abatement is not in general incompatible with energy conservation. There are some outstanding examples where the best strategies for each objective coincide (for example electrification of railways and the accelerated introduction of the more fuel-efficient wide-body aircraft). Even in the case of the conventional motor car, good fuel performance and quietness are not incompatible unless extremes are sought. In general, the long-term prospect of decreased emphasis on the internal combustion engine and increased emphasis on electricity is favourable to noise reduction.

Other problems related to noise abatement, such as visual pollution, safety, urban planning and so on, are less clear in their interactions. In most cases we have some idea of the causes and effects for the subject itself (for example road safety), but its interactions with noise control have not yet been studied in a systematic way.

BACKGROUND REPORT NUMBER 10

INTERNATIONAL CO-OPERATION AND HARMONISATION IN THE FIELD OF NOISE ABATEMENT

CONTENTS

1. INTRODUCTION

1.1 International Co-operation and Harmonisation in the Field of Environmental Policies

Since the launching of environmental policies in Member countries, the question of their international dimension has arisen. Many international organisations are striving to promote co-operation and the international harmonisation of environmental policies.

The very concept of "international harmonisation" is not easy to define, and covers a vast area ranging from uniformisation (of standards, methods, regulations, etc.) to agreement on general principles, each country being left free to apply them according to its own lights. Where standards are concerned, harmonisation may mean making them uniform or agreeing on orders of magnitude so as to avoid any undue discrepancies. In some cases, it can be a question of various forms of concerted action or co-operation through the exchange of information, joint research programmes, etc.

The scope of harmonisation moreover varies considerably according to the particular framework: an integrated economic zone (of the European Communities type), or merely some *ad hoc* agreement, bilateral or multilateral harmonisation, etc.

Thus, within the framework of international organisations such as the International Civil Aviation Organisation (ICAO) and the Economic Commission for Europe (in particular Working Party 29 on motor vehicles), harmonisation is essentially a matter of drawing up codes of good practice or setting standards which do not have the force of law unless they are incorporated into legislation at the national level. On the other hand, the European Economic Community issues Directives which impose a legally binding obligation on Member States to put the relevant provisions into effect. Finally, there is the OECD whose aim, apart from exceptional cases, is not standardisation or the drawing up of a uniform legislative framework, but rather continuous co-operation through the exchange of information and joint research, and a framework for concerted action and negotiation; the OECD Council can, however, issue Decisions which are binding on Member Countries and - the more frequent case - Recommendations which impose a moral obligation on Member Countries to put the relevant provisions into effect. Here, harmonisation stems directly from co-operation and concerted action since the Acts of the Council are drawn up jointly by all the countries involved and are adopted unanimously.

That being the case, international harmonisation is not an end in itself; three leading aims are involved:

(i) Avoiding or minimising any adverse economic effects which environmental policies may have on an international scale; this in particular refers to non-tariff trade barriers resulting from too-widely divergent product standards; it may also be a matter of reducing distortions of competition by harmonising the environmental constraints imposed on the production sector and, especially, the methods of allocating the associated costs. In the first case, action is mainly called for in regard to the technical specifications of products traded internationally (product standards), while in the second case a kind of "code of good behaviour" is required consisting of a common set of principles agreed at the international level: among these is the "Polluter Pays Principle" proclaimed by the OECD Council in 1972 and by the Council of the European Communities in 1975, the purpose here being to avoid the subsidising of an industry in one particular country to the detriment of competing industries in other countries.

(ii) Promoting environmental protection; this would be achieved, for example, through the use of common solutions to certain problems, and through international co-operation for improving environmental quality.

(iii) Controlling transfrontier pollution processes resulting from the transfer from one country to another of polluting substances or equipment.

In the case of noise, harmonisation at the international level may cover a number of fields:

- harmonisation of the legislation specifying noise emission limits for noisy equipment traded internationally;
- harmonisation of noise measurement procedures, applicable to the various products;
- harmonisation of product use (agreements concerning heavy-vehicle traffic, curfews at airports, etc.);
- harmonisation of policy instruments other than noise limits, which may have commercial implications (rate-setting agreements in regard to transport infrastructure - including noise charges; principles designed to govern the implementation of new regulations; product labelling; compensation; agreements concerning the conditions under which new plant and infrastructure can be built and operated);
- harmonisation of noise control strategies (this may be in the nature of a genuinely comprehensive joint policy justified on the same grounds as national policy in relation to local

policy; that is, for the purpose of programmes and actions in the common interest, which are more effectively dealt with at a higher level).

1.2 Advantages and Drawbacks of Harmonisation

The harmonisation of national noise abatement policies should here be understood to mean not the uniformisation of national laws concerning objectives and means of implementation, but a policy for bringing them closer together, so that under like conditions identical effects can be achieved. Harmonising laws and regulations in the field of noise, as in other fields, is justified by the desire, as well as to protect the environment, to facilitate the free trade in goods. The benefits to be anticipated result from a widening of the markets which permits a greater specialisation, and at least in theory such benefits are reflected in lower production and distribution costs.

Moreover the existence of an area of harmonised policies encompassing several countries may induce others less concerned with protecting the environment to join in order to become a part of such a free-trade area, with salutary effects on environmental protection and health.

It is however important to point out that although there are advantages in harmonising noise abatement policies as well as those in other fields, there are also some significant drawbacks.

To begin with, harmonisation involves costs - not only those of an administrative kind, but also economic costs as a result of the necessary investment or disinvestment. These may be considerable whenever, owing to harmonisation, heavy equipment is rendered obsolete.

Furthermore, from the standpoint of noise abatement, one result of harmonising national policies, which at first sight may seem rather paradoxical, is the possibility of a step backwards. This is because harmonisation introduces an additional constraint in dealing with the problem - the need for all countries to reach solutions which are similar, or where at least the end results are the same, means that the policies selected may be less well suited to local requirements.
One goal must be to prevent harmonisation from leading to alignment on the least ambitious objectives to the detriment of effective environmental protection (a policy known as that of the "lowest common denominator").

Another critical factor of harmonisation is the complexity involved in choosing a harmonised policy. Thus determination of the optimum level of a noise limit, no easy task at national level, is even harder internationally. This may be a pretext for inaction, or may at the least delay progress.

Lastly, overhasty harmonisation has the disadvantage of doing away with the diversity of experience and hence of forfeiting the best policy choice based on the results of such experience.

1.3 Objectives and Layout of the Report

The purpose of this report is to discuss the value of further harmonising noise abatement policies in the light of the advantages and drawbacks involved. More specifically, the aim will be to:

- define the present status and trends observed regarding the harmonisation of noise policies, with particular reference to noise emission sources (motor vehicles, aircraft, construction equipment and household appliances);
- describe the role played by international organisations in this connection and the types of action they undertake;
- analyse the areas where the furthering of international harmonisation may be desirable and describe various actions for the purpose.

Section 2 will deal with motor vehicles; Section 3 with aircraft; and Section 4 with construction equipment and household appliances. Conclusions and proposals will appear in Section 5.

2. MOTOR VEHICLES

Of all noise sources, at present the most complex from the standpoint of harmonising noise abatement policies is that of motor vehicles. The diversity of vehicles, the number of people involved and the economic conditions at stake owing to the size of international markets are the main reasons. It will be noted that between 1980 and 1990 the overall demand for private cars throughout the OECD countries is expected to reach some 30 million to 35 million units each year. The number of private cars in the OECD countries now amounts to some 250 million units, i.e. 90 per cent of the world total. In 1978 the EEC countries as a whole exported 4.6 million cars and Japan more than 3 million.

2.1 Present Harmonisation and Future Trends

Where motor vehicles are concerned, the international harmonisation of noise-measuring methods and noise-emission levels still remains limited.

2.1.1 Private Cars

At present different methods of measuring noise are used in the United States from those used in Japan and Europe, between whom there are also differences of detail; only in Europe and Japan is the noise level of private cars regulated.

The Council of Ministers of the EEC adopted in 1970 a Directive which established maximum permissible noise levels for motor vehicles (measured in accordance with ISO Recommendation R362). This Directive was amended in March 1977 in order to reduce the noise emission levels; the new limits came into effect in April 1980 for new models and will apply to existing models from 1982.(1) Before 1980, the maximum permissible noise level was 82 dBA; it has now been reduced to 80 dBA. (The EEC's limits allow a tolerance of 1 decibel.)

In the United States the method now being used to measure noise is an SAE (Society of Automotive Engineers) standard. The principle is the same as that of the ISO standard: recording the maximum noise level of the vehicle accelerating at town speed. On the other hand the conditions of measurement (position of microphones, approach speeds) are different, and seem better suited to the American context (large-engined cars, wide roads, strict speed limits) than those of the ISO standard.(2) The effect of the SAE methods is to record noise levels some 5 to 6 dBA less than those obtained by the ISO method. No rules are as yet imposed limiting the noise emissions of American cars.

In Japan, the noise - measurement method used is a slightly altered version of the ISO R 362 standard (with in addition a steady running noise level test at town speed and a stationary noise level test). The Japanese regulations limiting noise emission are almost identical to the most recent EEC limits. The maximum permissible limit has been 81 dBA since 1979 and will be reduced in the future to 78 dBA although the target date has not yet been fixed. (Unlike the position in the EEC, Japanese limits do not allow any tolerance which means that the noise emission limits for private cars are currently the same in Japan as in the EEC.)(3)

In the medium term is would seem possible to harmonise <u>methods of noise measurement</u> as between Europe, the United States and Japan, but it may well be more difficult to harmonise emission limits.

The adoption of a single procedure seems feasible technically. For the past five years or so, the EPA (Environmental Protection Agency), manufacturers' associations and other government agencies have joined forces in drafting standards to replace the ISO and SAE methods. The IRT (Institut Francais de Recherche sur les Transports) and the CCMC (Committee of Common Market Constructors) propose the measurement of average rather than peak noise; such a

1) O.J.E.C. No. L 66, 12.3.77.

2) The ISO method penalises vehicles in the upper range (high power-to-weight ratio) although these are actually quieter at most town speeds.

3) The country which now has the strictest emission standards in view is Switzerland.

standard would impose a lesser constraint on large-engined cars. The ECE (Economic Commission for Europe) suggests a revised ISO standard: measurement of peak noise would be adjusted according to car weight.

OECD countries are not currently at the same level from the standpoint of legislation regarding the emission of motor car noise. In Europe such legislation has existed for a number of years and noise measurement systems have long since been established and refined. No regulations yet exist in the United States and the new systems of measurement still remain to be adopted. On this account it would appear more difficult for the Europeans to give up regulated systems of measurement than for the United States to adopt a basic method in initiating regulation. Moreover economic factors, in particular the potential effect on the various manufacturers' respective market shares, also influence the harmonisation of measurement methods.

As far as the harmonisation of noise emission limits is concerned, this can only be achieved by first adopting a single method of noise measurement.

2.1.2 Heavy Goods Vehicles

Methods of noise measurement and noise emission limits differ as regards Japan, the United States and Europe.

In the EEC countries it is the ISO R 362 standard which prevails; permissible sound levels were revised in the March 1977 Directive.(1) The levels were reduced from 89 dBA to 86 dBA for vehicles weighing more than 3.5 tonnes and from 91 dBA to 88 dBA for vehicles of over 12 tonnes and an engine power above 200 HP DIN. The new levels have been applied to new models since 1st April, 1980 and will be applied to all new vehicles put on the road after 1st October, 1982 whatever the year of the model.

In the United States the SAE J366B standard is the one adopted for noise measurement. Unlike private cars, noise emissions by medium-sized and heavy lorries (above 4.5 tons) are subject to regulation; as from 1978 the level has been 83 dBA, and in 1982 it will be lowered to 80 dBA.(2) Assuming a correction of 6 dBA owing to measurement differences, these figures would be equivalent to levels of approximately 89 dBA and 86 dBA according to the ISO R 362 method, hence roughly similar to the new EEC standards for medium sized lorries and slightly stricter for the heaviest lorries.

1) O.J.E.C. No. L 66, 12.3.77.

2) EPA's Rulemaking Program and Strategies for Reducing Surface Transportation Noise, 1978 SAE Congress and Exposition.

In Japan ISO R 362, slightly altered, is the standard which has been adopted(1), and the emission level authorised is 86 dBA for all vehicles of more than 3.5 tonnes. This limit will be reduced to 83 dBA in the future although the target date has not yet been fixed. For lorries of less than 3.5 tonnes, the same standards as for passenger cars are applied.

In the medium term it would seem possible to harmonise methods of measurement as between Europe, the United States and Japan.

2.1.3 Motorcycles

At present maximum permissible sound levels for motorcycles (excluding mopeds) are harmonised only between the EEC countries.

Such noise levels have been harmonised in the EEC countries since November 1978. A Directive(2) prescribes the method of noise measurement (ISO R 362) and permissible sound levels by engine category (from 78 dBA for engines of less than 80 cc up to 86 dBA for those above 500 cc). A draft Directive which aims at reducing the levels now imposed on the most powerful motorcycles to 80 dBA prior to 1985 is to be submitted to the Council before 1984.

Motorcycles are in the final stage of the United States Federal regulatory activity.(3) The motorcycle class has been divided into four distinct categories, with different regulatory requirements. It may be anticipated that the requirements for these categories will be: (i) street motorcycles will be required to meet at least an initial level of 83 dBA(4) which will be reduced to 80 dBA several years later, 78 dBA may be established to be effective at a later date; (ii) mopeds will be required to meet a level of 70 dBA; (iii) off-road motorcycles (170 cc or less) will be required to meet an initial level of 83 dBA, which may be reduced to a level of 78 dBA at a later date; (iv) off-road motorcycles (greater than 170 cc) will be required to meet an initial level of 86 dBA which may be reduced to an ultimate level of 82 dBA at a later date (approximately 6 dBA should be added to these figures to obtain the equivalent European measurement).

Japan also regulates the noise level of motorcycles: the measurement method of motorcycles is the modified version of ISO R 362. (The noise level of motorcycles measured by the Japanese method indicates approximately 3 dBA lower than that measured by ISO R 362.) Since 1979, the maximum permissible limits have been equivalent to 81 dBA (on the basis of ISO R 362) for motorcycles with an engine

1) Japan Environment Summary, Environment Agency, Tokyo, 1978.

2) O.J.E.C. No. L 349, 13.12.78.

3) EPA Noise Program, US EPA, May 1978.

4) Noise measured in dBA at 15 metres from the source.

capacity greater than 125 cc, and 78 dBA (on the basis of ISO R 362) for motorcycles with an engine capacity between 50 cc and 125 cc. These limits will be reduced to 78 dBA and 75 dBA (on the basis of ISO R 362) respectively, although the target date is not yet fixed.

With the exception of Japan, regulation in this field is very recent (1978 by the EEC and 1979 by the United States), while the types of vehicle covered by the standards differ according to country. In the United States levels differ according to how the vehicle is being used (whether in urban areas or not); in Europe they vary according to engine size.

2.2 The Role of International Organisations

At the present time two inter-governmental organisations play an especially significant harmonising role: the Economic Commission for Europe and the European Communities.

2.2.1 The Economic Commission for Europe (ECE)

Under the Geneva accords signed in 1958, the ECE defines guidelines for harmonising motor-vehicle noise abatement policies among the European countries, as prescribed by Rule 9. This rule is periodically updated in Working Party 29, which consists of government and manufacturers' representatives from 20 countries and of members of international organisations (ISO, etc.). The rule is incentive in character, and has so far been signed by six countries. The standards included are a foretaste of future noise reduction prospects. It was in the ECE that, strictly speaking, the harmonisation of noise abatement policies in the case of motor vehicles was launched. This body is now regarded as a leading forum for the discussion of environmental problems relating to motor vehicles.

2.2.2 The European Economic Community (EEC)

The objective of the EEC, laid down by the Treaty of Rome, is harmonisation on as wide a scale as possible. The first Directive adopted by the Council on 6th February, 1970 was based on ISO Recommendation R 362. Such action comes under two EEC programmes; the Environment Programme and the Programme for the Removal of Technical Barriers to Trade.

In addition to the activities of the above-mentioned two organisations, those of the ISO and GATT should be mentioned.

2.2.3 The International Standardisation Organisation (ISO)

To date the ISO is made up of the national standardisation agencies of 85 countries, whose membership in turn consists of governmental and non-governmental officials. Within it, technical committees draw up international standards.(1) The ISO's work on methods of measuring motor-vehicle noise began in July 1958 and the first draft standardised measurement procedure was issued in 1964 as ISO Recommendation R 362. The ISO standards were adopted by Japan, by the ECE and then by the EEC.

International standards are drawn up in accordance with technical requirements jointly with the international organisations concerned. Enforcement of the standards does not come under the ISO; neither does the question of noise emission limits.

2.2.4 The General Agreement on Tariffs and Trade (GATT)

Although it has no particular authority in noise matters, the GATT should be mentioned as an organisation having general jurisdiction in regard to international trade. In addition to rules concerning import duties and application of the most-favoured-nation clause, the GATT includes an "Agreement on Technical Barriers to Trade" formulated during the recent Tokyo Round: the signatory countries agree to avoid the creation of non-tariff barriers, to have the greatest possible recourse to international standards, and to inform their trading partners regarding product standards which they intend to introduce. A "Committee on Technical Barriers to Trade" is to deal with any possible conflicts. The agreement moreover stipulates that product certification systems shall be notified in advance to signatory countries through the GATT Secretariat.

2.3 Areas of Further Harmonisation and Types of Action Required

The closer harmonisation of noise measurement methods between the United States and Europe would appear desirable. The harmonisation of measurement methods affects that of noise emission levels. Thus so long as no single method for measuring noise is adopted, national regulations governing emission standards cannot be harmonised. There are two reasons for strengthening action already undertaken on this score: the need to lower the sound level of the noisiest vehicles and the changing international trade pattern as between Europe and the United States.

Regarding this latter point, an increase has lately been noted(2) in the purchase by American consumers of cars with small and medium-sized engines, which favours European and Japanese manufacturers. This change in the United States market among other factors has induced the EPA to consider regulating noise emissions from cars.

1) The Noise Committee is No. TC43SC1.

2) EPA's Rulemaking and Strategies for Reducing Surface Transportation Noise, US EPA, 1978.

At international level the main effort is directed towards defining a noise measurement method which will satisfy both Europe and the United States. The systematic exchange of information on the results of work undertaken by various countries is more than ever necessary.

With regard to policies aimed at reducing noise in transmission and at reception, even if international harmonisation as such is not envisaged, it would nevertheless seem important at least to intensify international co-operation in its wider sense in this area.

The reason why actions undertaken at national level to reduce noise away from the source have not been harmonised is mainly because of the specific nature of local conditions and of economically feasible solutions. Depending on the country, various methods are used: the installation of noise screens, the building of roads in cuttings, sound-absorbing tunnel vaults, the use of better road-surfacing materials, specific traffic management rules, etc., and also land-use, transport and town planning policies. It would seem that international co-operation in this area ought to be included as a part of a global strategy rather than be considered in terms of separate measures; as for example by defining permissible noise levels by area of activity in order to allow for such requirements at the early stages of urban development projects. This approach has been considered by the EEC, which has already undertaken work preparatory to a general programme for the purpose. Solutions suited to the various national contexts are being sought and evaluated in the countries concerned, but a more systematic form of co-operation at the international level (joint research, economic and technical assessments, etc.) would be useful.

3. CIVIL AIRCRAFT

If there is any area where the need for harmonisation can easily be argued, it is that of aircraft. Aircraft in fact provide the classic example of noise sources which have to be regulated on a world-wide basis. From an economic standpoint alone, for example, manufacturers and airlines would find it extremely difficult to comply with regulations varying from country to country.

3.1 Present Harmonisation and Future Trends

Currently only helicopters, supersonic aircraft and heavy propeller-driven aircraft are not covered by international regulations setting maximum noise emission levels.

The first set of international aircraft noise recommendations was adopted by ICAO (International Civil Aviation Organisation) under what is known as Annex 16 to the 1944 Chicago Convention on International Civil Aviation. This Annex, which is periodically updated(1), lays down methods of noise measurement by type of aircraft(2), as well as noise emission limits.

It is on the basis of this document that the regulations of most ICAO Member countries are formulated; thus policies for reducing noise at the source are dealt with at the international level before the national level (except possibly for domestic aircraft). At the present time aircraft covered by Annex 16 are as follows:

- subsonic jet aircraft: the permissible maximum noise level(3) ranges from 103 EPNdB for aircraft weighing more than 400 tonnes to 94 EPNdB for aircraft weighing less than 35 tonnes.
- propeller-driven aircraft weighing more than 5.7 tonnes and less than 35 tonnes: the permissible maximum noise level increases, according to aircraft weight, from 96 EPNdB to 103 EPNdB,(3).
- propeller-driven aircraft weighing no more than 5.7 tonnes; the permissible maximum noise level ranges from 68 dBA to 80 dBA according to aircraft weight.(4)

There is currently no firm agreement on stricter noise emission levels for future-generation aircraft.

Specifications for aircraft noise certification covering heavy propeller-driven aircraft and helicopters have been drawn up by ICAO: a further stage will consist in drafting specifications for supersonic aircraft.

At present application of the ICAO aircraft noise certification recommendations varies according to country.

Once accepted by ICAO, the recommendations are sent to each country, which may if desired enact more stringent national legislation. For example, one ICAO recommendation covers a particular type of light aircraft: in Germany and Switzerland it was applied three years earlier than provided by ICAO(5), and in France to all types of light aircraft.

There are no international recommendations protecting areas around airports or governing procedures for reducing operational noise.

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1) The third and latest edition of Annex 16 to the Convention on International Civil Aviation adopted by ICAO was issued in July 1978.

2) The ISO and ICAO joined in drawing up these methods.

3) Effective perceived noise level (EPNdB) at the reference measurement points. The figures given here relate to the measurements at the lateral noise measurement point.

4) Effective perceived noise level according to the IEC (International Electrotechnical Commission) method: passage of the aircraft at maximum authorised power 300 metres above the measurement point.

5) In fact, the ICAO took up and modified a regulation which was already applied in Switzerland.

In many countries(1) airport operation is subject to measures for reducing noise in residential areas; thus noise-preferred runways are used and airports are entirely or partially closed down at night. Internationally no harmonisation of these methods exists. ICAO however plans to consider the subject at the Conference on Airport and Route Facility Economics to be held in 1981.

Methods for reducing noise upon landing and take-off are currently either in force or being tested in order to reduce noise in the neighbourhood of the airport. According to ICAO, standard methods are difficult to formulate, since they depend on the type of aircraft, airline and airport.

In forthcoming years it would seem that efforts should first focus on the timetable for applying international regulations, particularly in regard to the retirement of uncertified aircraft, and then on the strengthening of international standards.

With regard to aircraft not complying with Annex 16 (Chapter 2), the ICAO is currently studying various possible timetables for taking them out of service or of modifying them to the required standards by 1st January, 1988.

Discussions are now taking place in ECAC (European Civil Aviation Conference) for scheduling the gradual retirement of non-complying aircraft. Generally speaking, the gradual withdrawal of non-complying aircraft is preferred to the alteration of existing models or engine replacement, which in most cases would appear to be a financially unacceptable solution.(2)

Harmonisation as regards airport operations and planning would appear to be very difficult owing to the variety of local conditions and the divergent interests of various groups of countries. In this field and in the short term, ICAO plans on merely partial recommendations.

The system of charging for noise made by aircraft as a complement to other noise abatement measures is now being spot tested, but in the next few years such a type of incentive policy may come into increasing use.(3)

What we may be sure of is that the greater the number of airports making use of such charge systems, the more efficient these will be. Moreover the methods of calculating and collecting the charges in airports should preferably be fairly similar without necessarily being uniform. (Charge rates, that is, amounts collected, need however by no means be the same: they should correspond to the specific needs of each airport.)

1) Report on Measures Adopted or Planned to Deal with Noise Problems at Airports, ICAO, 1978.

2) See Background Report No. 8, The Cost of Noise Abatement.

3) See Background Report No. 5, Noise Charges.

Hence in this respect there is ample room for international co-operation especially as joint research can but benefit all countries.

3.2 The Role of International Organisations

The roles of ICAO, ECAC and IATA will be considered in turn.

3.2.1 The International Civil Aviation Organisation (ICAO)

ICAO is a United Nations' agency, in which the governments of 145 countries are represented. This body, established owing to the problems of air transport policy, has proved a suitable forum for the discussion of environmental issues connected with this mode of transport. Noise-related activities are conducted by the CAN (Committee on Aircraft Noise), in which the 30 manufacturing countries are represented.

The role of ICAO is twofold: to deal with the technical as well as regulatory aspects of the questions dealt with. The technical aspects are handled through the CAN (which since 1971 periodically revises Annex 16 to the Convention on International Civil Aviation). ICAO also issues basic recommendations in Annex 16 which will usually later be adopted in various forms by each Member country.

The economic and financial difficulties stemming from application of these recommendations have led ICAO to consider dealing not only with the technical and regulatory aspects of limiting noise emissions, but also with the economic effects of application in each country.

3.2.2 The European Civil Aviation Conference (ECAC)

While representing the views of European countries, ECAC is not, strictly speaking, an international organisation. The 21 European countries are members. ICAO recommendations ultimately become the subject of ECAC recommendations. An EEC Directive on subsonic civil aircraft has been based on an ECAC recommendation. The essential role of ECAC, which is far less technical than the CAN, is to prepare recommendations as determined by the European countries' economic environment.

3.2.3 The International Air Transport Association (IATA)

Membership in this non-governmental organisation consists of representatives from many airlines. It has had considerably less impact since certain major airlines have ceased to be represented, and today its role in noise matters is attendance of ICAO discussions in an observer capacity. Its criteria are mainly of an economic kind, in view of the problem of financing the replacement of aircraft not complying with the ICAO regulations. It also takes technical action by regulating flight operations and landing procedures.

3.3 Areas of Further Harmonisation and Types of Action Required

The increased harmonisation of methods for reducing operational noise and noise in the vicinity of airports would appear desirable.

The use of different procedures specific to each country, as in regard to landing and take-off, presents certain drawbacks; thus the diversity of landing and take-off procedures calls for sustained attention on the part of the pilot and imposes an additional task. To harmonise these procedures, even partially, would seem well-advised.

The limiting of movements around airports and curfew measures interfere with operations and may prove very costly; however, harmonisation of these aspects would no doubt be unwarranted owing to the weight of local constraints and interests; it should merely be sufficient to ensure that such measures are compatible with each other so as to avoid any adverse effects on air traffic between countries.

A discussion on difficulties resulting from the application of different national noise-limiting measures would prove a useful step for promoting harmonisation in this field; such a discussion might be planned as part of the role which the ICAO appears to have assumed (see Section 3.2.1).

At the present time the strengthening of international aircraft noise emission limits is not regarded as economically desirable by the international organisations concerned(1). For some airports, however, the level of these limits is inadequate for protecting public health. It is moreover common knowledge that the time needed for new standards to improve the noise environment is some 10 to 15 years.(2) Hence the door should not be closed on future improvements and the prospect over the long term of stricter limits on an international scale.

This is because from a strictly technical standpoint present standards can indeed be reinforced, the technological threshold, i.e. the noise level produced by the aircraft passing through the air not yet having been reached. (In this regard it should be noted that improvement of the acoustic performance of aircraft has gone hand in hand with lower fuel consumption.) On the other hand, the resulting economic and financial problems would seem extremely significant,

1) Even if the revision of such standards were only to cover future-generation aircraft.

2) See Reducing Noise in OECD Countries, OECD, 1978; Background Report No. 1 The Present and Future State of the Noise Environment; and Background Report No. 5, Noise Charges.

judging by the difficulties involved in bringing existing aircraft into conformity with current standards. These difficulties are due to three main factors: the estimated lifetime of equipment, the financing capacity of airline companies and the production capacity of manufacturers.

- In-service lifetime: replacement of the fleet often creates a serious problem when aircraft have not reached the end of their estimated lifetime;
- The airlines' financing capacity varies, and the fact that some are government-controlled is not without influence on their financing capacity;
- Manufacturers' production capacity is another essential parameter to be taken into account, in order that the interests of the various countries may be represented when an acceptable solution for retiring non-complying aircraft is being sought.

Consideration of these factors at international level would be facilitated by assessing national needs in financing fleet conversion projects and especially the capacity for such financing.

Even though national problems may be involved, their evaluation and the search for solutions need not necessarily be at the national level and might be undertaken in some international organisation, which could help in reaching objective assessments.

Another field in which a common approach between countries would be desirable is the question of who should be designated as responsible for the noise pollution. In some countries, the airport authorities are regarded as having responsibility; in others it is the airline companies. It would be useful to harmonise the designation of responsibility, if only to facilitate compensation arrangements.

4. CONSTRUCTION EQUIPMENT AND HOUSEHOLD APPLIANCES

This is the field in which harmonisation at the international level is least advanced, the chief reasons being the wide variety of products, and the fact that the international implications of the widely varying regulatory positions concerning those products were not clearly perceived until very recently.

4.1 Present Harmonisation and Future Trends

At present there is no harmonisation at the international level of legislation concerning noise produced by construction equipment or household appliances, though some action has been taken through the setting of standards by the ISO and IEC, and through regulation within the EEC.

4.1.1 Construction Equipment

Methods of measuring the noise produced by such equipment are different in Europe and the United States: permissible sound levels are not harmonised in Europe and are not regulated in the United States.

In 1975, the EEC Commission submitted Directives to the Council of Ministers aimed at limiting noise from construction plant and equipment while ensuring its free circulation. The Directives envisage:

- the fixing and time-tabling of maximum permissible noise levels based on a harmonised measurement procedure;
- product-labelling by the manufacturer of the guaranteed noise level;
- a certification procedure (EEC type-approval or type-verification) laid down by the framework Directive on Construction Plant and Equipment;
- a Committee on Adaptation to Technical Progress.

The equipment to be covered consists of:

- pneumatic concrete breakers and jackhammers;
- compressors;
- current generators for power supply and welding;
- tower cranes.

In December 1978, a General Directive was adopted(1) on the approximation of the laws of the Member States relating to the determination of noise emission levels. It lays down that the noise emission of plant and equipment should be described in terms of sound power level. This method of measurement adopted is very largely identical to ISO Standard 4872.

In the United States the method of noise measurement differs from the ISO standard. An acceptable level has been set by the EPA(2), and construction equipment is accordingly labelled to show its sound quality, but the manufacturer is not necessarily compelled by regulation to ensure that the approved noise level is observed. The noise level of some newly manufactured types of construction equipment is currently regulated, however, and other types will be regulated in the future. Some types of regulated equipment may also be required to be labelled to show their noise emission levels. And other types of equipment are not necessarily excluded from potential labelling requirements irrespective of whether they are subject to noise emission regulation.

1) O.J.E.C. No. L 33, 8.2.79.

2) EPA Noise Control Program, US EPA, 1978.

4.1.2 Household appliances

No harmonisation of national legislation has yet been brought about. Some broad lines of policy are nonetheless apparent.

For the EEC countries, two types of approach are being considered, according to the state of the art and the market for the product:

i) prescribing methods of noise measurement and mandatory emission levels. Noise measurement methods would be based on ISO and IEC (International Electrotechnical Commission) standards, where available. Lawn-mowers would be the first appliances of this type(1) to be covered by approximated legislation, with an initial limit of 103 to 111 dBA (sound power level) to be reduced at a later date;

ii) promoting public information through labelling, to help consumers when choosing an appliance.

The United States has adopted the same principle as for construction equipment.

4.2 The Role of International Organisations

The international organisations responsible for standardisation of noise measurement methods are the International Standardisation Organisation (ISO) and the International Electrotechnical Commission (IEC). In addition, the European Economic Community (EEC) plays an important role in harmonising the legislation of Member States. With regard to the work of the EEC, the standards for noise measurement procedures established by the ISO or by the IEC (in cases specifically of electrical and electronic technology) are likely to be taken up either in the form of strict reference or by being adopted in a Directive.

4.3 Areas of Further Harmonisation and Types of Action Required

Further harmonisation of noise measurement procedures and labelling of construction equipment and household appliances appears desirable. The information about sound levels to be shown on current or proposed labelling is based on different measurement procedures (sound pressure level in the United States, sound power level in Europe), and this may cause difficulties for manufacturers and consumers alike.

Harmonisation of the sound characteristics of construction equipment is under way in Europe on a regulatory basis, along much the same lines as for motor vehicles and aircraft. In the United States, the EPA has opted to combine regulation with an approach relying on market forces.

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1) Sometimes classed otherwise than as household appliances.

The absence of national regulations for many types of appliance means that harmonisation at the international level can be considered at the outset without having to adjust systems that have already been established, unlike the case of cars, for instance, where European and Japanese regulations are hard to reconcile with those of the United States.

With a view to improving the sound characteristics of appliances, the advisability of backing some particular policy at the international level might be assessed by analysing the results of labelling systems now in use and the regulations adopted by the EEC for construction equipment in terms of impact on sound characteristics, markets, employment and competition.

5. CONCLUSIONS AND PROPOSALS

5.1 Present Trends in International Harmonisation of Noise Abatement Policies

The forum for discussing the international harmonisation of regulations governing aircraft is currently the ICAO, and the forum for motor vehicles is currently the ECE. At present no world-wide international organisation acts as a forum for the discussion of household appliances or construction equipment.

The EEC plays a decisive role in harmonising the national legislations of the nine Member States. The ISO is concerned with technical matters and purely with setting standards.

In the short term aircraft will probably continue to be the main target of international harmonisation of noise abatement policy; while the USA and European countries are working together on a common standard for the measurement of motor car noise. The procedures for measuring noise from other motor vehicles (lorries, motorcycles) and from construction equipment and household appliances will however take longer to harmonise.

Specific action now in hand or likely to be taken shortly at the international level is listed below.

For motor vehicles:

i) efforts by the EEC countries, Japan and the United States to devise a common procedure for measuring car noise;(1)

ii) reduction in the maximum permissible noise emission levels currently in force in the EEC countries, the United States and Japan.(2)

1) See Section 2.1.1 (it should be noted that the regulations likely to be established in the United States on vehicle noise emission constitute a favourable factor for the future harmonisation of procedures).

2) See Sections 2.1.1, 2.1.2, and 2.1.3.

For aircraft:

i) existing civil sub-sonic aircraft to be brought into conformity by 1st January, 1988 with the emission standards in Chapter 2 of Annex 16 to the Civil Aviation Convention;

ii) specifications for supersonic aircraft to be devised by the ICAO;

iii) preparation of ICAO recommendations for harmonising noise abatement policies concerning in-flight operations.

For construction equipment and household appliances:

i) development in the EEC countries of regulations on household appliances of the same type as in the United States, with particular reference to product labelling so that consumers can consider sound characteristics when choosing an appliance;(1)

ii) introduction of standardised measurement procedures and noise emission limits for certain construction machinery in the EEC countries. Unlike the policy with regard to household appliances, in this area the European countries have opted for mandatory noise limits.(2)

5.2 Proposals

In the light of the foregoing, the following general guidelines may be proposed:

i) the purpose of international harmonisation and co-operation should not solely be to achieve trade advantages. Such harmonisation and co-operation should equally aim at protecting the environment, in the present instance to endeavour at international level to improve the noise environment;

ii) harmonisation should not mean falling back on the lowest common denominator;

iii) harmonisation should be dynamic, i.e. it should help to promote steady progress. In this respect it is most desirable to fix in advance a timetable for gradually strengthening noise emission limits, harmonised at the international level, (in accordance with the OECD Recommendation on the Guiding Principles concerning International Economic Aspects of Environmental Policies). (3)

1) See Section 4.1.2.

2) See Section 4.1.1.

3) C(72)128.

A number of more specific proposals may also be made:

i) standardisation of measurement procedures for motor vehicle noise, in particular between Europe, Japan and the United States;

ii) harmonisation of standards applicable to construction equipment and household appliances (new models);

iii) promotion and harmonisation, at international level, of sound labelling systems for noisy products and equipment;

iv) inclusion in product standards of specifications regarding the lifetime of noise abatement devices (for instance, car exhaust pipes or insulating material);

v) international co-operation through regular exchanges of experience and information and regular appraisal of the costs and effectiveness of noise abatement strategies.

5.2.1 Comparative Evaluation of Noise Abatement Policies

The various possible forms of harmonisation are currently being compared and evaluated at national level but, with the exception of aircraft, the matter is not really being dealt with in an international forum. Devising a practical methodology for studying the potential impact of a harmonisation project on the environment and economy of the countries involved would clear the way for international comparisons, which cannot readily be made at present. The methodology could be used for studying the international impact (before and after the event) of stricter noise abatement regulations in a given country, and for studying national policies (charges, tax incentives) meeting the aims of international harmonisation.

5.2.2 Economic Benefits of Harmonisation and Co-operation

Harmonisation and co-operation in the field of noise abatement policies is here understood to mean not the standardisation of national legislation but a policy of approximating such legislation to produce similar effects under similar circumstances.

Noise abatement policies, as those in other fields, must be harmonised if the aim is to facilitate free trade. Removal of non-tariff barriers thus brings a number of economic benefits, including:

i) removal of quantitative restrictions on trade;

ii) avoidance of higher costs which producers would otherwise incur in complying with different sets of standards (economies of scale through standardised production);

iii) smaller risk and uncertainty in export and import transactions;

iv) fewer delays caused by checks on product specification.

PART III

(Technical Annex)

THE COST OF NOISE ABATEMENT :
A COMPREHENSIVE STUDY

PAGE N°

CONTENTS

INTRODUCTION

This report has been written as a background report for the OECD Conference on Noise Abatement Policies (7-9 May, 1980).

It is mainly based on a special study sponsored by the Dutch Ministry of Environment and done by J. Crayston and S.P.C. Plowden from Metra Consulting Group. The French Ministry of Environment also sponsored some research as an input to this study. Many governmental and private organisations, in various Member countries, have helped by providing data and comments. Professor D.W. Pearce of Aberdeen University was also actively involved in this study. Full references to sources are given in the text.

The report examines the available data on the costs, and cost effectiveness, of measures concerning the abatement of road traffic noise, aircraft noise and industrial noise.

Noise abatement is a large subject with a correspondingly large literature which is constantly developing. It is inevitable that a review of it will miss some relevant material, particularly more recent publications, and even when the sources are the best available at the time of writing they may be superseded at any moment. But although one cannot therefore claim that this report is completely comprehensive or up-to-date, it is believed that it gives a good idea of the more promising lines of attack on noise and of their costs.

The report is arranged in three parts :

Part A : Road Traffic Noise
Part B : Aircraft Noise
Part C : Industrial Noise

Each part is a self-contained report (with the exception of a few cross-references), and has its own index, appendices and reference lists.

This report is issued by the OECD Secretariat.

PART A : ROAD TRAFFIC NOISE

CONTENTS

1. MEASUREMENT

Noise abatement means the reduction of noise nuisance; any report to do with noise abatement must therefore start by saying something about how noise nuisance is measured. It would be beyond the scope of this report to go into detail on this vast subject; all we have attempted to do is to show how the limitations of current methods make it difficult to evaluate the cost effectiveness of alternative strategies for abating road traffic noise and can even sometimes give a misleading impression as to the efficiency of a particular measure.

1.1 Measuring Single Moments of Noise

Measurements of single moments of noise are not often of direct use except in specifying the maximum noise that can be tolerated in given circumstances. But all more elaborate measurements of nuisance are constructed in some way from measurements of noise at single moments. The unit universally used for road traffic is dB(A). This unit systematically underweights low frequency noise in comparison with the unweighted decibel unit. The weightings were devised in the first place in order to produce a scale which would correlate better than the unweighted unit with subjective impressions of loudness. But loudness is not the same as annoyance and there is evidence that low frequency noise, infra-sound and the vibration associated with them can be particularly annoying.

The remedy is to supplement the dB(A) measurements in appropriate contexts with dB(C) measurements or other measurements which relate particularly to low frequency.[1] In the meantime, it is important to be aware of the possible distorting effects of working exclusively in terms of dB(A).

i) Insufficient attention may be paid to reducing the nuisance caused by vehicles which emit low frequency noises. There is, however, little present risk of this consequence, since the existing types of the vehicles concerned, buses and large lorries, show up badly even when assessed by measurements based on dB(A).

ii) Inappropriate ways of modifying vehicles in order to cope with noise may be sought. For example, it might be possible to design a lorry which emitted less noise in terms of dB(A) than present lorries, not because it produced less sound energy in total but because it produced less sound energy at high frequencies and more at low. The nuisance would not be diminished and might increase.

iii) An exaggerated impression of the protection given by the distance between the source and the receiver and by the insulation of buildings may be created, since in each case the attenuation affects low frequency noise much less than high.(1)

1.2 Measurement of Noise Over a Period

For many purposes it is necessary to be able to measure the noise experienced at a given point over a certain period of time. One way of proceeding, which is in fact the only way now adopted for road traffic, is to measure the noise continuously over the period, or alternatively at a large number of moments within it, in terms of decibels, and hence to derive a frequency distribution of decibel measurements related to that period. It is then possible to select a parameter of the frequency distribution, or to construct an index out of several parameters, to produce a single index figure of the noise at the point of measurement during the period in question.

One such index is Leq and it is now accepted in OECD countries that the trend towards the use of Leq as the measurement of noise over a period should be encouraged.(2) The most important test of an index is that its values should correlate well with scores on annoyance scales in social surveys carried out among people exposed to noise. Leq appears as good by this test as other possible indices such as L_{10}(3) and the fact that it is widely used internationally for noise from various sources, not from road traffic only, commends it.

Nevertheless, certain other indices are likely to survive for some time. In the USA a modified version of Leq called the day-night sound level has been constructed so as to give more weight to noise occurring between 10.00pm and 7.00am.(4) In Sweden, another corrected version of Leq has been constructed to allow more weight to evening noise (6.00pm to 11.00pm) than to daytime noise and more weight still to noise at night (11.00pm to 6.00am). L_1 is used in France (5) and Switzerland[6] for noise in the evening or at night. In Britain, the use of L_{10} is stipulated by law for purposes of calculating whether insulation grants are payable for traffic noise resulting from the use of newly constructed roads. With insular eccentricity, the calculations are based on the noise levels in each hour between 6.00am and midnight rather than the complete 24 hours.[7]

There are two problems in the use of such an index, whichever one is chosen.

i) Work to validate indices against social survey annoyance scores has been confined to residential situations. However, there is good evidence from Britain[8] that more people are annoyed by noise when out on foot in their local area than when at home. The figures, taken from a survey conducted in 1972 based on a large representative national sample, are shown in the following table.

TABLE 1.1 : PEOPLE BOTHERED BY TRAFFIC NOISE AT HOME AND OUT IN THEIR AREAS

Bothered	Traffic Noise	
	At Home	Out in Area
Very much	2%	5%
Quite a lot	7%	11%
Not very much	40%	38%
Not at all	50%	46%

This relative order was found again in answers to another question in which people were asked to make a direct comparison between the extent to which they were bothered by the noise when at home or when outside, to which the answers were as shown in Table 1.2.

TABLE 1.2 : DIRECT COMPARISON BETWEEN TRAFFIC NOISE AT HOME AND OUTSIDE THE HOME

	People bothered by traffic noise
More at home than out	22%
More out than at home	37%
In both situations equally	6%
In neither	35%

(ii) Most of the work on validating noise in the residential situation has concentrated on noise from freely flowing traffic. There is evidence that noise indices which work well in this situation do not necessarily also work in congested conditions. A recent British study[9] suggests that in congested conditions the proportion of heavy vehicles in the traffic stream is a better indicator of annoyance than either L_{10} or Leq. Yet another type of traffic situation, where traffic is slight and annoyance is related to intermittent noises, has so far scarcely been studied. Although this is not the most severe situation, it is the one which is experienced by the greatest number of people. There are no grounds for supposing that the existing indices are suitable in these conditions; indeed the British national environmental survey mentioned above shows that some of the traffic noises that annoy people at home are of a type that would hardly be represented in the usual indices, with the possible exception of L_1. Table 1.3 presents the results.

TABLE 1.3 : THE TYPES OF ROAD TRAFFIC NOISE THAT BOTHER PEOPLE

Type of Noise	People Bothered	
	At all	Very much or quite a lot
General traffic noise	18%	9%
Starting, gear changing	21%	10%
Motor cycles	26%	15%
Lorries	22%	12%
Car doors slamming	20%	9%
Car horns	13%	6%
Brake, tyre squeal	22%	13%

Research in Sweden[10] also indicates the importance of isolated incidents, particularly lorries passing, in causing annoyance.

This discussion suggests the following practical conclusions:

(a) Insufficient attention may have been given to the abatement of road traffic noise in general (since this noise is resented even in situations to which little attention has been paid).

(b) Although the priority given by most governments to alleviating the worst instances of residential noise is probably right, and although insulation may often be the only suitable way, the possibilities of using other methods which would reduce noise nuisance outside the home as well as inside should always be thoroughly examined before deciding on insulation.

(c) To deal with intermittent noise requires not only the intensification of efforts which are needed anyway to make moving vehicles quieter or to remove particularly offensive vehicles from unsuitable streets, but also that attention should be given to other types of measure which have so far been neglected. Such measures would be directed at the noise vehicles make when starting, parking, manoeuvring, etc., and would include:

- improvements to starter motors;

- changes in the design of doors to reduce the need to slam them and to make them less noisy when they are slammed;

- making horns quieter, at least when vehicles are travelling at low speeds.

We have seen no discussion of the costs of such improvements, but prima facie, it is unlikely that they would be expensive.

1.3 Measures of Community Annoyance

Given that each point in the reception area of some noise source can be allotted an Leq (or other index) value to show how noisy it was there during a certain period, it is a simple extension to produce a noise map for that area with contour lines joining points of the same index value. Hence it is possible to count the number of dwellings, households, persons or other such entities within each contour band. The next problem is to construct a measure of community annoyance so as to be able to compare states such as those shown in the following table in order to decide which deserves priority for abatement.

TABLE 1.4 : NOISE FROM FREELY FLOWING TRAFFIC EXPERIENCED AT HOME IN THE DAYTIME

Units : People

Contour Bands of Index I	State One	State Two
less than 50	20,000	17,000
50 - 59	7,000	9,000
60 - 69	8,000	10,500
70 or over	2,000	500
TOTAL	37,000	37,000

NOTE: These figures are chosen arbitrarily to illustrate the point in the text.

One way of comparing such states is to allocate a weight to each contour band so that a weighted sum of the numbers of people affected can be produced. But even if a non-arbitrary weighting system could be found, this solves the problem only for a given type of situation. In order to consider such questions as whether a noise abatement programme should pay more attention to noise at night or during the day, or to noise at home rather than noise in the streets, some way of comparing the different situations must be found. Even if the same index, such as Leq, can be applied to the various situations, it does not follow that a certain value on the index has the same significance in them all. Indeed it is known that a given Leq value is not so serious for traffic noise heard by residents in the daytime as at night. It was seen above that modifications of the Leq index to take account of the extra nuisance of night noise have been introduced in some countries; evidence from various countries confirms the underlying point that noise is more resented at night[11, 12, 3].

The ideal way to solve this problem would be to have monetary values, representing the nuisance caused by noise, to apply to people in each band of index values; the monetary value applicable to a given band could vary according to the type of situation. Not only would one then be able to compare different situations to determine priorities for abatement, but it would also be easier to decide, other than by political judgement as at present, what resources society should devote to noise abatement in general vis-a-vis other desirable ends. Although monetary values for aircraft noise nuisance have been estimated and used in some airport studies, there is still disagreement about the principles of measurement as well as about the particular figures that have been suggested[13]. The study of monetary values related to road traffic noise is even less advanced.

The lack of measures of community annoyance, whether monetary or other, limits the extent to which one can compare the cost-effectiveness of noise abatement policies. If the policies are very specific measures which would act in a similar way, e.g. two different ways of quietening a given type of lorry, there is no need to introduce the concept of community annoyance. But if we were comparing different types of policy (such as action on the vehicle as compared with traffic restraint) or entire noise abatement strategies, measures of community annoyance are required. In their absence, the search for and justification of appropriate policies inevitably lacks rigour. Nevertheless, as will be seen below, some elements of a rational strategy for the abatement of road traffic noise can be identified with fair confidence.

2. PREDICTION

2.1 The Need

If one prerequisite of a noise abatement strategy is to have a way of measuring noise annoyance, another is to be able to predict how the values of appropriate indices would change as a consequence of any proposed means of noise abatement. Partly this is a technical problem within the field of acoustics, involving questions such as the following:

- if the noise of a particular vehicle component is changed, what will the effect be on the noise emitted by that vehicle at different speeds?

- what would be the effect on the total noise emitted by a certain type of road vehicle, travelling on a given road surface at a given speed, of reductions in power train noise unaccompanied by any reduction in rolling noise?

- how is the noise emitted by a given stream of traffic affected by characteristics of the road and the traffic stream such as gradient, road surface, traffic volume, traffic speed, proportion of heavy vehicles?

- what is the relationship between noise levels at the roadside and those some distance from it given the nature of any intervening screens, buildings or vegetation?

- what is the relationship between noise levels immediately outside a building and those within it having regard to the type of walls, windows and other features of the construction?

Expert opinion is that the technical acoustical problems are solved, at any rate for the noise indices most commonly used such as Leq and L_{10}. The values of indices such as L_1 which might be suitable for measuring the nuisance caused by intermittent noise are extremely hard to predict as a function of traffic conditions. This difficulty in prediction is, indeed, one reason why the study of such situations has been relatively neglected. But in order to predict the effect of any proposed action in reducing community annoyance, it is also necessary to know the number of people within the area that would be affected who are exposed to noise of various degrees. If the action being assessed is inherently local in its effects, such as the erection of a screen, such information can be obtained by an ad hoc count. But if it is one with widespread effects, such as the reduction of the noise emitted by all vehicles of a certain type, large-scale social surveys, preferably repeated at regular intervals, are required to obtain the necessary information about exposure: such surveys would have to distinguish between and deal separately with the various types of noise situation described in Section 1. We have not found any surveys which fully meet the requirements. Those that have been done are limited to residential situations, and sometimes only to residential situations alongside main roads where conditions are expected to be particularly severe. This is appropriate for the immediate task of implementing statutory schemes designed to give protection to those entitled to it, or for calculating what the cost of such schemes might be, but may be misleading in planning a wider noise abatement strategy.

The need for systematic methods of predicting the effects of alternative means of noise abatement is illustrated by the relative neglect of noise from cars. It seems to have been assumed that since individual cars offend much less severely than individual lorries, buses or motorcycles, there was little point in doing anything about the car category as a whole. This reasoning sounds plausible in the absence of a predictive model, but it ignores the fact that cars account for a very high proportion of total traffic, especially on certain types of road, such as residential streets, on which quiet conditions may be particularly desirable. A study by the British Transport and Road Research Laboratory, which used a model relating roadside traffic noise to the composition and other characteristics of the traffic stream, concluded as follows:

"It seems therefore that while reducing lorry noise should bring worthwhile reductions of noise on the busiest roads, reductions of noise from both cars and lorries are needed if any general benefit is to be experienced. A further calculation indicated that whatever vehicle quietening may be undertaken, traffic noise wil hardly be reduced until the quiet vehicles have replaced at least 50 per cent of the existing vehicles. This report therefore has shown the need for including in the present programmes of research into quieter vehicle development an urgent programme to reduce the noise emitted by the car category"[14]. (See Table 3.1 below for some supporting figures ultimately derived from this report.)

Although the report was published in 1974, and this conclusion should apply to other OECD countries as much as to Britain, it seems to have had little influence on the noise abatement programme of any country.

2.2 Test Procedures

A particular question relating to prediction concerns the relationship between the noise vehicles emit under controlled test conditions and the noise they are likely to emit in everyday use. Manufacturers have especially criticised the ISO procedures for testing cars, which are virtually identical with the procedures prescribed by law in EEC countries. They have argued that these procedures are not designed to reproduce the urban conditions in which vehicles will mostly be used or, at least, in which their use is likely to cause most nuisance. The danger is a double one, that too much attention will be paid to measures which will enable a vehicle to pass the test but have little relevance to the real life situation, while too little is paid to measures that would help in real life but not in the test. A 1973 report by Renault[15] makes the point that the ISO test produces a bias against more powerful cars vis-a-vis popular cars: for example, superior American cars would perform badly on this test although they are acknowledged to be particularly quiet in urban conditions. This criticism is repeated in a very recent article[16] by an author from Renault which concludes that the ISO R362 regulation is ineffective in that it permits the use of large numbers of poorly soundproofed vehicles (the smaller popular cars) and is at the same time extravagant in that it forces larger cars to be excessively soundproofed. The same point is made in an article published in 1977[17] by an author from Opel who states "...with this test procedure we will achieve with great costs technical development in the wrong direction. Years later we would realise that we failed our goal in general noise reduction...".

The CCMC has a working group which is studying various possible changes to the ISO test, designed to remedy these alleged defects.

Other experts, however, while accepting the point that present procedures would be unfair to the larger American cars, believe that otherwise the present ISO procedures are well suited to the purpose of type testing.

3. QUIETER VEHICLES

This section discusses the possibilities of reducing noise by making the vehicles themselves quieter. The section is not concerned, however, with rolling noise - the noise that a vehicle would make when coasting with the gears disengaged - but only with power train noise. Since rolling noise is almost entirely due to the interaction of the tyre and the road surface, and can be altered by action on either of those elements, it is convenient to discuss it separately (see Section 4 below).

3.1 Lorries

3.1.1 The Importance of Lorry Noise

With the possible exception of motorcycles when poorly maintained and inconsiderately used, lorries are the noisiest vehicles on the roads. Current EEC regulations permit the heaviest lorries to emit 91 dB(A) on the ISO test; this will be changed to 88 dB(A) in 1980. These ratings are respectively 2 dB(A) and 6 dB(A) more than those for buses and 9 dB(A) and 8 dB(A) more than those for cars. As well as being noisy individually, lorries constitute a significant proportion of the traffic flow; their contribution to traffic noise levels is therefore very great. The reductions in noise level that would be brought about by quietening lorries have been calculated by the Transport and Road Research Laboratory and are shown in Table 3.1. The first number in each space shows the reduction in noise level if all lorries were quietened by 10 dB(A) while nothing was done about cars and the number in brackets shows the reduction that would arise from quietening all lorries by 10 dB(A) and all cars by 5 dB(A). A single carriageway two-lane road is assumed and an observation point ten metres from the roadside with grassland in between.

TABLE 3.1 : REDUCTIONS IN L_{10} (dB(A)) THAT WOULD FOLLOW FROM REDUCTIONS IN THE NOISE OF INDIVIDUAL VEHICLES

Flow (vehicles per hour)	Percentage of lorries (4 tonnes gross vehicle weight) in the flow			
	10%	20%	40%	80%
200	1.4 (5.6)	2.5 (6.3)	4.5 (7.3)	8.4 (9.3)
400	1.4 (5.6)	2.5 (6.4)	5.1 (7.9)	8.8 (9.6)
800	1.5 (5.9)	3.1 (7.0)	5.9 (8.8)	9.0 (9.8)
1500	2.0 (6.4)	4.2 (7.8)	6.3 (9.1)	9.0 (9.8)

SOURCE: "A Quiet Heavy Lorry", article by L.H. Watkins of TRRL, reprinted from Commercial Motor, March 22, 1974

In addition to their effect on noise levels, lorries are often the cause of particular incidents of noise nuisance which, as noted in Section 1, cause considerable annoyance.

There would therefore be great benefits in reducing lorry noise. At the same time, it is argued in Section 6 that, apart from the technical problems of quietening lorries and the time it would take for the majority of existing lorries to be replaced by quiet ones, it is fallacious to think that the problem of lorry nuisance in towns can be solved simply by making the lorries quiet: restraint of lorry use will also be required.

3.1.2 Sources of Noise and Means of Reduction

Table 3.2 shows the classification commonly used for the component-sources and, within each source the noise-emitting parts, of heavy goods vehicles. None of the items listed under "others" is relevant so long as the attempted reduction in noise emission does not exceed about 10 dB(A). Since power train noise, in effect made up of the first five items on the list, dominates rolling noise of lorries at present in almost all operating conditions, it is there that most reductions should be sought. Even if power train noise could be reduced to 80 dB(A) under the ISO test, which is on a dry surface and involves speeds of 40 to 50 km/h, rolling noise would have little significance in the conditions of that test. But on wet surfaces at such speeds, or on dry surfaces at higher speeds, it would be of comparable importance to power train noise.

Within power train noise, noise from the transmission makes only a small contribution. The means of reducing noise from the other four component-sources making up power train noise will now be discussed; the information in the following paragraphs is drawn primarily from a paper by Mr. J.W. Tyler of the Transport and Road Research Laboratory[18].

An engine produces noise because various pieces within it cause the surface of the engine structure to vibrate. There are therefore three broad ways in which the problem of quietening engines can be tackled: by reducing the forces, by reducing the vibrational response of the structure to them and by encapsulating the vibrating structure in a noise-isolating enclosure. The predominant noise from diesel engines is produced by the rapid rise in cylinder pressure following combustion; secondary mechanical sources are the pistons and fuel injection systems. Turbocharging an engine smooths out the abrupt rise in cylinder pressure and thus reduces noise.

TABLE 3.2 : SOURCES OF NOISE IN HEAVY GOODS VEHICLES

No.	Component -Sources	Noise-Emitting Parts
1	Engine	Oil sump, sides of engine block, manifold and supercharging unit, valve cover, front of engine, cover of distributor housing
2	Air Inlet	Inlet opening
3	Exhaust System	Exhaust opening, exhaust pipe and silencers
4	Cooling System	Fan, drive, water pump, radiator with wind tunnel
5	Transmission	Gearbox, differential
6	Tyres	Tyre profile (interacting with road surface)
7	Others	Auxiliary units (e.g. fuel pump), coachwork and chassis, air brake, drop sides, etc.

SOURCE: "Feasibility study into the design of quieter goods vehicles". Study programme of the Interdepartmental Commission on the Abatement of Noise, Report No. VL-HR-04-01. Minsterie van Volksgezondheid en Milieuhygiene, 1977.

But apart from turbocharging, which is already a common practice, there is little that can be done to reduce the forces within the engine without reducing power and increasing fuel consumption. The vibrational response of the structure can be reduced by redesigning the engine cylinder block and the crankcase in order to stiffen them; this method has already been used in some developments of quieter vehicles and is still the subject of research. Most has been achieved through encapsulation, although it introduces difficulties of weight, access for maintenance and the cooling of engine and ancillaries.

The main method of controlling noise from the air inlet and the exhaust system is to fit larger silencers, which can be a problem on the tractor unit of an articulated lorry where space is limited. The characteristics and timing of the valves are also important: reductions of 10 to 15 dB(A) can be achieved by attention to the exhaust valves.

Noise from the cooling system is mostly caused by the working of the fan, which can produce noise levels exceeding 90 dB(A) at 7.5 metres. The amount of noise produced is determined by the speed of rotation of the fan tip. Means of reduction are to design more aerodynamically efficient cooling systems, which involve lower fan speeds and close-fitting shrouds, and to use thermostatically controlled fans or other devices which ensure that the fan is used only when required.

3.1.3 The American Quiet Truck Programme

Since 1972 the Department of Transportation in the United States has been sponsoring a research programme on the reduction of lorry noise through changes in the vehicle.

Three major lorry manufacturers, Freightliner Corporation, the International Harvester Corporation and the White Motor Company, have been involved as contractors with numerous subcontractors. The programme has involved not only the development of quiet lorries but also their use in circumstances which would allow problems in operation and the reactions of operators, drivers and mechanics to be determined. The quietest lorry, with a noise rating roughly equivalent to 78 dB(A)* on the ISO test, was produced by Freightliner, but the company warns that although it has demonstrated "that it is possible to build and operate a heavy-duty diesel powered truck having a noise rating of 78 dB(A), these findings do not establish that it is possible to build all heavy-duty trucks to 81 dB(A)".(19) It was estimated on the basis of the tests that the increase in the price of a new lorry rating 81 dB(A), as compared with an unquietened version rating 94 dB(A), would be about 5%. Fuel costs would go down because of improvements to the fan, but maintenance costs would increase, owing mainly to increased problems of access. The net effect on annual cost would therefore depend on the method of use of the lorry: it was estimated that for a lorry engaged in general cargo haulage, annual costs would be reduced by 0.1%, but for one engaged on bulk haulage they would increase by 1.4% (19, 20).

In March, 1976 the Environmental Protection Agency published (21) estimates of the changes in cost that would arise from the measures required to meet different noise levels envisaged as Federal standards. These estimates draw heavily on the result of the Quiet Truck Programme, although the EPA's calculations and costs are not totally accepted by American lorry manufacturers including the main contractors for the programme (22). It is not possible for us to evaluate the truth and force of the various criticisms. The figures regarded by the EPA, on several grounds, as the most conservative or "worst case" are presented in Table 3.4. Table 3.3 shows some of the data used in arriving at the figures. Further assumptions used in the calculation of the change in net present value were that the average life of lorries was ten years and the rate of return on capital before taxes was 10%. It will be seen that the calculations cover petrol-driven lorries as well as diesels. Petrol-driven lorries still constitute the substantial majority of medium-sized lorries in the U.S.A. and a large minority of large lorries; this would not be true of most other OECD countries. Results are quoted both with and without the fuel savings which the use of more efficient fans, fan clutches and exhaust gas seals would produce. At present, relatively few American lorries are fitted with such equipment, but the rising price of fuel is likely to increase the demand for it irrespective of any noise regulations.

*Throughout this section American test numbers have been converted to ISO equivalents by the addition of 6 dB(A).

An item not mentioned by EPA in the source document is the loss of revenue arising from the reduced payload of a lorry due to an increase in its own weight. According to Freightliner,(22) the extra weight of the heavy diesel to meet the 81 dB(A) regulation would be 320 kg. and the subsequent loss in revenue for a bulk haulier would be $1,000 annually (1973 prices). This is presumably the worst case, involving both the heaviest vehicle and maximum use. There is also a danger of double counting if both the fuel penalty and the loss in payload of a vehicle arising from its increased weight are included. We cannot tell from the document whether this danger has been avoided or not.

TABLE 3.3 : DATA FOR THE EPA COST CALCULATIONS

Type of lorry	Average $ Price of vehicle (1973 prices)	Km. per year per vehicle	Fuel Cost $ per litre (1973 prices)
Medium petrol	5,836	16,000	.11
Heavy petrol	11,613	28,800	.11
Medium diesel	7,360	33,600	.066
Heavy diesel	25,608	86,400	.066

SOURCE: Reference 21, Tables 6.4, 6.13

3.1.4 The British Quiet Heavy Lorry Project

A government sponsored project to produce a lorry emitting 80 dB(A) by the British Standard BS 3425 (very closely comparable to the ISO test), and being at least 10 dB(A) quieter than the current vehicles under all normal operating conditions, was launched in 1972. The organisations involved were the Transport and Road Research Laboratory, the Institute of Sound and Vibration Research, the Motor Industry Research Association, British Leyland, Foden and Rolls-Royce Motors. By 1979 a demonstration vehicle, i.e. a fully engineered practical vehicle capable of serving as a prototype for commercial production, had been produced which achieved the project target of 80 dB(A). An official project report with cost information is expected early in 1980. According to

TABLE 3.4 : EXTRA COSTS PER LORRY OF IMPLEMENTATION OF ANTI-NOISE MEASURES

Units: $ 1973 prices

Increases in:	Type of Lorry	Permitted Noise Levels dB(A)			
		89	86	84	81
Price of new lorry - actual	Medium Petrol	35	180	330	665
	Heavy Petrol	135	280	480	815
	Medium Diesel	426	865	1059	1624
	Heavy Diesel	387	715	976	1454
- as % of former price	Medium Petrol	0.6%	3.1%	5.6%	11.4%
	Heavy Petrol	1.2%	2.4%	4.1%	7.9%
	Medium Diesel	5.8%	11.8%	14.4%	22.1%
	Heavy Diesel	1.5%	2.8%	3.8%	5.7%
Fuel, allowing for improved fan etc. (annual costs)	Medium Petrol	(44)	(78)	(104)	(102)
	Heavy Petrol	(256)	(255)	(255)	(251)
	Medium Disel	(59)	(121)	(138)	(135)
	Heavy Diesel	(238)	(233)	(230)	(201)
Fuel, not allowing for improved fan etc. (annual costs)	Medium Petrol	0	1	1	3
	Heavy Petrol	1	2	2	6
	Medium Diesel	2	6	6	10
	Heavy Diesel		10	12	41
Maintenance, (annual costs)	Medium Petrol	9	19	91	98
	Heavy Petrol	19	38	110	136
	Medium Diesel	(6)	25	195	277
	Heavy Diesel	(20)	32	85	180
Present value of total changes allowing for improved fan etc.	Medium Petrol	(283)	(365)	7	402
	Heavy Petrol	(1594)	(1333)	(690)	(162)
	Medium Diesel	33	286	1422	2512
	Heavy Diesel	(1169)	(489)	111	1346
Present value of total changes not allowing for improved fan etc.	Medium Petrol	80	280	848	1243
	Heavy Petrol	149	403	970	1494
	Medium Diesel	724	1373	2475	3595
	Heavy Diesel	511	1180	1729	3015

NOTE: Figures in brackets denote savings

SOURCE: Reference 21, Tables 6.1, 6.4, 6.14, 6.15, 6.17, 6.22, 6.23

press reports (The Times, November 23, 1978) the extra cost of a 38-ton vehicle would be approximately £2,000 ($4,000) or about 10% of the capital cost; we understand, however, that this may be pessimistic and that the extra capital cost may turn out to be about 8%. Because the noise reduction is achieved by a substantial redesign of the engine, not by encapsulation alone, fuel consumption is not increased. No increase in maintnenance costs is expected(23).

3.1.5 Research in Other Countries

The only other country that has completed an officially sponsored research and development programme to produce quieter lorries appears to be Japan. In 1974 the Ministry of International Trade and Industry launched a three-year programme involving four manufacturers of heavy lorries and buses. The objective was less ambitious than the American and British ones: to achieve a rating of not more than 86 dB(A) on the ISO test, which is the level due to come into force in Japan in 1979. Three experimental lorries and one bus achieving this standard were produced: the source document does not reveal the costs(24).

In Sweden, both Volvo and Saab-Scania have worked on the reduction of lorry noise. In 1972 Volvo estimated that within the existing manufacturing constraints it would be possible to produce a large lorry emitting 86 dB(A) and a medium-sized one emitting 84 dB(A), a reduction of some 5 dB(A) in each case as compared with vehicles then being produced. This could be achieved by means of sound absorption material within the engine compartment, shielding the sides and the bottom of the engine, a new silencer on the exhaust and a better cooling system to compensate for the shielding. It was estimated in 1972 that the extra capital cost per lorry would amount to 4,000 Crowns (1978 US $1,465) if the modifications were made only on vehicles for the Swedish market and 2,300 Crowns (1978 US $ 840) if made on all vehicles. An increase of 2,300 Crowns would have been equivalent at that time to somewhere between 1.5% and 3% of the price of a new lorry, depending on its size. Volve also estimated that the weight penalty would have been 60kg. and that difficulties of access to the engine would have added 1,000 Crowns annually to maintenance costs (1978 US $ 366)[25]. Saab-Scania's estimates were not quoted in such a precise form but appear to be broadly in line with Volvo's. But neither company is at present contemplating building vehicles quieter than stipulated by the new EEC regulations.

A German source[26] for lorries of under 3.5 tonnes gives the following estimates (Table 3.5) for the capital cost of noise reduction.

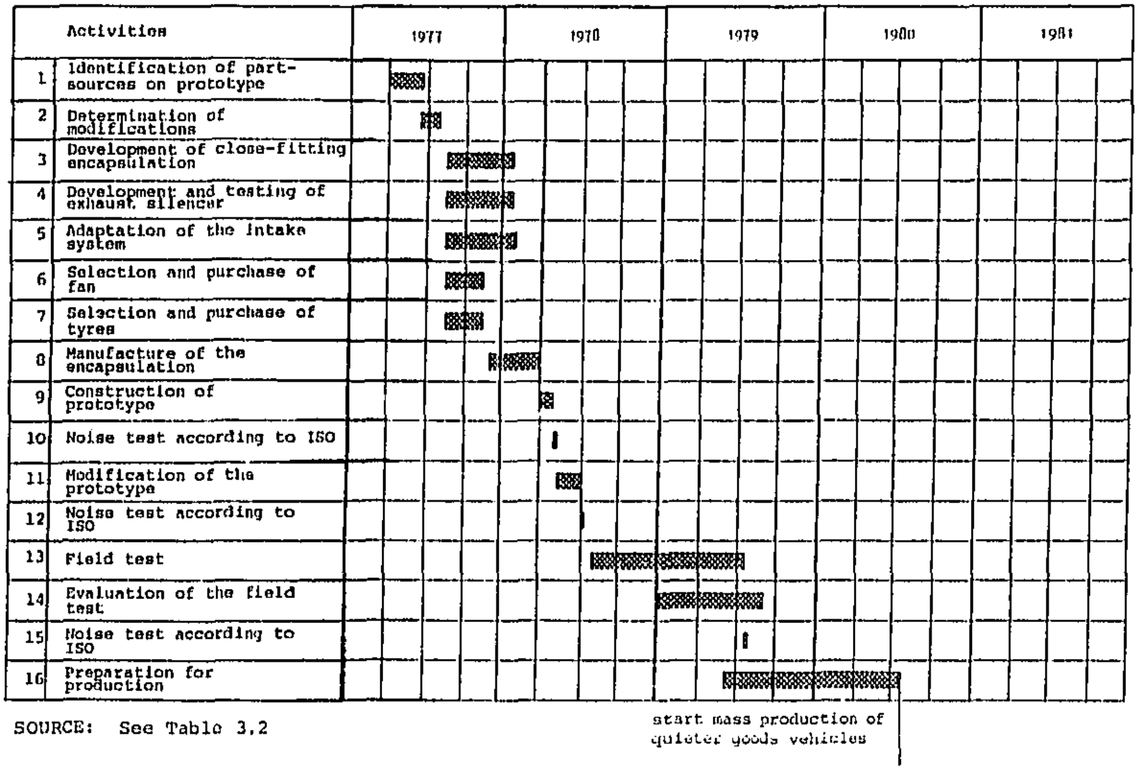
TABLE 3.5 : SOME RECENT GERMAN ESTIMATES

Lorry Type	Extra capital cost DM, 1975	Equivalent $, 1978	dB(A) Reduction
Petrol lorry type 1	720	375	2-3
Petrol lorry type 2	450	235	2-3
Petrol lorry type 3	620	325	4
Diesel lorry type 1	880	460	4
Diesel lorry type 2	920	480	4

NOTE: For reasons of commercial confidentiality, the source document does not give the capital costs of the vehicles. However, as a very broad indication, it is likely that the extra capital costs shown amount to somewhere between 3% and 9% of total capital costs.

In the Netherlands, the Interdepartmental Commission on the Abatement of Noise has undertaken a feasibility study into the design of quieter goods vehicles as one of a series of studies on traffic noise. The aim of the report was to provide a basis for discussion with the industry about arriving at practical solutions to the problem of vehicle noise. It was concluded that the greatest reduction that it was sensible to seek was 10 dB(A) - down to a level on the ISO test of 81 dB(A) - since reductions in tyre noise which would allow total vehicle noise to be brought below that level could not be envisaged. It was also concluded that it would be pointless to attempt this reduction in stages; it should be done in one step. The report estimated that it would require about four years from

FIG. 3.1 : SUGGESTED DUTCH PROGRAMME FOR THE DEVELOPMENT OF THE "QUIETER GOODS VEHICLE"



SOURCE: See Table 3.2

the time of selecting a prototype vehicle for modification to the time that mass production of the modified vehicle could start. Figure 3.1 taken from the report shows the suggested sequence of the development programme.

In France, Berliet has reduced the noise of a medium-sized diesel lorry from 89.5 to 84 dB(A) on the ISO test by the partial encapsulation of the engine and the fitting of more efficient silencers. The extra cost was 3,800 francs at 1977 prices or US $ 834 at 1978 prices, which represents an extra 5.5% of the selling price of the vehicle, but in mass production this penalty would be reduced to 4%.

It has been shown that further action along the same lines could reduce the noise to 82.5 dB(A) but the extra capital cost has not been calculated and there would also be some adverse effect on the vehicle's performance(27).

3.1.6 Retrofit

Little attention seems to have been given to the possibility of retrofitting existing lorries, partly because the life of a lorry, which rarely exceeds ten years, is too short to require it and partly perhaps because to impose standards on existing vehicles more stringent than those in force when they were produced is something which governments dislike doing except for compelling reasons of safety. However, some work on retrofit was done in the course of the American Quiet Truck Programme. One study was concerned with two lorries, a Kenworth K-123 with a Cummins NTC-350 engine and a Peterbilt 352 A with a Detroit Diesel 8V-71T engine. It was found that modifications to the fan and to its speed of rotation were sufficient to produce substantial reductions in each case at a very small capital cost and trivial, if any, operating penalties. Presumably these results are accounted for by the fact that both lorries were intially extremely noisy; no general conclusions should therefore be drawn from the findings. The figures from the source document(28) are given in Table 3.6.

TABLE 3.6 : COST OF MATERIALS AND INSTALLATION FOR IMPROVED FANS AND CONSEQUENT NOISE REDUCTIONS

Vehicle	Cost $ 1976 prices	Previous dB(A) level, ISO test	Subsequent dB(A) level, ISO test
Kenworth K-123	246	97	92.5
Peterbilt 352 A	252	95	90.5

3.1.7 Vans

The problem of vans is in general comparable to that of cars. However, the fact that many vans regularly operate in conditions which do not require either high speeds or long ranges has aroused interest in the possibilities of electric vans. A test programme now in progress in Britain has produced some extremely encouraging results. In appropriate conditions electric vans have operated at costs very close indeed to that of their diesel or petrol counterparts. Drivers like them and they have operational advantages, such as being able to drive right into food warehouses, as well as general environmental advantages. Table 3.7 is copied from the proceedings[29] of an international conference held in Britain in 1978. The electric van in question has a payload of 1.75 tonnes, a top speed of 65 km/h and a range on a single charge, assuming urban delivery conditions,of at least 80 km. For a description of another electric goods vehicle which has been in use in specialised urban situations for a number of years, see Section 6.1.

3.2 Buses

3.2.1 The Need for Quieter Buses

Buses account for only a small proportion of national or urban vehicle travel. But on certain roads they constitute a significant part of the flow and these roads are likely to be particularly frequented by pedestrians. The need for buses to stop and start more often than other vehicles will also add to the contribution they make to the noise levels on such roads. There are increasing moves to give buses priority in central areas of cities; indeed, they may be the only motor vehicles allowed in pedestrianised areas for large parts of the day. It is also often desirable for them to be able to penetrate other

TABLE 3.7 : COMPARATIVE COSTS: ELECTRIC VERSUS DIESEL VANS

Electric Vehicle		Diesel Vehicle
Silent Karrier Mk IA with high-roof integral van body. Inclusive of battery, charger and delivery charges	Specification	Dodge KC40 (3.12m. wheelbase) with integral high-roof van body. Inclusive of delivery charges
£	Purchase Price	£
7,390	Chassis-scuttle, anti-corrosion treatment and delivery charges	-
3,000	Battery	-
800	Charger	-
2,300	Body	-
250	Charger installation and battery topping-up trolley	-
£ 13,740	TOTAL (excluding price of tyres)	£ 5,685
2.42	Price ratio (Diesel = 1)	1
10 years (5 years for battery)	Assumed life required	6 years
16,090 km	Annual required user (250 working days)	16,090 km
£ p.a.	Annual Costs	£ p.a.
	Depreciation:-	
1,049	Vehicle	948
600	Battery	-
25	Charger installation and topping-up trolley	-
85	Road Tax	140
-	MOT : 'O' Licence	23
344	Fuel (including heating)	410
185	Tyres	145
550	Maintenance and repairs	950
168	Replacement Hire	306
£ 3,006	TOTAL	£ 2,922

SOURCE: Reference 29

sensitive areas, such as residential estates, and to operate at times of day, for example in the early morning, when there may be few other vehicles about. There are therefore substantial advantages to be gained from a quiet bus.

3.2.2 Feasibility of Noise Reduction and Means

Most buses now in use in OECD countries are probably of the old unquietened generation. The noise emitted by such buses is likely to be in the range 86 to 91 dB(A), when tested according to the ISO procedures, or even higher if the vehicle is poorly maintained. However, there is no doubt about the feasibility of reductions since quieter vehicles are now in operation. The application of retrofit packages has brought the noise emitted by some buses of the older generation down to 80 to 82 dB(A). Changes in production, consisting sometimes of modifications to an existing model and sometimes of a new type of bus,have brought noise levels of new buses down as far as 76 to 80 dB(A).

Further reductions would be hard to achieve, since rolling noise would then become the dominant noise. It could also be said that there is little point in producing a bus quieter than the quietest now available (the Scania buses shown in Table 3.8), since they are already quieter than many makes of car and it may be advantageous for safety reasons that heavier vehicles should emit more noise than others. On the other hand, the bus may be the only kind of motor vehicle permitted in some places, at least for part of the day, and it would always be possible to fit a bell or other auditory warning device. Such a device need not be in constant operation but could be switched off at night or on main roads, or in other circumstances when it was not required.

To retrofit a bus usually involves the partial encapsulation of the engine. Once that has been done, various components will be emitting similar amounts of noise and all therefore will have to be modified in production to reduce power train noise, and hence total vehicle noise, below 80 db(A). The most important action is likely to be to enclose the engine as fully as possible. This requires the radiator to be separated from the engine, with consequent changes to the design of the cooling system. The noise made by the fan can be reduced if the fan is thermostatically controlled and designed to operate at low revolutions. The air intake should be constructed

TABLE 3.8 : EXAMPLES OF CAPITAL COSTS REQUIRED TO QUIETEN BUSES

Bus	Reductions achieved by retro-fit or in production	Reduction dB(A), ISO or ISO equivalent	Cost and Year	1978 US $ equiv-alent	Cost as % of total cost of vehicle	Comments	Source
D20 Double Decker (Modified Fleet-line)	P	From 88 to 82/83	£ 1,200 1977	2,450	3.4%	Bus now in service	London Transport
DAF City bus	R	From 88 to 82	Fl. 11,672 1978	5,165	7.5%	The figures are estimates rather than being derived from retrofits actually installed	Letter from DAF to Ministerie van Volksgezondheid en Milieuhygiene
CAB Inter-city bus	R	From 90 to 83	Fl. 7,350 1977	3,250	2.5%	" " " " "	Letter from CAB to Ministerie van Volksgezondheid en Milieuhygiene
Detroit Diesel 6V-71	R	89 to 83 (left side) and 84 to 81 (right side)	$ 610 1974	765	N.S.	The same package of meas-ures applied in both cases	US Department of Transport[34]
Berliet PR 100	P	From 90 to 80	Reduction achieved between 1972 and 1977	1,650	2.5%	Commercial production of 80 dB(A) bus started in January 1978. Slight adverse effect on fuel consumption	Renault/Berliet and CFRN
Various American	P	From various existing levels down to 83	Estimates given in 1977 report	N.S.	1.8% to 8.8% depending on bus size and type	The costs are estimates; vehicles with the necessary changes are not yet in commercial production	EPA[35]
Scania BR112 and CR 112	P	From 85/87 (previous BR 111 and CR 111 models) down to 77	N.S.	N.S.	N.S.	Since this bus was designed from the outset as a quiet bus it is impossible to identify particular items which are extra as compared with an unmodified vehicle. However, the bus is 7% to 8% more expensive than its nearest equivalent of a conventional kind. The bus is suitable for long dist-ance as well as urban work	Saab-Scania
Mercedes Benz O305-407	P	From an un-specified level to 77-79	1973	N.S.	4% Max.		OECD[36]
Magirus Deutz	N.S.	Reduction of 5 to 6 dB(A)	1974 or earlier	N.S.	4% Max.		OECD[36]

as a noise trap and a large silencer, or preferably more than one silencer, should be fitted on the exhaust. The turbocharging of diesel engines also has a beneficial effect.

3.2.3 Capital Costs

The cheapest substantial noise reduction has been achieved on the Berliet model PR 100. A reduction from 90 to 80 dB(A) on the ISO test was brought about at an extra capital cost of 2.5%; fuel consumption has also risen by 2.5%[30, 31].

In the Netherlands, the buses now bought for urban services or for services between cities and villages in the surrounding countryside are provided with an encapsulation. The cost of this, together with that of the consequential changes such as improving the capacity of the cooling system, comprise about 5% of the price of the complete bus. To retrofit buses already in use in similar ways is more expensive and can amount to as much as 7.5% of the price of the bus.

Table 3.8 shows various examples of reductions that manufacturers have achieved or believe, after study, to be possible, with the associated capital costs. The figures relate to the ISO test. It seems fair to conclude that the capital cost penalty is small in relation to the benefits.

3.2.4 Other Costs

The extra weight of a quiet bus (the weight being in the radiator, fan, insulation material, cooling system and exhaust system) gives rise to an increase in fuel consumption. The weight penalty of the Leyland B20, which is a modified Fleetline, is about 270 kg, which represents about 3% of the unladen weight and 2% of the laden weight. Since fuel consumption is approximately proportional to weight, fuel consumption can be expected to increase by a similar figure. This is corroborated by an EPA document[32] which states that "energy consumption of buses is expected to increase by no more than an average of 3% with the implementation of the proposed levels". It is possible that other changes required to reduce noise, for example, the thermostatically controlled fan, would help to reduce fuel consumption.

A second weight-related problem is that in some cases the extra weight has caused the axle weight limit to be exceeded. To solve this, the Dutch authorities raised this limit from 10 to 11 tonnes at the end of 1978. Presumably this has some effect in increasing the damage that buses do to road surfaces, but the alternative, a reduction in the passenger carrying capacity of the bus of about 20% (in the case of the DAF bus the absolute figures were from 92 to 75) would have serious implications for bus operators.

It has not been possible to establish how widespread this problem is but uncorroborated verbal references mentioned a similar situation in Germany.

A final category of cost associated with quiet buses is maintenance. Quiet buses can be more expensive to maintain for two reasons, because there are extra or more complex parts that need to be serviced and because engine encapsulation makes the engine less readily accessible. No figures are at present available.

3.2.5 Electric Buses

Electric buses might be quieter according to the ISO test than the quieter type of diesel bus now in operation, although rolling noise would be dominant, or becoming so, for both types of bus. But the complete silence of the electric bus in starting and at low speeds is an advantage not reflected in the ISO test. The fact that the electric bus is without fumes is also important, particularly when a bus is required for use in sensitive areas.

Several types of electric bus have been in operation in Great Britain in recent years; recent accounts[33] suggest that diesel buses still have an advantage in cost terms notwithstanding the popularity of electric buses among both drivers and passengers.

3.2.6 Other Types of Quiet Buses

In the Netherlands, investigations are being carried out into some other types of quiet buses. An investigation on the safety of LPG delivery stations is being made in order to see if the LPG bus can be used. Not only is it a quiet bus; the fact that it causes very little air pollution also makes it very attractive.

There are plans to put the trolley bus into service in a part of one of the big cities in the Netherlands, as the sound emission of that type of bus is low in city traffic.

Another investigation deals with a diesel electric bus. It is expected that that bus will be quieter in the city than a conventional bus and it also uses less energy.

3.3 Motorcycles

3.3.1 The Importance of Motorcycle Noise

Conventional indices of annoyance are probably least satisfactory where motorcycles are concerned. In Britain in 1972, the year of the national environmental survey, motorcycles accounted for less than 2% of road vehicle mileage and probably made a trivial contribution to Leq noise levels. Nevertheless, more people claimed to be annoyed when at home by noise from motorcycles than from any other single traffic noise, and when noise in the streets as well as noise heard at home was taken into account, 19% of respondents mentioned motorcycles or mopeds in reply to the question "what sort of vehicles make the worst noise?" Corresponding figures for other vehicles were lorries 39%, buses and coaches 5% and cars 4%(37). In the United States, motorcycles currently account for 1.7% of traffic volume but public opinion surveys show similar findings:

"Motorcycles were confirmed to annoy people out of proportion to their population. More than one-third of the national population is not at all annoyed from motor vehicles and only 10 per cent of the population is very annoyed by noise from motor vehicles. However, noise from motorcycles bothers more people than are bothered by noise from any other type of motor vehicles and for people who are at all annoyed by noise from motor vehicles in general, about one-third are very annoyed by motorcycle noise."(38)

In a recent French survey more town dwellers mentioned the motorcycle as the most important cause of traffic noise nuisance experienced at home then mentioned any other specific cause(39).

Although there would therefore certainly be great benefits from quietening motorcycles, it may be questioned whether for motorcycles, as for lorries (see Sections 3.1 and 6.1), the problem is one of noise level alone. Motorcycles cause a variety of nuisances; noise is annoying in its own right but may also have become the focus of other types of disturbance. It is possible that a quiet motorcycle, particularly if also heavy and fast, might be worse, especially in towns, than a noisy one. At the 1975 OECD seminar Better Towns with Less Traffic it was suggested that cyclists and moped riders could be mixed with pedestrians in some pedestrian streets provided that the speed of mopeds was limited to no more than 20 km/h (40). Perhaps this suggestion could be extended to say that in towns as a whole the only motorcycles that should be permitted are ones whose use is compatible with that of pedal cycles.

3.3.2 Mopeds

The official American definition of a moped is

"Any motorcycle that (a) has an engine displacement less than 50 cubic centimetres; (b) produces no more than two brake horse power; (c) with an 80 kg. (176 lbs) driver cannot exceed 48 km/h (30 mph) over a level paved surface; and (d) is equipped with fully operative pedals for propulsion by human power "(41).

Although the definition used in other countries may not be identical, such machines are in common use in several OECD countries. In France "cyclomoteurs" do not have to be licensed so the exact number of them in use is not known, but it lies between three and four million. The present legal limit in France for new mopeds is 72 dB(A) and there would be no problem if mopeds remained in the condition in which they were originally sold. However, it has been found that 40% of machines are in bad condition. This is partly due to ageing but more to the removal of the silencer. Silencers have to be removed in order to decarbonise the engine and may not always be replaced, or young people may remove them for fun(42). For existing machines the problem is one of enforcement, either through ordinary police action or through the more specific methods described in Section 7. In the longer term, the solution lies in making mopeds with which one cannot cheat and which produce less carbon. The most suitable machine in this respect would be an electric moped. We have been told that some manufacturers have produced limited numbers of such machines but we have not had confirmation of that. Development work on a novel design of motor, which appears to have reached an advanced stage, was described at a recent conference[43].

3.3.3 Larger Motorcycles

For larger motorcycles as for mopeds there is a major problem of ensuring that machines remain in good condition. In France, of a population of approximately 600,000 motorcycles the proportion in poor condition is (as for mopeds) 40%[42].

In the United States, it is estimated that the exhausts have been modified on at least 12% of existing motorcycles (excluding those not permitted for normal road use, more of which were modified) and that modification adds more than 15 dB(A) to the noise emitted by a machine travelling at a steady 40 to 50 km/h[44]. An approach to this problem through a fundamental change in design does not seem feasible; enforcement becomes all the more important.

But for larger motorcycles, unlike mopeds, there is also a serious problem of producing a machine that would be reasonably quiet even in its initial state. The EEC has just agreed to issue its first directive covering motorcycle noise; the levels will be as shown below. Even when these regulations come into force, large motorcycles will continue to be the noisiest vehicles permitted except for the heaviest lorries.

TABLE 3.9 : EEC MOTORCYCLE NOISE LEVELS

Category of Motorcycle by cubic capacity of engine	Permissible sound level dB(A)
≤ 50	78
≤ 125	80
≤ 350	83
≤ 500	85
> 500	86

We have not seen estimates of the costs of implementing these regulations. French research on how best to modify the 350 cc Motobecane machine so as to reduce emitted sound from the present 91 dB(A) to the 84 dB(A) limit then proposed showed that a reduction of 9 dB(A) in the noise emitted by the engine and gear box would be required. It was concluded that to achieve this within the present technology would be difficult[45]. The only cost estimates that we have seen of reducing noise from motorcycles by changes to the design are American: the most recent and authoritative are those of the EPA.

3.3.4 The EPA's Estimates

The context of the EPA's work was the need to set noise standards under the terms of the 1972 Noise Control Act. Cost estimates were made from data supplied by the manufacturers of all the main types of machine sold in the United States; for the more stringent standards the manufacturers' own estimates were based on engineering judgement not on operational prototypes. Although the EPA's approach to noise control has been criticized for relying unduly on setting construction standards for new models, rather than paying more attention to problems of enforcement, the cost estimates themselves seem to be accepted as reasonable[46].

It was found that the type of measure required to quieten motorcycles varied extensively from machine to machine, but included action on the exhaust, air intake, engine and transmission and in some cases major changes in the model configuration, such as a conversion from two-stroke to four-stroke or the enclosure of the engine.

The increases in unit costs that would arise from compliance with different noise levels, by size of motorcycle, are shown in Table 3.10.

Fuel consumption would also be adversely affected by amounts varying from zero for the smallest machines and least stringent standards to 15% for the largest machines and most stringent standards. The extra annual costs of petrol per machine corresponding to this 15% figure would be just under $3, assuming 1,500 miles travelled a year, 47 mpg and petrol at $0.60 per gallon: these figures were derived from current (1975) data. It was estimated that the time required for maintenance would increase slightly but that even for the largest machine and the most stringent standard the extra time would amount to only forty-five minutes per year. However, if it became necessary for an owner to replace a silencer or exhaust system on a machine which was satisfactory initially, the extra cost could be substantial. The worst case would be to replace a complete exhaust system on a large motorcycle meeting the most stringent, 81 dB(A), standard. The cost would be $265 at 1975 prices as compared with $140 for replacing the exhaust system on a machine of similar size of current (1975) design.

3.4 Cars

3.4.1 The Importance of Car Noise

Comparatively little attention has been paid so far to the reduction of car noise. Manufacturers have not felt obliged to because most cars already conform, or are close to conforming, not only with the present EEC limit of 82 dB(A) but also with the new 80 dB(A) limit which comes into force in 1982. The reason that there has been little pressure from governments to set lower levels is presumably that other kinds of vehicle, taken individually, are so much noisier. But in spite of this, as was shown in Section 2.1 and Table 3.1, the proportion of cars in the traffic flow is so great that substantial general reductions in noise levels cannot accrue without something being done about them.

This section discusses what can be done to reduce the power train noise of cars through changes in design. The question of rolling noise and the relationship between power train noise and rolling noise are discussed in Section 4. As a generalisation it may be said that in urban conditions a reduction in power train noise is always necessary and often sufficient to reduce total car noise, but on high speed roads in free flow conditions, a reduction in the power train noise of cars will have little effect, since at such speeds rolling noise predominates for cars.

The development work that this section reports on has been carried out in the context of the ISO test procedures; therefore the warnings mentioned in Section 2 that the ISO procedures may be misleading in the urban context should be borne in mind. Also, as was mentioned in Section 1.2.2, there are important sources of noise nuisance from cars which are related

TABLE 3.10 : INCREASES IN UNIT COSTS OF NEW MOTORCYCLES ARISING FROM COMPLIANCE WITH PROPOSED NOISE EMISSION STANDARDS

Units: $

SIZE OF MODEL	COST CHANGES	REGULATORY LEVEL (ISO EQUIVALENT)				
		92dB(A)	89dB(A)	86dB(A)	84dB(A)	81dB(A)
Less than 100cc	A. Current (1975) retail price			484		
	B. Expected increase in cost of production	0	2	2	16	42
	C. B as % of A	0%	0.4%	0.4%	3.3%	8.7%
	D. Expected % increase in retail price	0%	0.4%	0.4%	3.9%	10.3%
	E. "Worst case" increase in cost of production	0	2	2	16	42
100-169cc	A. Current (1975) retail price			680		
	B. Expected increase in cost of production	0	5	15	62	125
	C. B as % of A	0%	0.7%	2.2%	9.1%	18.4%
	D. Expected % increase in retail price	0%	0.9%	2.6%	10.9%	22.1%
	E. "Worst case" increase in cost of production	0	5	33	124	171
170-349cc	A. Current (1975) retail price			997		
	B. Expected increase in cost of production	0	13	43	110	202
	C. B as % of A	0%	1.3%	4.3%	11.0%	20.2%
	D. Expected % increase in retail price	0%	1.6%	5.2%	13.2%	24.2%
	E. "Worst case" increase in cost of production	0	13	82	154	210
350-749cc	A. Current (1975) retail price			1,429		
	B. Expected increase in cost of production	0	17	50	136	257
	C. B as % of A	0%	1.2%	3.5%	9.5%	18.0%
	D. Expected % increase in retail price	0%	1.4%	4.2%	11.4%	21.6%
	E. "Worst case" increase in cost of production	0	17	100	188	266
750cc and over	A. Current (1975) retail price			2,571		
	B. Expected increase in cost of production	0	19	62	153	280
	C. B as % of A	0%	0.7%	2.4%	6.0%	10.9%
	D. Expected % increase in retail price	0%	0.9%	2.9%	7.2%	13.1%
	E. "Worst case" increase in cost of production	0	19	113	215	290

SOURCE: Reference 44, Tables 7-21 and 7-27

NOTES:

1. 1975 prices.
2. Production costs allow for research and re-development, retooling and all other expenses which manufacturers would incur in adopting the new standards.
3. Item (D) differs from item (C) because it allows for the effect of the likely increase in retailers' margins consequent upon an increase in manufacturers' costs.
4. Figures relate only to "street-legal" machines as opposed to machines licensed for use only off the public highway.

neither to power train noise nor to rolling noise, although they could be alleviated by changes in design and appear appropriate candidates for regulation: these include doors, starter motors and horns.

We have not come across any discussion of the possibility of modifying existing cars to make them quieter, although the life of some cars is long enough to give some point to such action. The way that cars are driven and maintained can have an important effect on emitted noise; enforcement problems are discussed in Section 8. None of the work we have come across deals with diesel cars or cars with two-stroke engines.

3.4.2 Sources of Power Train Noise and Means of Abatement

Power train noise comes mostly from the engine and associated systems rather than from the transmission.

The chief importance of the transmission is indirect: it affects the rate at which the engine turns and hence the noise it emits. Burhop[17] claims that the widely held view that vehicles equipped with automatic transmission are quieter only under test conditions is incorrect. He states that records of engine revolutions under normal operating conditions have clearly proved that the revolutions are far below those reached with manual transmission. Theys [47] gives the noise reduction due to an automatic gearbox as 4 dB(A) with an associated cost of 1,000 to 3,000 francs at 1975 prices (equivalent to US $ 260 to 800, 1978 prices).

The main individual sources are the engine itself, the fan and the air intake and exhaust systems. The importance of each varies from model to model, but on most models all are worth looking at as a means of reducing total power train noise.

i) Engine The emitted sound energy of a combustion engine is primarily caused by the combustion process and by associated mechanical noise. There are three basic ways in which this noise can be reduced. First, the forces within the engine structure can be reduced, secondly the vibrational response can be reduced and thirdly the engine can be partially or totally encapsulated.

The only way to reduce the forces within the engine structure, short of a radical change in engine design, is to switch from small cylinder volumes and maximum rotation rates (as in European cars) to large cylinder volumes and limited rotation rates (as in American cars). Renault[48] found with an experimental R12 that a 25% increase in cylinder volume with a corresponding decrease in speed reduced total engine noise by 4 dB(A). To make such a change on a model already in production would of course require extensive modification to the production line. Schärer and his colleagues[49] report other experimental work by Renault on the R4 GTL. By increasing engine capacity from 850 cc to 1100 cc., engine revolutions were reduced from 5,000 to 4,000 per minute with unchanged output. This resulted in a dB(A) value on the ISO test of 73 (although Schärer does not mention this, the usual value for a Renault 4 is 77 dB(A))[50]. This change also produced a considerable saving in fuel consumption and very low exhaust emission values.

The second possibility, the reduction of vibration levels, depends largely upon the re-design of the engine cylinder block and crankcase, to make them stiff, and upon the introduction of rubber sealing to cut down on the propagation of vibrations. These are not simple measures and they are still the subject of research. Furthermore they are limited in their effectiveness. Burhop[17] estimates that the reduction obtained would not exceed 1 dB(A).

The third approach, to enclose the engine, is the most promising in the short term. Encapsulation combined with acoustical treatment of the engine compartment is estimated by Burhop to reduce engine noise by 2 dB(A). Renault[48] reported a gain of 1.6 dB(A). Tests conducted in the United Kingdom by the Motor Industry Research Association have shown that putting absorbent materials on the walls of the engine compartment of passenger cars seems to be enough to reduce noise by 3 to 4 dB(A) without affecting engine cooling[51]. Theys[47] gives the reduction achieved by encapsulation as 4 to 5 dB(A); this agrees substantially with a figure of 5 dB(A) given by Lambert[52].

ii) Fan Fan noise is proportional to the speed of the fan tip. One important way of reducing fan noise is to fit a thermostatically controlled fan or to use a governed fan clutch such that high engine speeds do not automatically give rise to high fan speeds. Such fans are being introduced anyway for reasons of fuel conservation.

According to Burhop[17], other possibilities of reducing fan noise for a given amount of cooling are very limited because most cars are already fitted with shrouds to increase the air flow volume.

(iii) Air Intake and Exhaust Systems Both the inlet and exhaust noise from the internal combustion engine are caused by gas column vibrations which are transmitted to the atmosphere. Silencers reduce the induced pressure fluctuation, and without them the exhaust and inlet would be the dominant sources of engine noise, producing noise levels of from 90 to over 110 dB(A).

The design of exhaust silencers has improved in recent years, and although further improvements are possible, they present certain design problems (basically because the improvement requires an increase in the volumes of silencers, and therefore more space). Renault[48] recorded improvements of 1.4 dB(A) for the R16TS and 0.7 dB(A) for the R17. Lambert[53] gives the possible reduction from an improved silencer as 2 dB(A) for a car with a silencer already in good condition and 8 dB(A) for a car with one in poor condition.

3.4.3 Possible Reduction and Cost

There is now a wide variation in the ratings achieved by different models on the ISO test, as the data in Table 3.11, derived from Dutch type testing, indicates.

TABLE 3.11 : DECIBEL RATINGS OF MODELS TESTED IN THE NETHERLANDS SINCE 1976

Sound Level on ISO Test	Models Achieving the Level	
	%	Cumulative %
70 or less	0	0
70 - 71	1	1
71 - 72	1	2
72 - 73	2	4
73 - 74	6	10
74 - 75	6	16
75 - 76	14	30
76 - 77	16	46
77 - 78	12	58
78 - 79	14	72
79 - 80	11	83
80 - 81	9	92
81 - 82	8	100

SOURCE: Ministerie van Volksgezondheid en Milieuhygiene

For every model there is a limit to what can be achieved within existing production constraints, that is by means of shielding and minor modifications rather than radical changes in design, but models vary too much in their design and "architecture" for it to be possible to generalise about what that limit is. Studies of several different models now over 78 dB(A) suggest that shielding etc., could bring the level down to that figure but that further reductions would become increasingly difficult to achieve. Shielding increases the weight of the car and hence has some slight adverse affect on fuel consumption, but we have not seen a precise statement of this. Maintenance is also made more difficult; Volvo estimated that the shielding required to bring about a reduction from 84 dB(A) to 78 dB(A) (see Table 3.12) would also add at 1972 prices 150 Crowns (1978 $55) to annual maintenance costs.

Several French sources[54, 55, 56] suggest that for the first few decibels (i.e. those atttainable by minor modifications) the extra capital costs are likely to be 1% per dB(A). It is not clear however, whether these estimates are based on different work or all relate to the same studies. The figures in Table 3.12 derived mainly from manufacturing sources, are roughly consistent with the 1% per dB(A) rule. Volvo is an apparent exception, but given that Volvo started with a relatively noisy car, and therefore with the possibility of particularly cheap initial reductions, their findings should not be regarded as inconsistent with the others.

A German study reported on in 1974 concluded that by means of the same kind of measures as listed in the table, noise from the existing noisier types of German car could be reduced by 4 dB(A) at an average net capital cost per vehicle of DM 480 (1978 $267)(57). The test procedures used in this study were not those of the ISO test; nevertheless this finding can be taken as broadly supporting the others.

TABLE 3.12 : SOME ESTIMATES OF CAPITAL COSTS INVOLVED IN ACHIEVING CERTAIN REDUCTIONS IN THE NOISE EMITTED BY A CAR UNDER ISO CONDITIONS

Source	Reduction dB(A)	Means of Reduction	Cost and Year	1978 US $ equivalent	Cost as % of total cost of vehicle	Comments
Dunlop (17)	From 82 to 80	Single improvements to the engine and limited shielding	Up to 300 DM 1977 prices	66	2% (approx.)	Figures in the source document appear to be derived from estimates of various manufacturers but it is not clear what tests had been done
Dunlop (17)	From 82 to 80	Partial encapsulation of engine and engine compartment plus improved cooling system	Up to 800 DM 1977 prices	176	5% (approx.)	In order to achieve a result of 78 on the ISO test, it is necessary, according to this source, to reduce power train noise to 75; such a reduction is presupposed in the costs
Renault (18)	From 82.5 to 78.5 (at best)	Engine screening, increase in size of silencers on air intake and exhaust, improved design of joint to exhaust manifold	375 to 525 Francs 1973 prices	126 to 175	2.5% to 3.5%	The calculations were based on tests made on an R16, but it was not thought possible to modify the existing R16 at this cost; a new model would be required
Renault (40)	From 81.5 to 74.5	Extensive screening, enlarged silencers, improved design of joint to exhaust manifold, enlarged cylinders	1050 Francs 1973 prices	351	7%	Calculations based on an R12, but the estimates both of noise reduction and of cost increases are somewhat speculative and could not be achieved on the existing R12. The estimate of 74.5 does not appear to take account of the influence of rolling noise
Volvo (25)	From 81 to 80	Improved silencer, engine shielding and use of sound absorbing material	250 Crowns 1972 prices	91	1%	Estimates based on work done on existing Volvo cars
Volvo (25)	From 84 to 78	As above plus more engine shielding, new pipe from exhaust manifold to first silencer, enlarged silencer on air intake, sound absorption material in gear box to prevent noise "leaking" from engine, thermostatic fan, changes to sump, crankshaft and transmission hood	700 to 1050 Crowns	256 to 384	2.5% to 3.8%	The source documents give a figure of 700 to 800 Crowns but it is not clear whether this sum is in addition to or includes the 250 Crowns required to achieve the smaller reduction
Schärer (49)	From 77 to 73	Enlargement of engine capacity from 850 to 1100 cc.	250 DM presumably at 1970 prices	120	2.5% (approx.)	Other benefits in the form of reduced fuel consumption and low exhaust emission resulted from this change

4. ROLLING NOISE

4.1 Nature and Importance

Rolling noise is the noise which would still be emitted by a vehicle coasting under its own momentum or the force of gravity even with the engine switched off and the gears disengaged. Although aerodynamic noise enters into it, by far the most important component is the noise caused by the interaction between tyres and road surface. Rolling noise increases with speed; Harland[58] reports French, German and British work showing that for both light and heavy vehicles doubling speed produces an increase in rolling noise of some 9 dB(A) over a wide range of speeds (50 km/h to 100 km/h for the French and German work and 10 km/h to 90 km/h for the British).

The point at which rolling noise dominates power train noise varies with the type of vehicle, being lower for cars than for heavy vehicles, and with the type and condition of the tyres, the nature of the road surface and the weather. On most surfaces in dry weather, power train noise will dominate rolling noise at speeds likely to be attained in urban conditions (other than on urban expressways), although Harland has shown that for light vehicles at 20 kph travelling on a hot rolled asphalt surface rolling noise is sufficiently close to power train noise for a reduction of 5 dB(A) in rolling noise to bring about by itself a reduction of 1 dB(A) in total vehicle noise. However, in wet weather the rolling noise of light vehicles will equal or exceed power train noise at 50 kph[58]. Research in Britain by MIRA showed that rolling noise was 8 dB(A) higher on a cobbled surface than on a smooth and a Renault report[15] states that at 50 km/h car rolling noise on pavé is about 80 db(A) (presumably at a distance of 5 metres).

Even in urban conditions, therefore, there may sometimes be a point in action to reduce the rolling noise of light vehicles. On motorways and other high speed roads rolling noise will be the dominant noise for light vehicles; for heavy vehicles, rolling noise will not necessarily predominate but substantial reductions in total vehicle noise will be possible only if both rolling noise and power train noise are reduced[14, 59].

4.2 Tyre Noise

The literature on tyre noise is less extensive than that on power train noise, and it may be that the international conference held in the late summer of 1979 will produce information leading to the modification of some of the following remarks.

It seems to be accepted that little reduction can be foreseen in the noise produced by car tyres on any given surface[59] although the difference between different types of car tyre can be 2 to 4 dB(A)[58]. For lorries, there are considerable difference between rib tyres (the quietest), cross-bar and retreads; an American study of 1970[60] suggests that on some surfaces the difference between cross-bar and rib could be 10 dB(A) and between retread and cross-bar even more. An OECD study of 1973[61] states a 5 dB(A) difference in each case. Recent American studies by Leasure[62] conclude that quiet tyres (radial or bias-ply rib) are at least as advantageous both in safety and economy as noisier bias-ply cross-bar tyres, except perhaps in unusual operating conditions such as snow or mud. Hence, provided that regulations are not introduced with a lead time so short as to require premature replacement of tyres by users and similarly rushed action by tyre manufacturers, the use of the quieter tyre carries no cost penalty. Leasure calculates that the use of quieter tyres on lorries, combined with an equivalent reduction of their power train noise, would bring a significant reduction of some 4.5 dB(A) in the noise level (Leq) associated with high speed highway traffic even if lorries accounted for only 7% of the flow. This result is at first sight difficult to reconcile with a TRRL study[14] which suggests that when lorries account for 10% of the flow the greatest reduction in the noise level (L_{10}) that can arise by quietening each individual lorry by 10 dB(A) is 2.4 dB(A). This study, was, however, based on a single carriageway dual-lane rural road on which speeds must presumably have been lower than those (unspecified) in the American example. This and other differences in the test situations may account for the apparent discrepancy.

4.3 The Road Surface

As was stated in Section 4.1, the difference between rolling noise from pavé and cobbles on the one hand and from asphalt or similar surfaces on the other is substantial. It follows that in towns where pavé and cobbles are still used, the possibility of changing the surface in order to reduce noise should be considered seriously. The elements of cost to be taken into account would then be:

i) the once-and-for-all cost of making the transition;

ii) changes in maintenance costs thereafter, including costs imposed on traffic by the need to close sections of road when works are in progress;

iii) changes in road safety arising primarily from the difference in the skidding characteristics of different road surfacing materials, but possibly also from changes in vehicular speeds;

iv) changes in vehicle operating and maintenance costs arising from the difference in roughness of surface.

In addition, considerations of appearance might arise. We have come across no studies in the literature making these comparisons.

There are, however, several relevant studies comparing more conventional road surfaces with each other with respect to noise and skid resistance: the other elements of cost, as listed above, which would be relevant to a decision on which surface to use are not covered in these studies. Recent work by the TRRL(63) covering the range of concrete and asphalt surfaces commonly encountered on trunk roads and motorways in the UK showed differences of 9 dB(A) in the noise emitted from each surface (peak noise level at 7.5 m and 70 km/h). Unfortunately the same research showed a very clear positive relationship between noise level and skid resistance. Some limited experimental work in Illinois(64) suggests that this relationship does not always hold: the experimenters concluded that: "minimum raw traffic tyre noise may be produced by a roadway surface having a texture depth of 0.04 to 0.05 metres. Please note that skid resistance is maximum for such a surface". This study showed a reduction of between 1 to 2½ dB(A) in the L_{10} noise levels and of more than 3 dB(A) in the L_{50} noise levels when a highway on which skid resistance had dropped to an unacceptably low level was resurfaced to produce "a moderately rough surface of the open-graded resistant type".

4.4 Conclusions

1. In most urban conditions power train noise dominates rolling noise. Therefore a significant reduction in noise levels cannot be achieved in towns by changing tyres or road surfaces except where pavé, cobbles or similar materials are now used or alongside urban expressways.

2. On high speed roads rolling noise dominates power traffic noise for cars and is of at least equal importance for lorries. There is little prospect of reducing the rolling noise of cars through changes in tyres. Changes in lorry tyres can reduce the rolling noise of lorries with no cost penalty, but significant changes in roadside noise level will result from this only if the power train noise of lorries is reduced as well. The road surface affects roadside noise levels on such roads, but the evidence suggests that there is a trade-off between quietness and skid resistance and hence accidents. Other costs which would have to be taken into account in a calculation of the costs of noise reduction, such as road maintenance and vehicle wear, have not been studied in this context.

5. LONG DISTANCE TRANSPORT POLICY

Various features of long distance transport policy as now practised in a number of OECD countries have a bearing on noise abatement, even though it has rarely been a reason for their adoption, nor have the consequences in terms of noise levels and exposure been calculated. The lack of data means that it is possible only to discuss very briefly how some aspects of policy which appear particularly relevant might be modified if more attention were given to noise abatement.

5.1 Road Building

If the relief of noise and other nuisance in towns and villages through which main roads pass were treated as the main objective of the inter-urban road building programme, rather than as subsidiary to the aim of creating a "strategic" road network, one would expect emphasis to be given to bypasses for those individual towns particularly badly affected, rather than to motorways. It is claimed in Britain that this will be the emphasis in future.

5.2 The Transfer of Goods Traffic from Road to Rail

The benefits flowing from some transfer of longer distance goods traffic from rail to road could include not only noise abatement but a reduction in accidents, the stress experienced by other road users, congestion and road maintenance. The cost would fall on shippers of goods in the form of extra operating costs and/or reduced convenience. A study carried out in Norway in 1973 showed that if goods now moving over distances of more than 100 kilometres on roads parallel to rail routes were transferred to rail, a 50% reduction in heavy vehicles on the roads concerned would be achieved. The consequential noise reduction was not calculated at the time, but further work is now in progress on this aspect. The report showed that such a transfer would produce a net cost saving of some fifty million N.kr. a year (1973 prices, equivalent to US $ 16 million at January 1978 prices) mainly due to reduced road maintenance costs. The calculation allowed for the cost of extra handling of goods but not for the possible loss of convenience for consignors in using rail rather than road[65].

Governments could encourage such transfers either by regulation; or by taxing lorries in a way which reflected more closely the costs, material or environmental, they impose on others; or by subsidies to railways. Although subsidies to the relatively inoffensive substitute are a "second best measure" in terms of economic theory to the correct pricing of offending modes, they may be easier to introduce. Many governments already support railways, but the main reason for this, apart from the importance of the industry, has been to keep important passenger services going. More attention to noise and other social costs could lead to more subsidisation of freight services. The rate of subsidy would vary between routes according to the quality of the local roads and the degree of relief therefore caused by a transfer of traffic from road to rail. Rail services which involved complete door-to-door journeys would be particularly encouraged, e.g. by grants for private sidings (as are now being given in Britain).

5.3 Speed Limits

Speed limits, if observed, would have a direct effect on reducing noise in that the noise emitted by a vehicle varies with the logarithm of its speed. A Swiss expert committee has estimated that a reduction in authorised speed from 100 to 80 km/h would bring a reduction in noise levels of 2 to 3 dB(A)[66]. There would also be an indirect effect in that some longer road journeys would be suppressed, replaced by shorter journeys or transferred to non-road modes. Both the direct and indirect effect would be greater if more stringent limits were applied to lorries than to cars, since the difference in noise emitted at any given speed between a lorry and a car is of the order of 10 dB(A).

Although it may rarely be the case that noise reduction alone would justify the imposition of speed limits outside towns, it would reinforce the other arguments. Following the oil crisis of 1973, many countries imposed speed limits outside built-up areas in order to save fuel. This also led to a saving in accidents, both through a decline in traffic volumes, which of course had other causes as well, also related to the oil crisis, and through a reduction in the accident rate. In Britain there was a decline in accident rates in 1974 vis a vis 1973 of 10% on motorways and similar roads, and 9% on rural roads, following the imposition of 50 mph speed limits, as compared with a decline of 3% which previous trends suggested might have taken place without special action(67). We have not seen any attempts to put a value on these benefits, or on the disbenefits arising from longer journey times.

5.4 Traffic Restraint

The scope for traffic restraint is greatest in towns and is discussed in the urban context in the next chapter. However some restraint schemes operate nationally. An interesting example is the Swiss restriction on the movement of heavy goods vehicles at night and on Sundays and public holidays. The night time ban operates between 10 pm and 4 am from April to October and between 9 pm and 5 am from November to March. The source document(68) does not provide any information on costs or on the benefits, either in noise reduction or to other travellers, arising from this restriction, but clearly the effect is substantial.

6. URBAN TRAFFIC RESTRAINT

Over the last ten years increasing attention has been paid to the restraint of urban traffic. Perhaps the most important stimulus has been the realisation that the indiscriminate use of motor vehicles, now that the vehicle population is so large, is inconsistent with the efficient movement of people and goods. There are also certain types of scheme for which evnironmental enhancement has been the principal objective, but pedestrian safety and convenience have usually been more important than noise. Nevertheless, traffic restraint is both actually and potentially a very important means of noise abatement; the fact that it would often be justified independently of any noise reduction makes it all the more interesting, since the noise reduction can then be regarded as a free by-product.

In Norway, several studies have been made of the effectiveness of traffic restraint as a means of noise abatement. It has been shown that the costs of achieving a specified level of indoor noise by means of traffic restraint in combination with insulation of buildings are much lower than when insulation is used by itself. Since traffic restraint also reduces external noise, this is a very important finding. Some of the Norwegian experience is described below.

6.1 Schemes Concerned Specifically with Lorries

It was seen in Sections 1 and 3 that it is of particular importance to reduce the noise from lorries and that quiet heavy lorries are not yet at the stage of commercial production. Even if they could be produced, they will not be until regulations are changed to require it, and it would then take some years for the greater part of the stock to be replaced, as is necessary for a significant reduction in noise to be obtained.* But apart from the time required, the quiet heavy lorry is not the solution because it would be almost as out of place in towns as the noisy heavy lorry.

*When lorries account for less than 20% of the traffic flow, the reduction in noise level from substituting quiet lorries for noisy ones is linearly related to the proportion substituted, but the total reduction obtainable is limited. When they account for more than 20% of the flow, the potential relief from replacing noisy lorries is greater but significant gains accrue only when at least 50% have been replaced(14, 54).

Large lorries are visually intrusive, obstruct the traffic and are a major cause of anxiety about road safety. A French report has suggested that the high annoyance scores associated with lorry noise cannot be accounted for by decibels alone but must be partly due to anxiety(54). The British national environmental survey(8) has shown that road safety is easily the most important cause of concern about traffic, by far surpassing noise and fumes. None of these other nuisances would be reduced by making lorries quieter; anxiety and, indeed, actual danger, would be increased.

The only remedy is to exclude the more offensive types of lorry from towns altogether, or at least from the more sensitive districts. This can be achieved either by bans, by which lorries of the prohibited type are denied access to certain areas, or by regulations which allow access but prescribe the routes that lorries may take. The main items of cost and benefit (other than noise reduction) in such a scheme are:

- costs to highway authorities in signposts and other capital works;

- costs to police in enforcement;

- costs to lorry operators and their customers in having to change their routes or other arrangements;

- change in accidents and casualties;

- change in delays caused by lorries to other road users.

The first two items are straightforward, but the others are extremely hard to determine. It is particularly difficult to know how operators will adjust, especially in the longer term, to minimise the extra costs caused by restrictions on lorries. It is therefore not surprising that although restrictions are found in many towns, especially on the continent of Europe, and in some cases have been in existence for a long time, we have found no attempts to cost existing schemes.

Although Britain is probably less advanced than other countries in the implementation of urban lorry schemes, widespread feeling against heavy lorries has stimulated a considerable research programme in recent years on possible restrictions and their costs. Some detailed theoretical work has also been undertaken in Norway. Although the costs are highly specific to the places studied, some of the findings may at least suggest approaches which could be fruitful elsewhere.

i) The potential of banning entry to a town for heavy goods vehicles not requiring access to premises within it diminishes as town size increases. In small towns, 80% to 100% of movements of heavy goods vehicles are likely to be going through; in a town of approximately 100,000, 30% to 50% and in the largest conurbations only a very small percentage. The cost to operators of conformity with the ban clearly depends entirely on the quality of the next best alternative option, which will usually be an alternative road. Enforcement can become a substantial problem if the next best alternative involves a detour of more than 4 to 5 minutes(69).

ii) To confine lorries to certain routes within towns is likely to cause only a small increase in noise levels on the route selected, since they will usually be busy roads, in return for large reductions on the roads which are relieved. The costs may also be quite small. A study of a lorry route network for the whole of London suggested that there would be little effect (precise figures were not estimated) on lorry journey times and hence on operating costs. However, the equity of imposing an extra burden on people living in particularly poor conditions in order to improve conditions for those who are already relatively well placed is questionable. For this and other political reasons the scheme was not adopted.

It was estimated that a more limited scheme to restrict through movements of heavy lorries within Inner London (an area of 320 km^2), with one through route allowed, would have cost initially £159,000 for sign posting and subsequently £300,000 a year to operators in extra travel (1975 prices, equivalent to US $ 224,000 and 422,000 at 1978 prices) in return for a reduction of heavy lorry traffic of some 5% to 6% in the area as a whole but as much as 60% on some particularly bad routes. Because of the objections raised by boroughs adversely affected, and difficulties of enforcement claimed by the police, this proposal was not pursued(70, 71, 72).

A study was conducted in Grünerløkka, a residential inner-city area in Oslo containing some 4,168 dwellings, to assess what the effect would be of banning heavy vehicles from the three major roads enclosing the area (this was after the area itself had been subjected to a traffic management scheme which is described below). Heavy vehicles accounted for some 8% to 13% of the traffic flow on the roads concerned. It was calculated that such a ban would have reduced Leq by some 3 to 4 dB(A) and that maximum noise levels at night would have been reduced by 10 dB(A). Table 6.1 shows what it would have cost to have reduced the existing indoor noise levels in nearby buildings to a specified figure by insulation alone, unaccompanied by a lorry ban, and what it would have cost if a lorry ban had also been in force; it will be seen that the lorry ban would reduce insulation costs substantially. The lorries would have been diverted to surrounding urban highways which already carry high volumes of heavy vehicles and form part of the planned urban lorry network in Oslo. The cost to operators from using a longer route was not calculated.

TABLE 6.1 : THE COSTS OF INSULATING BUILDINGS TO SATISFY DIFFERENT INDOOR NOISE LEVELS ON THE MAIN ROADS SURROUNDING GRÜNERLØKKA

Units: N.Kr., 1975 prices
US $, 1978 prices

Means of noise abatement	Indoor noise levels in Leq		
	35 dB(A)	40 dB(A)	45 dB(A)
Insulation alone	N.Kr. 4.5 mn. $ 1.1 mn.	N.Kr. 3.8 mn. $ 0.92 mn.	N.Kr. 2.3 mn. $ 0.56 mn
Insulation accompanied by a ban on heavy vehicles	N.Kr. 4.1 mn. $ 1.0 mn.	N.Kr. 2.6 mn. $ 0.6 mn.	N.Kr. 1.1 mn. $ 0.3 mn.

SOURCE: Reference 73

iii) A course of action which might have some effect in reducing lorry noise - though noise perhaps less than other aspects of lorry intrusion - would be to replace larger lorries by smaller. A study by the TRRL which throws some light on this investigated how the costs to a supermarket chain in making deliveries to a large number of shops within 100 mile radius of a single depot would vary according to the size of lorries used. The TRRL's summary of the results is shown in Table 6.2. Table 6.3, drawn from the same source, relates these results to the retail cost of the goods.(74)

TABLE 6.2 : EFFECTS ON THE COSTS OF A DISTRIBUTION SYSTEM OF VARYING MAXIMUM VEHICLE WEIGHT

GVW of vehicles (tons)	Number of vehicles required	Total travel Kms/week (Thousands)	Delivery cost per ton (£)	Average number of visits to each shop/week	Total fuel gallons/ week
32.0	45	48	3.80	6	4200
24.0	53	59	3.95	8	4200
16.0	72	88	4.30	11	4900
8.5	135	184	6.60	23	7700

TABLE 6.3 : COST PENALTY FROM THE USE OF LIGHTER LORRIES RELATED TO THE RETAIL PRICE OF THE GOODS

GVW of vehicles (Tons)	Delivery cost per ton (£)	Delivery cost as % of retail value	Extra delivery cost per ton as compared with 32-ton vehicles (£)	Extra delivery cost as % of retail value
32	3.80	1.52	-	-
24	3.95	1.58	0.15	0.06
16	4.30	1.72	0.50	0.2
8.5	6.60	2.64	2.80	1.12

Not all the resource costs arising from the use of heavy vehicles are borne by the distributors or reflected in these figures: the cost of accidents (except as reflected in insurance premiums), road maintenance (except as reflected in annual licence fees) and congestion are not. All these costs increase, per vehicle mile, with the size of the lorry. It is possible therefore, that, despite the extra vehicle miles involved, the inclusion of these costs would have shown 24-ton lorries, or even smaller ones, to be cheaper than 32-ton lorries.

iv) A possible way of reducing the number of lorries circulating in a town without increasing their size is to encourage consolidation schemes. This may apply particularly to shop deliveries, since it is not uncommon for lorries entering a shipping centre to call at one shop only in order to make quite a small drop. One way to achieve consolidation would be by means of a municipal operation whose use would be made obligatory or would be strongly encouraged by such means as bans or time restrictions on other large lorries. Several British studies, including one carried out by the TRRL in Swindon(75), suggest that, notwithstanding some savings, such arrangements would result in a net cost penalty to distributors. These studies, however, have calculated only the savings that would arise in the short term, since they have assumed that distributors would continue to send their goods in the same vehicles performing the same rounds at the same times of day as before. The only difference would be that instead of the vehicles going into the centre to deliver to the shop, they would leave the consignment at an interchange depot on the outskirts. Hence the only possibilities for cost reduction are in the mileage and time saved in travelling through the town, and in parking, waiting and unloading at the shop.

In the longer term, however, many more ways of profitable adaptation are possible. This is illustrated by a recent physical distribution study for a British manufacturer who was distributing nationally from a single factory via nine regional depots. The study examined the possibility of closing the depots and using instead the services of bauliers already offering consolidation services in each region. The difference between this scheme and those studied by the TRRL and others is that the local hauliers' depots were therefore a substitute for, rather than an addition to, a link in the manufacturer's own distribution system. The savings to be expected were conservatively estimated as follows as a percentage of the current distribution costs(76).

Depot	Saving
1	22%
2	23%
3	15%
4	26%
5	12%
6	13%
7	9%
8	32%
9	30%
Total of these 9	20%

To encourage existing commercial services is preferable to setting up a municipal organisation with monopolistic powers. The fact that similar commercial operations are now growing in Britain at a rate of 10% per year(77) suggests that the encouragement required might not have to be very great.

A further attraction of area schemes, however run, is that they would facilitate the introduction of goods vehicles specially designed for towns. Because such vehicles would not need the range, speed and (very often) hill-climbing capabilities of lorries used for long distance work, they could be much quieter than conventional vehicles of similar capacity. An example of such a vehicle is the Dutch Creusen range of electric lorries, now being developed as an Anglo-Dutch joint venture. These vehicles have operated for many years in the Netherlands as travelling shops and have now been ordered by Cambridgeshire

County Council to serve as mobile libraries. The decision was taken after studies based on conservative assumptions had shown that the Creusen vehicles would cost the County Council 18% to 33% less, in terms of capital and operating costs together, than the nearest equivalent i.c. engined vehicle. The largest vehicle in the range has a payload of five tonnes and a gross vehicle weight of 10.2 tonnes. Its top speed is at present 20 km per hour, but a vehicle capable of 56 km per hour is now being developed and will be tested in late 1979. The range in multi-stop operation is 56 kilometres(78).

6.2 General Traffic Volumes

There is a wide range of restraint measures which have the effect, although it may be incidental to their purpose, that traffic volumes over a large area of a town are lower than they would otherwise be. These include subsidies to public transport, bus priority schemes and parking control. As a result traffic noise is also less than it would otherwise be, although where restraint measures have been in existence for a long time this consequence may not be appreciated. An interesting recent case of a deliberate attempt to reduce the traffic levels then prevailing was that of Singapore, where the method used was to charge vehicles to enter the central business district. An attitutde survey showed that reduction of noise was ranked high in importance and suggested too that people had noticed some improvement in this respect as a result of the scheme, which was also judged successful on other grounds(79).

As well as the direct effect in reducing noise, methods of general restraint create or strengthen opportunities for canalising traffic onto main roads. It was noted in Section 6.1 that canalisation is effective in that the extra noise on the main roads is likely to be small in relation to the gain on the relieved roads.

Objections on grounds of inequity apply less strongly if canalisation takes place in the context of a general reduction in traffic volumes so that, as far as possible, no one is worse off than before, and if compensation is paid to anyone who does become worse off.

A form of general traffic restraint which has so far received very little attention, except in the Netherlands and a few towns elsewhere, is to encourage cycling. A recent British study[80] suggests that if effective measures could be found the impact would be very great. The study took the form of a statistical analysis of the proportion of people living and working in the same town who cycle to work. This proportion varies between towns from virtually zero to over 50%; regression analysis was used to find what factors accounted for the variation. It was found that the main deterrents to cycling were hilliness, danger and rainfall, in that order, and that the influence of all other factors was slight. Danger is something which can be directly influenced by policy: it was found that "a highly dangerous town which is otherwise average with respect to other factors would have a 2% level of cycling as opposed to 20% if it were safe". Hilliness can be overcome by the use of power-assisted bicycles, of which there are now several types under development, or indeed of mopeds, which are in common use in many countries. Table 6.4, taken from this report, illustrates the possible consequences of overcoming both hilliness and danger.

TABLE 6.4 : INFLUENCE OF CONDITIONS ON THE PROPENSITY TO CYCLE

Characteristics of Town	Predicted share of journeys to work by cycle	Examples	Actual share of journeys to work by cycle
Hilly and dangerous	0%	Sheffield Plymouth Burnley	1% 2% 2%
Hilly but safe	4%	Matlock Worsley Bodmin	4% 4% 6%
Flat but dangerous	6%	Hammersmith Liverpool Barking	5% 3% 9%
Flat and safe	43%	Goole Newark Cambridge	52% 42% 36%

Even rainfall does not lie outside the scope of policy, in the sense that protection from it can be provided: the opportunities are greatest in new developments where streets can be arcaded.

These findings are likely to apply with equal or greater force to the journeys to school of older children, perhaps less to journeys for other purposes.

The terrain in the Netherlands is favourable to cycling and much has been done to encourage it by cycle tracks and priority measures. 25.5% of all journeys to work are made by bicycle and 9.4% by moped. The proportion made by either mode is naturally greater when distances are short, as Table 6.5 shows.

TABLE 6.5 : CYCLING TO WORK IN THE NETHERLANDS

Distance to work (km)	% of journeys by bicycle or moped
0 - 4	53.2
5 - 14	28.1
15 and over	3.1

SOURCE: Labour Force Sample Survey, 1975, Netherlands Central Bureau of Statistics

Cycling is also important in the Netherlands for day trips (made mainly for purposes of outdoor recreation and visits to family or friends): 22% of them are made by bicycle and 4% by moped.

The cost of cycling schemes varies greatly according to circumstances and the nature of the scheme. In Britain, there has been some revival of official interest in cycling in the last two years which has led to various schemes being started. One approach is to make cycle routes through residential streets and other quiet streets by reserving a section of the existing carriageway. A rough indication of the cost is £1,000 ($2,000) per kilometre when the work involved is limited to painting lines, putting in bollards and traffic islands, altering kerbs etc.; clearly much greater sums arise when it is necessary to put in traffic lights or to treat junctions in a special manner. It is also estimated in Britain that to construct a new cycle track three metres wide in open space (e.g. through a park) costs some

£20,000 to £30,000 ($ 40,000 to 60,000) per kilometre. This again excludes elaborate junctions, special lighting etc. which may sometimes be required. The British schemes are being monitored by the TRRL, but it is too early to say whether they are successful either in making cycling safer or in encouraging people to switch from motorised means of travel to cycling on a scale which would make a difference to traffic volumes and traffic noise(81).

At the other extreme, the Delft Transportation Plan included a proposal to provide a comprehensive bikeway network in this city of some 90,000 people. This included new subways under roads and new "bikes-only" bridges across canals in addition to numerous smaller measures. The cost was estimated at 20 million guilders in 1975; (1978 US $10.4 million); at that time most of the smaller works had been completed. It was claimed that this cost was very small in comparison with expenditure on provision for motor traffic to transport the same number of people(82).

6.3 Speed limits

A reduction in speed is unlikely to be very effective in itself in reducing noise in most urban situations where top speeds are already low. The reason is that engine noise predominates and the use of low gears means that engine speed does not fall with vehicle speed. Speed limits do, however, have an important indirect effect on noise through the restraint of volume, as the examples given in Section 6.5 below show, and, if enforced, would also reduce the noise emitted by the occasional vehicle at night travelling at a relatively high speed. Speed limits can have some effect in reducing the noise from urban expressways, especially in combination with other measures such as a reduction in the proportion of heavy lorries in the flow. A report(83) by CERN (IRT) illustrates this. It is assumed that initially cars travel at 80 and lorries at 65 km/h, and that a speed limit of 60 km/h is then imposed on both kinds of vehicle. The effect depends on the percentage of lorries in the flow, as is shown in column A of Table 6.6. Column B shows that this effect is less than that of suppressing the lorries entirely, without changing car speeds. The effect of both measures simultaneously (Column C) is more than the sum of the two taken separately, and as the report points out is also more than can be expected from measures to quieten vehicles.

TABLE 6.6 : THE EFFECT OF SPEED REDUCTIONS AND THE SUPPRESSION OF LORRY TRAFFIC ON THE NOISE FROM URBAN EXPRESSWAYS

Percentage of lorries in the flow	Reduction in Leq to be expected from:		
	A. Speed limits only	B. Suppression of lorry traffic only	C. Speed limits and suppression of lorries
10	2.0	2.8	6.6
15	1.7	3.9	7.6
20	1.5	4.9	8.6

Such reductions in speed would not reduce the capacity of an urban expressway. The narrowing of the differences in speed between urban expressways and other roads could lead to some drivers attempting to find short cuts via less suitable streets. If this could be prevented, the only costs would be those arising from increased journey times. Such increases are hard to calculate, since even on a particular journey the loss of time on one section may not result in a loss of the same amount on the journey as a whole, and in the slightly longer term marginal journeys will be suppressed or shortened.

6.4 Town Centre Pedestrianisation

Many towns in OECD countries have pedestrianised their centres, with varying degrees of completeness, in the last ten years; these schemes are usually accompanied by measures to give priority to public transport. Access for delivery vehicles is often limited to short periods of the day. Although noise reduction is sometimes an explicit objective, less effort seems to have been made to monitor changes in noise than in other aspects. (An exception is Munich where, according to a 1975 report(84), maps are being prepared to register all noise resulting from traffic.) Reductions in noise are to be expected in the restricted areas themselves, but since the restrictions often give rise to an increase in traffic elsewhere in the town, and some vehicular journeys will be longer, a net benefit in reduced noise nuisance, though likely, is not certain. A report[85] of a town centre scheme in Gothenburg stated that the noise level in the main shopping street was reduced from 74 to 67 dB(A). The accompanying increase of 25% in traffic on the ring road had given rise to no complaints from the public.

The common story of the early schemes is that they were at first resisted by shopkeepers, who feared loss of trade if people were not allowed to drive to the shop door, but proved commercially successful to the extent that shopkeepers have pressed for their extension.

6.5 Residential Environmental Areas

Attempts are now being made to extend the use of comprehensive restraint measures from shopping centres to residential areas. The most ambitious efforts have been in the Netherlands, especially Delft and Groningen. In a large scheme in Delft, traffic is allowed to enter the area but the physical design of the streets has been changed in a way that ensures that it is kept subordinate. Techniques include narrowing the street, either throughout its length or at certain points along it; making the level of the footpaths, rather than that of the road, continuous at intersections, so that motor vehicles have to go up a small ramp; designing corners such that they cannot be taken at speed; giving the road a rough surface to ensure low speeds. We have not seen a systematic evaluation of this scheme but from observation noise levels are low.

Various traffic management schemes in residential areas have been carried out in Norway. One for which the noise effects were studied with particular care was at Grünerløkka (see Section 6.1 above). A "package" of management measures involving road closures, bus-streets, no through traffic, parking restrictions etc. was introduced in 1975, at a total cost of 200,000 N.kr (1978 US $ 50,000). The before-and-after situation, in terms of the percentage of dwellings exposed to noise levels of different degrees, is shown in Table 6.7.

TABLE 6.7 : DWELLINGS EXPOSED TO DIFFERENT DEGREES OF NOISE BEFORE AND AFTER THE GRÜNERLØKKA TRAFFIC MANAGEMENT SCHEME

Leq, measured in dB(A)	Before	After
75 or over	15%	11%
70 or over	51%	29%
65 or over	83%	62%
61 or over	87%	76%
All dwellings	100% 4168	100% 4168

A more detailed analysis showed that for 45.5% of dwellings the noise climate had improved as a result of this scheme, for 47.5% there was no change and for 7.5% the noise climate was worse. The changes for the worse were usually slight, whereas some of the improvements were very marked.

A further calculation was made of what it would cost to achieve specified indoor noise levels in this area by insulation alone and by insulation combined with traffic management. Table 6.8 shows that insulation combined with traffic management would be cheaper. This finding is supported by similar evaluations of other Norwegian traffic management schemes(73).

TABLE 6.8 : THE COSTS OF ALTERNATIVE STRATEGIES FOR ACHIEVING SPECIFIED NOISE LEVELS IN GRÜNERLØKKA

Strategy	Indoor noise levels, Leq		
	35 dB(A)	40 dB(A)	45 dB(A)
Insulation only	N.kr. 21.1 mn. $ 5.1 mn.	N.kr. 14.3 mn. $ 3.5 mn.	N.kr. 5.3 mn. $ 1.3 mn.
Insulation and traffic management	N.kr. 17.3 mn. $ 4.2 mn.	N.kr. 10.1 mn. $ 2.5 mn.	N.kr. 4.8 mn. $ 1.2 mn.

NOTE: N.kr. are in 1975 prices; $ in 1978 prices

In Britain there has been an experimental programme on the use of speed control humps in residential roads. These have been shown to be effective in reducing traffic volumes and speeds and hence noise. The results for three schemes are shown in Table 6.9 (86, 87, 88).

TABLE 6.9 : RESULTS OF THE INTRODUCTION OF SPEED CONTROL HUMPS

Parameters \ Towns		Abbotsbury Road Kensington	Motum Road Norwich	Cuddesdon Way Cowley
Flow (16 hours)	Before	8154	398*	2905
	After	5833	271*	1104
Mean speed (Km/h)	Before	48	49+	44
	After	27	40+	23
Noise Level (L10, 18 hrs.)	Before	71	57	65
	After	66	55	61

*Over nine hours

+85th percentile on the fastest section of the road.

The TRRL, which was responsible for these experiments, estimated that of the 4 dB(A) reduction in noise achieved at Cowley 3 dB(A) was attributable to reduced volume and the rest to reduced speed. Some diversion of traffic onto other roads within the residential estate was experienced, although not all the traffic diverted from Cuddesdon Way appeared on them: it is assumed that the rest was diverted to main roads outside the estate.

It is not surprising that residents of Cuddesdon Way approved of this scheme, but so did residents on other local roads, even those on which traffic increased as a result of the humps. Motorists also approved, even though for someone driving the whole length of the road the effect was to add approximately a minute to his journey time. Accidents in the estate as a whole decreased; it appears that safer conditions and reduced anxiety were the benefits most appreciated by residents. Noise benefits can be thought of as an extra. Nine humps were provided in Cuddesdon Way; the cost of constructing and installing each one in 1975 was £718 (1978, $ 1,900). This cost was said to have been higher than would have been necessary if permanent humps had been installed. No vehicle damage was reported.

6.6 Conclusions

The potential of traffic restraint as a means of noise abatement is as yet little explored but is clearly very great. One great advantage is that it deals simultaneously both with noise and with other kinds of nuisance from vehicles which other methods leave untouched or may make worse; this is especially true of pedestrian danger which is the most resented nuisance of all and which could be itensified by the introduction of quieter vehicles unaccompanied by other changes. The costs of traffic restraint schemes are also often justified by improved transport arrangements alone, without regard to a reduction in nuisance from vehicles. This can therefore be a highly cost effective means of noise abatement.

7. ENFORCEMENT

The noise emitted by vehicles depends not only on their type and their characteristics when new but also on how they are maintained and driven. Regulations governing maintenance and drivers' behaviour exist in all countries; their effectiveness depends on how well they are enforced.

In some countries inspection of older vehicles is required as a condition of the renewal of the vehicle licence. The main purpose of such inspection is to ensure safety, but a check on noise could be included and in Britain now is, although only in the form of the tester's judgement.

Some countries have found it advantageous to set up special police units to deal with offences involving noise. In Switzerland, a police noise brigade typically consists of six people. Their responsibilities cover noise from building sites, industry, places of public gathering and houses as well as from traffic. For road traffic the brigades can deal with noise from vehicles which are poorly maintained or deliberately modified and also with noise arising from inconsiderate behaviour, including running the engine at an excessive speed or driving pointlessly up and down a street. The costs of these units are not stated in the source document but it is claimed that they are cheap and effective(89).

In France, similar mobile brigades, each consisting of three men, have been in operation since 1973. They are concerned only with traffic but with fumes as well as noise. The brigades are equipped with measuring equipment. Drivers whose vehicles are found to produce excessive emissions are obliged to have the fault rectified and to report for a test within a specified time; in some cases they are not allowed to use the vehicle in the meantime. No costs are stated but again this seems to be regarded as a cost-effective measure(90).

Similar units, usually a team of two men, operate in San Francisco, apparently concerned only with vehicles and only with noise. It is claimed that between 1973, when the units were started, and 1978, the noise level (Leq) in the major business area has decreased by 3 dB(A) and that between 1974 and 1976 there were reductions in most areas of the city. The units are partly financed by fines levied on offenders; in 1975 revenue from fines exceeded $ 106,000. Total costs are not stated but in the opinion of a writer from the San Francisco Police Department "vehicle noise control is not difficult but rather practical, rewarding and easy to implement"(91).

Other states and municipalities in the United States have adopted programmes to control noise which include the control of vehicular noise as a central feature. One such municipality is the city of Colorado Springs, whose experience is described in a recent EPA report (92). In 1971 the city council passed a noise control ordinance based on a model community ordinance provided by the EPA. This prescribes a maximum noise level of 80 dB(A) at a distance of 25 feet for vehicles weighing 10,000 lbs (4535 kg) or less. For vehicles weighing over 10,000 lbs, the maximum permitted level is 88 dB(A) during the day, but from 7pm to 7am the maximum for such vehicles is also 80 dB(A) except on certain designated streets, consisting of arterial roads, where the daytime maximum obtains. Effective methods of enforcement have been developed over the years. The monitoring equipment is now mounted inside the police vehicle and has digital readout in dB(A) which can be locked in: evidence based on such readouts is accepted in court. First offenders are subject to a fine of $ 25, of which $ 15 is returnable provided that the fault is rectified and a compliance certificate obtained within thirty days. Penalties are increased for second or subsequent offences.

There has been no system of noise measurements to monitor the effect of the noise control programme but it seems to be accepted and regarded as worthwhile by the public. The annual budget of $ 60,000, or 30 cents per inhabitant, covers the salaries of the noise administrator and two noise enforcement officers as well as the cost of equipment. This sum relates to the entire noise control programme and not to the control of road vehicle noise only, although that is the major component.

8. PROTECTION

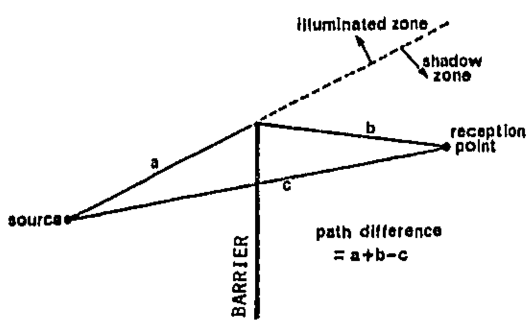
The previous sections have been concerned with ways of reducing noise at the roadside. The alternative is to protect people from the noise emanating from the road. In most existing situations the only feasible methods are to erect some kind of barrier near the road or to insulate buildings. With new roads or buildings, other possibilities for giving protection arise.

8.1 Barriers Versus Insulation

The effect of these two methods is not the same since insulation gives protection only inside buildings, and then only when the windows are closed, whereas barriers give protection outside as well. Given the importance people place on quiet conditions outside (see Section 1.2.2), barriers start with a great advantage. Insulation gives a higher degree of protection, however, which may be important in some very noisy situations, and the fact that it helps to keep heat in as well as noise out ought to be taken into account when deciding which method to choose in any particular circumstances. In practice, however, a direct choice will arise only rarely, since the dimensions of effective barriers (see below) are such as to preclude their use in most urban situations except alongside urban expressways.

8.2 Barriers

For barriers to be effective, they should be long and unbroken; this requirement immediately rules out their use when access is required to the carriageway at frequent intervals, as in most urban streets. In addition, a barrier must be so constructed that the noise transmitted through it is less than that radiated over the top. An approximate rule for fulfilling this condition is that the mass must be at least 10 kg per square metre. A barrier has a very small effect in reducing noise in the illuminated zone (see diagram); its effect in reducing noise in the shadow zone depends upon the difference between the length of the path joining the source, the top of the barrier and the reception point and the direct distance from source to reception point. The reduction in noise level at the reception point for various values of the path difference is shown in Table 8.1, taken from an



illuminated zone
shadow zone
reception point
b
a
c
source
path difference
= a+b-c
BARRIER

official British source.[93] The figures relate to the L_{10} index but should apply reasonably well to Leq although probably not to other measures such as L_{50}. Checks made by the TRRL at a number of sites[94] show good agreement between reductions predicted by the formula on which Table 8.1 is based and actual reductions.

TABLE 8.1 : REDUCTION IN L_{10} PRODUCED BY A BARRIER IN RELATION TO THE PATH DIFFERENCE

Path Difference, Metres	Reduction dB(A)
0.01	5
0.1	9
0.5	13
1	15.4
2	17.2
3	19.2

The most satisfactory type of barrier, where it can be erected, is an earth mound or earth-filled dry wall. The earth mound has the attraction that it can be planted but it may become unstable in dry weather. The disadvantage of both types of structure is that the width at the base is likely to be at least 1.5 metres for a structure 2 metres high and proportionally more for taller structures. A wall will always require a guardrail; a mound may not. If an earth barrier is put up at the same time as the road is built, the cost can be very small and conceivably even zero, in that building a mound may be the cheapest way of disposing of the surplus soil. When a barrier of this form is constructed alongside an existing road, a major determinant of cost is likely to be the transport of the soil, the extent of which will vary widely from site to site. Another variable factor is whether suitable equipment is to hand or has to be brought in. The costs arising on any particular contract can therefore only be treated as a general guide.

In the British examples, shown in Table 8.2, barriers were put up at the same time as roadworks were in progress. A guardrail was required in each case.

TABLE 8.2 : RECENT BRITISH EXAMPLES OF EARTH BARRIERS

	1	2	3
Type of Structure	Earth-filled Dry Wall	Earth-filled Dry Wall	Earth Mound with welded mesh
Height (metres)	1.4	2.2	2.1
Date of Erection	1972	1974	1975
Total cost per metre of installation, less guardrail, £ at date	10	66	26
Equivalent cost $ 1978	43	226	72
Cost per metre of guardrail, £ at date	9	10	N.S
Equivalent $ 1978	39	34	N.S

SOURCE: Department of Transport, Engineering Intelligence Section

Where enough width cannot be provided, which is particularly likely to be the case when a high barrier is required in order to protect the upper storeys of buildings, a screen rather than an earth barrier is required. Except when constructed on the parapets of bridges or overhead roads, screens are rarely less than 2 metres in height and may be over 5 metres. Sometimes it is possible and advantageous to place a screen some way back from the road, but it should usually be placed alongside the road and will then need to have a guardrail in front of it. It is sometimes possible to mount the guardrail on the same supports used for the screen; by this means the total width required at ground level can sometimes be reduced to as little as 1.25 metres.

Tere are two types of screen, absorptive and reflecting. Absorptive screens are more expensive but may be required when both sides of the road require protection. British studies have found that a reflecting screen can increase the noise level on the opposite side of the road by up to 1 dB(A) (94).

The purely acoustic requirements of a screen could be met by a brick wall or heavy timber fence, but the design and costs are determined by the engineering requirements of such a high structure, especially the need to be able to withstand high winds. Hence the total cost of installation even of a prefabricated screen of a given type can vary considerably from site to site. In addition, a requirement to choose materials with good appearance can add substantially to costs.

A great deal of information on costs is available but is not always expressed in a useful form; nor is it always clear exactly what the costs cover. In the examples in Table 8.3 from various European countries, the costs are believed to be those of the total installation, but without any guardrail, except where otherwise stated. Costs are per metre of length. Costs given in the source documents per square metre have been converted to a cost per metre of length on the assumption that the screen would be 3.5 metres high, which is a frequently found height. Some screens, especially if made from wood, plastic or glass, are likely to require maintenance, but we have found no information on these costs.

American experience with barriers is very fully described and illustrated in a 1975 report of the US Department of Transportation (95). Information on a number of projects which had been completed shortly before the publication of that report is given in Table 8.4, but the full report would be of interest to anyone concerned with barrier design and selection. Costs are for the complete installation.

In some cases, particularly where high rise buildings border a road, acoustic barriers would not suffice but an acoustic shelter, in effect a tunnel, would have to be provided. Apparently there is experience of acoustic shelters in Japan (96) but costs have not been supplied. Table 8.5 presents costs from a recent French study; (97) the figures are based on experience of particular installations.

No.	Country and Place	Material	Height (metres)	Year	Cost per metre length	1978 $ equivalent	Comment	Source
1	Netherlands Papekop	Aluminium	2	1978	672 fl	297	In this and the following Dutch examples prices include tax at 18%	Ministerie van Volksgezondheid en Milieuhygiene
2	Netherlands Kapelle	Aluminium	2	1978	635 fl	281		" " " "
3	Netherlands Gouda	Aluminium	2	1976	697 fl	331		" " " "
4	Netherlands Dordrecht	Aluminium	2	1976	550 fl	261		" " " "
5	Netherlands Amsterdam	Wood	2	1977	440 fl	195		" " " "
6	Sweden	Steel covered with plastic	3.5	1974	1,000 Sw.Crowns	311	Neither this nor any of the following examples are taken from actual sites although the costs allow for installation	Swedish Traffic Noise Committee
7	Sweden	Laminate of mineral wool enclosed by painted sheets of aluminium	3.5	1974	1,200 Sw.Crowns	374	Highly absorptive	" " " "
8	Sweden, but manufactured in W.Germany	Sound absorbing material enclosed in plastic. Steel columns and horizontal members. Concrete foundations	3.5	1974	1,500 Sw.Crowns	467	Highly absorptive	" " " "
9	Sweden	Triangular elements of concrete, with wood on side away from road, to be filled with soil	3.5	1974	1,050 Sw.Crowns	327	Cost excludes soil fill	" " " "
10	France	Concrete	3.5 (notional)	1978	1,750 F to 3,325 F	370 to 703	This example and the next two are not taken from particular sites. The variation in the cost of screens made from concrete or plastic depends upon their absorbing properties	IRT
11	France	Concrete	3.5 (notional)	1978	2,030 F to 3,325 F	429 to 701		IRT
12	France	Glass	3.5 (notional)	1978	2,975 F	629		IRT
13	France Bron	Concrete	5	1976	2,156 F to 2,556	519 to 615	For this and the following project the date is taken to be that of the source document. The dates of the projects themselves are not known but it is assumed that they were recent or that costs were expressed in the report in 1976 values	IRT

TABLE 8.3 (contd)

No.	Country and Place	Material	Height (metres)	Year	Cost per metre length	1978 $ equivalent	Comment	Source
14	France Bron	Concrete	6	1976	3,000 F	722	The cost reflects special care to make the wall look more attractive	IRT
15	Britain	Concrete	3	1978	£50-£70	98-137	Range reflects experience at a number of sites. The accompanying guardrail would cost an additional £12 metre fully installed (this applies to the next example as well)	Department of Transport Engineering Intelligence Section
16	Britain	Timber with steel posts	3	1970	£50-£70	98-137	Range reflects experience at a number of sites. The material is more expensive than concrete but installation is cheaper because cranes would not be required.	" " " "
17	Britain Newmarket by-pass bridge parapet	Translucent glass reinforced plastic with wire mesh	1.5	1976	£30	71	Costs are exclusive of installation. This example is chosen as representing the upper end of the range in Britain	" " " "

TABLE 8.4 : AMERICAN EXAMPLES OF BARRIERS

No.	State	Material	Height (metres)	Date	Cost at date per metre length ($)	1978 $ equivalent	Comment
1	Michigan	Timber	4.1	1974	220	276	
2	North Carolina	Timber	3.0	1975	108	125	Work started 1974, expected completion 1976
3	Washington	Timber	3 to 4	1973	120 for 3 m high 190 for 4 m high	167 269	
4	California	Steel panels	2.4 to 2.7	1974	115	144	
5	California	Steel panels	1.8	1975	171	197	Overlapping sections with baffle walls of approximately 2 metres installed at right angles to fill the gaps between the sections
6	California	Stucco-covered chainlink fence	1.8 to 2.4	1975	171	197	
7	California	Reinforced concrete	1.8	1975	121	141	
8	California	Concrete: split face masonry blocks	2.4	1973	75	105	
9	California	Concrete: buff coloured masonry blocks	2.0	1974	66	82	

TABLE 8.5 : FRENCH DATA ON COSTS OF ACOUSTIC SHELTERS

Type of Tunnel	Total Costs per Metre Length of a Shelter 30 metres wide	
Light	F. 1978 $ 1978	70,000 to 79,000 14,800 to 16,702
Semi-heavy	F. 1978 $ 1978	103,000 to 121,000 21,776 to 25,581
Heavy	F. 1978 $ 1978	139,000 to 157,000 29,387 to 33,192

NOTES: 1. Costs include lighting at 13,500 F ($ 2,854) and ventilation at 5,100 F ($ 1,078) per metre.

2. A light shelter is one which serves an acoustic purpose only and would not bear any significant weight; the top of a semi-heavy shelter could be used by pedestrians or could be planted; a heavy shelter is in effect a tunnel over which heavy traffic could pass.

8.3 Insulation

To insulate against road traffic noise, it is generally necessary to treat windows only, although in particular cases airbricks, doors and chimneys may require attention. The seals of windows that are not designed to open, and the joints of those that are, are of especial importance and good materials must be used to prevent them becoming distorted and thereby less effective. The effectiveness of different types of insulation is illustrated by Table 8.6, taken from an official British source[98], but it must be remembered that insulation is less effective against low frequency noise (see Section 1). The reduction is measured by the difference in L_{10} (but the figures would also apply to Leq) just outside and just inside the building. In many situations in which insulation is judged appropriate, a reduction of at least 20 and sometimes of over 30 dB(A) is required to bring about good internal noise levels.*

*In Britain the noise level at which compensation against noise from new roads becomes due is 68 dB(A), measured by 18 hour L_{10}, and the highest level likely to be found, in the extreme conditions of a house adjacent to a motorway, is some 82 dB(A). An internal noise level of 50 dB(A) is regarded as a minimum standard and 40 dB(A) as a good standard [98].

The cost of making windows soundproof is less for a new building than an old, but in practice the problem of insulating old buildings arises much more frequently. The costs of installation then depend on the number, size and type of the windows to be treated, the type and quality of the equipment used and the general level of manufacturing and building costs. Ancillary costs of installing artificial ventilation and making good decorations etc. may or may not arise. Presumably certain types of installation will require more maintenance than an unsoundproofed window, and a ventilation system is likely to involve operating and maintenance costs. We have not seen references to such costs nor to the value of heat savings achievable through insulation.

TABLE 8.6 : REDUCTION IN NOISE LEVEL PROVIDED BY WINDOWS

Window type	Approximate sound insulation in dB(A)
Wide-open window	About 5
Slightly-open single window	10-15
Closed 'openable' single window	18-20
Sealed single window with powered extractor fan in window:	
3mm glass	23*
4mm glass	25*
6mm glass	27*
10mm glass	30*
Double window with staggered opening lights giving 5% 'indirect' ventilation (any weight of glass, with an air-space of 200mm and absorbent-lined reveals):	
When opening lights used for ventilation	20
When opening lights not required for ventilation	33
Double window with an air-space of 200mm and absorbent-lined reveals, outer light fixed, inner light openable but well fitted:	
4mm glass	40
6mm glass	42

* The figures given are for when the fan is shut off. When the fan is operating and the fan hood or shutters are open there is approximately a 5dB(A) reduction in sound insulation.

The variability of installation costs and the fact that the source documents do not always make it clear exactly what the quoted costs cover make it difficult to provide precise comparative figures, but the following data from various OECD countries may be useful as a guide to orders of magnitude. Table 8.7 shows costs of insulating windows per square metre in Britain and France. Table 8.8 shows similar information from Germany and Table 8.9 from the Netherlands. The French and German figures are believed to be total installation costs in all cases, but the British figures exclude labour charges. The costs relate to insulating windows in existing buildings unless otherwise stated. The reasons for the apparent differences between the two French sources are not known.

TABLE 8.7 : SOME FRENCH AND BRITISH COSTS FOR INSULATING WINDOWS: COSTS PER SQUARE METRE

No.	Country	Type of Fitting	Ventilation included	Year	Cost per m^2	1970 US $	Comment	Source
1	France	Single glazing with thick glass (8mm) and tight frames	No	1977	1,000 F	200		See Ref.22, Page 40 supplemented by other information from CERN
2	France	Double glazing in a single aluminium frame	Yes	1977	1,900 F	417		As example 1
3	France	A double window plus ventilation	Yes	1977	2,800 F	615		As example 1
4	Britain	Applied sash system	No	1973	£17	67	In this and the following British examples, labour costs are excluded	The environmental evaluation of transport plans, Department of the Environment Research Report No. 8, 1976
5	Britain	Sealed insulating glass units	No	1973	£18	71		As example 4
6	Britain	Horizontal sliding second window	No	1973	£20	79		As example 4
7	Britain	Vertical sliding second window	No	1973	£25	99		As example 4
8	Britain	12 mm glass panes	No	1973	£14	56		As example 4

TABLE 8.8 : SOME GERMAN COSTS FOR INSULATING WINDOWS

Type of Window	Damping Effect (dB(A))	Without Ventilation		With Ventilation	
		Wood Cost per sq.metre	Aluminium Cost per sq.metre	Wood Cost per sq.metre	Aluminium Cost per sq.metre
Compound window	25	DM 270 $ 171	-	DM 710 $ 449	-
Sound insulating window, single	30	DM 480 $ 303	DM 540 $ 341	DM 1,250 $ 790	DM 1,320 $ 834
Sound insulating screen	35 - 38	DM 510 $ 322	-	-	-
Compound sound insulating window	40	DM 650 $ 411	-	DM 1,430 $ 903	-
Sound insulating box type window	45 - 46	DM 680 $ 430	DM 760 $ 480	DM 1,450 $ 480	DM 1,540 $ 973
Sound insulating box-type window with separate frame	50	DM 700 $ 442	DM 810 $ 512	DM 1,480 $ 935	DM 1,590 $ 1,005

NOTES:

1. Information relates to a fitted window, including cost of removing the old one but not including VAT. There may be variations of ± 10%, according to difficulty of removing old window.

2. German costs relate to 1972; the dollar equivalent is for 1978.

SOURCE: "A study of environmental pollution by road traffic in urban areas". Directorate General for Transport, Commission of the European Communities. 282/V11/74 - E.

TABLE 8.9 : SOME DUTCH COSTS FOR INSULATING FACADES BY FITTING FRAMES WITH OPENABLE WINDOWS

Work Involved	Damping Effect dB(A)	Costs	
		f 1976	$ 1978
Supplying and fitting windows with single thick panes with airtight sealing in their original frames	25-32	50-100 per square metre	24-48
Supplying and fitting a ventilation unit above the windows		150-200 per metre of length	71-95
Removing old windows and supplying and fitting compound sound insulating windows	32-37	400-550 per square metre	190-261

NOTES: 1. The facades consisted of masonry walls.

2. In the second example, a ventilation unit above each window was also fitted although the costs are not shown.

3. The ventilation units were themselves soundproofed.

4. Costs are exclusive of value added tax.

SOURCES: Reports of project VL-11 "Experimental project on application of soundproofing to dwellings as protection against aircraft noise" and reports of project VL-12 "Inventory of knowledge pertaining to acoustic insulation of buildings". Interministerial Committee on Noise Abatement.

Figures relating to the costs of insulating rooms or houses are even harder to interpret without a very precise description of the work involved. However, some recent figures may be of some interest.

i) A French study in the Department of the Rhone estimated that the average cost of insulating the exposed facades of 600 dwellings was 20,000 francs (figures presumed to be 1978; equivalent to $ 4,228). This figure relates to dwellings having at least four rooms and includes the cost of ventilation (99).

ii) Another French study among people who had had their dwellings insulated showed the following costs (see Table 8.10), excluding any ventilation (99). Costs are again assumed to be at 1978 prices.

TABLE 8.10 : SOME FRENCH INSULATION COSTS PER ROOM

Number of Rooms Insulated	Total Costs	
	Francs	$
1	5,000	1,057
2	9,500	2,008
3	13,000	2,748
4	14,500	3,066
5	15,500	3,277

iii) Some French costs relating to new buildings and to an average dwelling show that to achieve a noise reduction 10 dB(A) superior to the protection provided by a standard building would add 1% to building costs; a reduction of 15 dB(A) would add 3% and a reduction of 22 dB(A) would add 7% (101).

iv) In Britain insulation costs are paid by the Department of Transport in certain circumstances for living rooms and bedrooms on the side of a house exposed to traffic. In late 1977 it was estimated that "a figure of £600 - £700 would probably be about correct for a standard property with few complications" (100). The 1978 dollar equivalent of this would be $ 1,200 to $ 1,400. The cost allows for ventilation.

v) A Dutch report shows the following costs (see Table 8.11), based on actual experience for insulating dwellings against road traffic noise. The calculations assume that for flats it will be necessary to treat one side of the building only but that some of the houses require treatment on more than one side.

TABLE 8.11 : SOME DUTCH INSULATION COSTS PER DWELLING

Noise Reduction		Cost per Dwelling	
		f 1976	$ 1978
20-25 dB(A)	Flats One Family Houses	4,000 4,000	1,900 1,900
25-30 dB(A)	Flats One Family Houses	6,000 7,000	2,850 3,325
30-35 dB(A)	Flats One Family Houses	9,000 12,000	4,275 5,700

SOURCE: Report VL-HR-20-01 : "Determining the financial consequences of policy standards and measures on abatement of traffic noise." Interministerial Committee on Noise Abatement.

8.4 Other Protection

When a new road is being planned or a new area laid out, or better still, both at once, various other opportunities for giving protection from noise arise. These include:

- Depressing the road. The effect is similar to erecting a barrier alongside a road at ground level and will operate only if the buildings to be protected are set back far enough to be in the shadow zone.

- Separating the road from the buildings or other facilities it is required to protect. Doubling the distance between source and receiver reduces noise levels by 6 dB(A), but as noted in Section 1 the effect is much less for low frequency noise.

- Inserting a screen of buildings, preferably buildings such as warehouses, which by the nature of the activity carried on within them can be exposed to road traffic noise without much harm being done, between the road and the areas it is required to protect. A continuous line of buildings gives protection much superior to that from a screen.

- Designing the road network in a way which encourages the canalisation of road traffic onto selected roads and discourages unnecessary vehicular movement or high speeds on other roads.

- Determining the number and location of facilities of a type which generate large volumes of traffic, particularly lorry traffic, in such a way as to minimise the mileage performed within the area as a whole or in more sensitive districts.

- Laying out streets and buildings in a way which avoids the reflection of noise.

- Designing particular buildings such that staircases, corridors or relatively unimportant rooms are exposed to the traffic and important rooms are on the protected side of the building.

To calculate the costs of adopting such measures in any particular situation requires the detailed specification and costing of the optimal design with the measures in question and of the alternative optimal design if noise were not a consideration. This labour will not normally be undertaken; moreover the results are likely to be highly specific to the particular circumstances.

A recent French study quotes several examples where alternative designs for new housing were considered. In one case, it seemed that a design for a residential estate substantially superior to the one which, unfortunately, had by then been followed would have been possible with no extra cost and indeed with some saving in the construction of noise barriers. In other instances the extra costs seemed very modest (102). These findings suggest that care in the design of new districts is important and does not necessarily carry a cost penalty. Nevertheless, some of the solutions listed above are hard to reconcile with other desirable urban qualities. To separate roads from buildings by distances which would be effective in reducing noise may mean an ugly and wasteful use of space. Also journey lengths will be increased, especially for pedestrians, by amounts which may be significant, and opportunities for casual social contact may be reduced. To design streets in such a way that the important rooms in the buildings which line them all face away from the street could have a devastating effect on their appearance and on the sense of community which traditional streets often help to create.

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100. Letter from Department of Transport to Metra Consulting Group dated September 19, 1977.

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PART B : AIRCRAFT NOISE

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1. MEASUREMENT

Aircraft noise is probably the most difficult type of noise to measure. It is therefore necessary to make some introductory comments on the methods used.

Whereas road traffic and industrial noise is usually fluctuating but continuous, aircraft noise consists of a series of discrete events corresponding to aircraft movements (take-offs, landings).

Therefore instead of referring to "measurements of single moments of noise" and "measurements of noise over a period", as we do in Parts A and C, aircraft noise is described in terms of single events and cumulative noise exposure.

1.1 Measuring Single Events

The most widely used measure is Effective Perceived Noise Level (EPNL), in units of EPNdB, and it is a time integral of Perceived Noise Level (PNL), adjusted for spectral irregularities.

Throughout this report we use this measure for single events. In order to make comparisons with other types of noise, the reader should subtract 13 units from the numerical value of EPNdB to obtain the approximate numerical value of dB(A).

Since the source is moving it is necessary to measure EPNL at more than one point. Three measurement points are commonly used, referred to as "take-off", "approach", "sideline".

1.2 Measuring Cumulative Noise Exposure

Many different aircraft noise exposure indices have been developed (for a list of the main ones, see "Reducing Noise in OECD Countries", page 42).

The main characteristics of all these indices is that they take into account:

i) the number of aircraft;
ii) their noise levels;
iii) time (day or night).

The measures used in this report are the British Noise and Number Index (NNI) and the American Noise Exposure Forecast (NEF) and Day/Night Sound Level (Ldn).

The general equivalencies are shown below:

NEF 20 = Ldn 55 = NNI 10

NEF 30 = Ldn 65 = NNI 32

NEF 40 = Ldn 75 = NNI 55

2. NOISE ABATEMENT AT SOURCE

The International Civil Aviation Organisation (ICAO, an agency of the United Nations) has set out noise certification standards for subsonic jet aircraft. These standards, referred to as "Annex 16"[1], are periodically updated to reflect the latest technology. In the United States, Part 36 of the Federal Aviation Regulations ("FAR 36") sets similar standards.

These standards require new aircraft types to conform now or in the near future with maximum noise levels which are much lower than those produced by earlier aircraft types. This has led to the introduction of new, quieter aircraft (e.g. DC-10, L-1011, Airbus). Nevertheless, it is still the older, noisier aircraft types that dominate at most major airports (e.g. B-707, DC-8, B-727, B-737, DC-9, BAC 1-11, Caravelle).

A recent US policy statement[2] comments:

> "A significant problem is posed by the older, four-engine models (B-707s, B-720s, DC-8s) in the current fleet. These aircraft are, for the most part, powered by JT3D turbofan engines and impose the most severe noise insult on airport neighbours because they cause the noisiest single events (10 to 12 EPNdB over Part 36). They are perceived to be at least twice as loud as the new wide-body aircraft. They are particularly significant contributors to the overall noise level at major airports having serious noise problems.
>
> The older two- and three-engine aircraft (B-727s, B-737s, DC-9s, BAC 1-11s, mainly powered by JT8D turbofan engines) are not as noisy on single events. But, because they are medium and short-range models, they take off and land more than four times as often per day as the long-range four engine models."

Thus, if significant reductions are to be made in community noise loads, it is necessary to adopt measures with regard to these older aircraft to ensure that their noise levels are substantially reduced. The possibilities for noise abatement at source in the case of jet aircraft consist of reducing the noise produced by the engines.

Three possibilities exist:

1. Jet Engine Retrofit
2. Jet Engine Replacement
3. Aircraft Replacement

Each is discussed separately below. Most of the studies that have been undertaken, on the costs of these measures, relate to the attainment by the older jets of the standards set out in Annex 16 or FAR 36. It should be borne in mind, however, that the attainment of these noise levels is no guarantee of the eradication of noise nuisance in the vicinity of airports, although it would certainly represent a substantial reduction in community noise loads.

2.1 Jet Engine Retrofit

The main sources of information on retrofit that have been brought to our attention are:

i) A retrofit investigation[3] set up by the European Civil Aviation Conference (ECAC) and undertaken by a group of experts from member states (known as "ANCAT"). This relates to compliance with Annex 16.

ii) Studies for UK[4] and the Netherlands[5], some of the results of which were used in (i) above.

iii) Studies by, or on behalf of, US governmental agencies[6, 7, 8, 9, 10] (e.g., FA, EPA).

Most of the cost data is now a few years out of date. The US studies were mostly carried out in the period 1973 to 1976, and in Europe attention has tended to move away from retrofit because of the high costs demonstrated in the ECAC investigation in 1975. In addition, significant numbers of the older aircraft types within the ECAC states have since either been retired (Caravelles, VC-10s, Tridents) or sold to areas outside Western Europe.

The technical possibilities for modifying jet engines in order to abate noise emission are concentrated today in two technologies:

i) Engine nacelle retrofit-acoustical treatment with sound absorption materials (SAM).

ii) Engine refan retrofit - new front fan with higher by-pass capability (REFAN).

The REFAN technology involves considerably greater expenditure since it entails modification and replacement of certain engine and nacelle components. Consequently SAM tends to be the more favoured of the two approaches and in fact was the only one considered by the ECAC/ANCAT group in their investigation.

Number of aircraft to be retrofitted

Table 1 summarises the number and type of aircraft that would need to be retrofitted: 6 - 700 in Europe, 1200 in USA. The European estimate excludes 121 aircraft that could not be modified to meet the standards of Annex 16.

In Europe there is a much wider range of aircraft types because of the importance of British and French aircraft (e.g. BAC 1-11, Trident, Caravelle). For further details of the aircraft/engine combinations and their status with respect to Annex 16, see Appendix 1.

TABLE 1 : NUMBER OF AIRCRAFT TO BE RETROFITTED

Aircraft Type	ECAC States (1975 Estimate)	USA (1976 Estimate)
B-707 & DC-8	160 [a]	270
B-727	79	454
B-737 & DC-9	240	448
B-747	4	45
Others	174 [b]	-
TOTAL	657	1217

(a) Includes 4 B-720

(b) Includes 82 BAC 1-11, 41 Tridents, 30 Caravelles, 11 Super VC-10 and 10 Mercure

Sources: For ECAC States, see Ref. (3), Table 2

For USA, see Ref. (2), p.38

TABLE 2 : ESTIMATED COST OF RETROFIT BY COUNTRY
(in thousands of 1975 US dollars)

COUNTRY	Number of aircraft to be retrofitted	Capital cost (incl. down time)	Financial costs	Operating losses	Total
Austria	9	1 980	716	1 735	4 431
Belgium	6	6 180	1 133	1 200	8 513
Cyprus	0	0	0	0	0
Denmark	23	6 529	1 862	2 840	11 231
Finland	20	5 690	1 718	5 807	13 215
France	58	35 059	13 998	49 697	98 754
Germany	75	27 885	5 112	15 343	48 340
Greece	12	10 860	3 010	4 310	18 180
Iceland	3	2 250	826	2 850	5 926
Ireland	18	8 005	4 688	3 760	16 453
Italy	63	22 220	11 114	18 734	52 068
Luxembourg	0	0	0	0	0
Netherlands	33	15 237	5 535	8 000	28 772
Norway	19	6 432	1 785	3 293	11 510
Portugal	19	17 870	4 549	8 520	30 939
Spain	66	22 630	7 353	13 860	43 843
Sweden	24	8 674	2 278	3 906	14 858
Switzerland	37	13 496	3 124	6 608	23 228
Turkey	13	2 900	1 062	1 755	5 717
United Kingdom	159	100 161	30 809	111 153	242 123
TOTAL ECAC	657	314 058	100 672	263 371	678 101

Source: Ref (3), page 11.

NOTE: In order to express these costs in 1978 US dollars, each figure should be multiplied by 1.16. However, there are dangers in doing so, because the original cost estimates were presumably expressed in local currencies, whose relationships with the US dollar may since have altered significantly.

Cost of retrofit

The SAM retrofit costs identified by ECAC/ANCAT[3] are summarised in Table 2. They include:

a) The capital cost of the retrofit operation. This includes the price of the hush-kit, spares, manpower costs and some other minor costs.

b) The reduction in net revenue, during the few days that it would take to make the modifications.

c) Operating losses caused by the modifications.

   These include:

   i) a reduction in net revenue caused by the loss of payload;

   ii) costs associated with increased fuel consumption;

   iii) increased maintenance costs.

d) Financial costs. A 10% interest rate was applied to the investments (the first two items above), which were written off linearly over the remaining aircraft life and expressed in constant currency (1975 dollars).

The total costs approximate to $1.0 million (1975) per aircraft, of which about 50% is the capital cost component. Table 3 presents the average costs per aircraft for 2, 3 and 4-engined aircraft, from which it can be seen that the retrofit costs for four engined aircraft are substantially higher than for the smaller aircraft. There are also significant differences within each category (e.g. the Trident cost is over 4 times that of the B-727). For details by aircraft type, see Appendix 2.

TABLE 3 : AVERAGE COSTS PER AIRCRAFT AND NOISE LEVEL REDUCTIONS FOR 2, 3 and 4-ENGINED AIRCRAFT

Average Cost per Aircraft ($m, 1975)	2-Engine Aircraft	3-Engine Aircraft	4-Engine Aircraft
Capital (including down time)	0.23	0.38	1.05
Operating Losses	0.19	0.37	0.86
Financial Costs	0.08	0.13	0.33
TOTAL PER AIRCRAFT	0.50	0.88	2.24
Range of Noise Level Reductions (EPNdB)			
Take Off	2 to 8	1 to 3	3 to 11
Approach	3 to 6	2 to 6	5 to 15
Sideline	-2 to 4	0 to 6	3 to 5

Source: ECAC Reference (3), pp. 3, 12-14

The US results are summarised in Table 4. They are in a different format than those for ECAC States - operating losses are expressed as a percentage rather than in absolute terms, and financial costs are excluded. However, there is a good correspondence between the two sources for the most important item, the capital costs associated with the retrofit operation.

The effectiveness of retrofit

In the ECAC Study[3], the noise reductions for different aircraft types were estimated by manufacturers under Annex 16 conditions. ECAC point out that the retrofit benefits are less marked beyond the ICAO

TABLE 4 : SUMMARY OF SAM RETROFIT COSTS FOR US AIRCRAFT

	Number to be Modified	Capital Cost $m/Aircraft	Total Capital Cost $m (1975)	Increase in Operating Costs
2-Engined				
DC-9	448	0.27	121	0.1%
B-737				0.2%
3-Engined				
B-727	454	0.225	102	0.1%
4-Engined				
B-707	270	1.2	324	0.5%
DC-8				0.6%
B-747	45	0.25	11	NS

Sources: Capital Costs - Ref (2), p.38

Operating Costs - Ref (10), p.183

measurement points (the furthest of which is 6500 m) because sound absorbent material primarily attenuates high frequencies.

In their report they present reductions as a range for 2, 3 or 4-engined aircraft (see Table 3), but do not give details for each aircraft type.

These details are however available from a UK study (see Appendix 3) and from various US documents (see Table 5), although they do not appear to be completely consistent with each other or with the ECAC ranges in Table 3. Nevertheless, despite these inconsistencies it can be seen that reductions are substantial on the B-707 and DC-8, but more modest on the smaller aircraft.

<u>Effectiveness at individual airports</u>

In support of the ECAC/ANCAT investigation some ECAC member states carried out studies on the noise exposure around individual airports for the 1980/5 period, assuming the extension of Annex 16 to all subsonic jets, (i.e., including aircraft of non-ECAC states).

Noise exposure was computed using methods developed locally in the different countries, i.e.:

- the Psophic Index — $\mathcal{N}$ (France)
- the "Kosten" Index — Ke (The Netherlands)
- the Critical Noise Level — KB (Sweden)
- the Noise and Number Index — NNI (United Kingdom)
- a "Modified Composite Noise Rating" — CNR (Denmark)

In order to have a common basis for the assessment of the effectiveness of retrofit, the following approximate relationships were adopted:

$$\mathcal{N} \simeq \text{NNI} + 38.5$$

$$\text{Ke} \simeq 4/3\ \text{NNI} - 8.2$$

$$\text{CNR} \simeq \text{NNI} + 56.5 \text{ (unmodified CNR)}$$

For Sweden, the contour corresponds roughly to a constant value of 35 NNI.

TABLE 5 : EXAMPLES OF THE NOISE LEVEL REDUCTIONS ACHIEVABLE WITH RETROFIT, EXPRESSED IN EPNdB

Aircraft	Condition	FAR 36 Limit	Non-Retrofit	Full Retrofit
707-320B	Takeoff	103.7	113.0	102.2
	Approach	106.3	116.8	104.0
	Sideline	106.3	102.1	99.0
DC-8-61	Takeoff	103.5	114.0	103.5
	Approach	106.2	115.0	106.0
	Sideline	106.2	103.0	99.0
727-200	Takeoff	99.0	101.2	97.5
	Approach	104.4	108.2	102.6
	Sideline	104.4	100.4	99.9
737-200	Takeoff	95.8	92.0	92.0
	Approach	103.1	109.0	102.0
	Sideline	103.1	103.0	103.0
DC-9	Takeoff	96.0	96.0	95.0
	Approach	103.2	107.0	99.1
	Sideline	103.2	102.0	101.0
747-100	Takeoff	108.0	115.0	107.0
	Approach	108.0	113.6	107.0
	Sideline	108.0	101.9	99.0

Source: FAA, Ref (2), p. 38

Using these relationships, the reductions in area in the year of maximum benefit, enclosed by the 35 NNI ($\mathcal{N}$ = 73.5; KB; CNR = 91.5; Ke = 38.5) contours was estimated to be:

15% (19.9 km^2) for Orly Airport

37% (238.3 km^2) for Heathrow Airport

8% (10.7 km^2) for Schiphol Airport

44% (48.0 km^2) for Kastrup Airport

7% (6.0 km^2) for Landvetter Airport

In terms of number of people living in these areas, the reductions correspond to:

20% (142,000 people) for all French airports

48% (681,400 people) for Heathrow Airport

24% (14,930 people) for Schiphol Airport

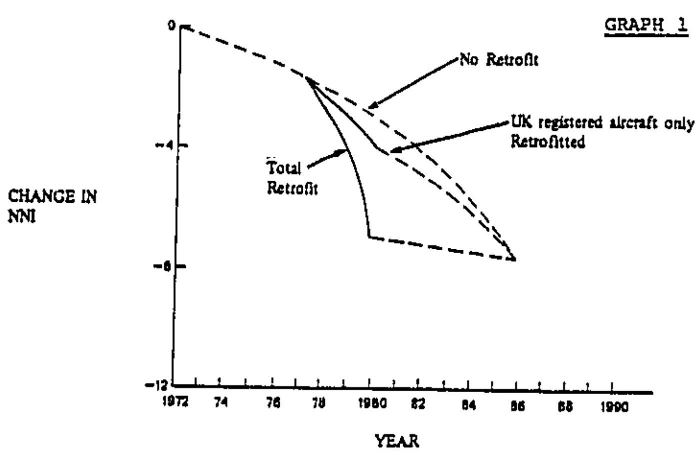
For Landvetter Airport, the study shows that the noise reductions are achieved outside residential areas. For Kastrup, no details are given.

With the proportion of new, quieter aircraft continually increasing, the time-scale needs to be borne in mind when considering these benefits. ECAC comments:

> "A retrofit decision would start to bring benefits about three years from its inception, with a maximum effect at about four to five years from inception; this benefit would slowly be overtaken by the natural replacement of the older, noisy aircraft, until between 1985 and 1990, when an equivalent position with or without retrofit would be reached. The size and timing of the benefits depend on the date on which a retrofit decision is made and the ability of manufacturers to supply kits."

This aspect is well illustrated in Graph 1, which relates to London Heathrow, although it is not known what traffic growth assumptions have been made.

GRAPH 1



The above graph assumes retrofit approved immediately and modification kits available one year later.

...... = Effect of commercial replacement

Source: Ref (4)

2.2 Jet Engine Replacement

Although at present it is not common practice, the opportunity exists of replacing noisy engines (JT3D, JT8D, etc.) by new, quieter ones on the same airframe. This is by no means straightforward since there are very few of a suitable size available. Most of the quiet engines were developed to power the new generation of wide-bodied jets, such as the CF6 (Airbus, DC-10) and the RB-211 (Tristar), and have a much higher thrust than the engines to be replaced.

Suitable engines are however emerging, particularly for JT3D replacement. The most promising appears to be the CFM56, being developed by CFM International (General Electric and SNECMA). Boeing are proposing to re-engine the 707 with these engines, for which it is reported[11] they would expect to charge US $9.5 million (1978) per aircraft.

It would also be suitable for the DC-8 Series 60 and in the early months of 1979 it was announced that three major US airlines are preparing for re-engining programmes that would convert approximately 50 of these aircraft. Total re-engining costs are reported to be about US $9 million (1979) per aircraft[11].

However the full cost implications for air transport operators are not yet clear. The old engines will presumably have to be written off, but there are substantial advantages associated with the new engines such as increased fuel efficiency. The US Department of Transportation[12] advise us that corporate officials responsible for the DC-8 re-engining effort estimate the CFM-56 powered DC-8-61 would experience a 20-25% improvement in fuel efficiency on long-range flights and 14-15% for the re-engined DC-8-62 and -63.

2.3 Aircraft Replacement

If old, noisy aircraft were replaced by the new technology aircraft, community noise exposure would be reduced in two ways:

a) The single event noise levels of the replacement aircraft would be lower than those of the older aircraft, even with SAM retrofit (see Appendix 3).

b) In some situations, the number of aircraft movements could be reduced, since the airlines might take the opportunity of introducing aircraft with a large number of seats than the aircraft that they replace. For example, one Airbus might replace one or more smaller aircraft such as a DC-9 or B-727.

At present these new aircraft types do not cover all the various airline requirements in terms of capacity and range (e.g. the low density routes). This problem can be partly overcome by some of the later versions of the "old" technology aircraft which are quieter than their predecessors (e.g. the DC-9 Super 80 series, powered by the new JT8D-209 engine).

The cost of replacing an aircraft will of course depend upon the age of that aircraft and its remaining lifetime. Any cost calculations are therefore likely to be sensitive to the interpretation that is put on the remaining lifetime of the aircraft. Air transport operators may differ in their interpretations. For example, some operators in highly competitive markets (e.g. charter operations) may be suffering from the recent increases in fuel costs, which may have made their older aircraft less competitive than modern, more fuel efficient aircraft. These operators may already be considering the possibility of retiring their aircraft in favour of the new ones. At the other extreme, some operators, in less competitive circumstances, may be very satisfied with their older aircraft and may be hoping to extend their lifetime for as long as possible within the constraints laid down by the aviation authorities. Among the aircraft that might be kept for as long as possible are the DC-8 series 60 aircraft, some of which are likely to last for as long as 80,000 flying hours which is equivalent to about 25 or even 30 years of commercial use.

Since any programme involving the early retirement of aircraft is likely also to assume that certain aircraft types are retrofitted, the cost studies that have been brought to our attention that discuss aircraft replacement are described in a separate section below.

2.4 Aircraft Replacement/Jet Engine Retrofit Combinations

Two major studies have been brought to our attention, one by the US Federal Aviation Administration (FAA)[9] in 1976 and the other by ECAC/ANCAT[13]. We understand however, that the latter is still at the Working Paper stage (late 1978) and remains confidential. This section could therefore only be based on the American study.

This study[9] considers the consequences of the FAA final rule which requires civil subsonic turbojet aircraft over 75,000 pounds maximum weight to comply with FAA Regulations Part 36 noise requirements under a schedule beginning January 1st, 1977 and ending December 31st, 1984. Only SAM quiet nacelle treatment along with early retirement of fleets are considered as alternatives in reducing noise at source to meet FAA requirements.

FAA anticipate that the airlines will modify (i.e. retrofit) the JT8D powered aircraft (B-727, B-737 and DC-9) and the small number of B-747 that do not comply with FAR 36. Exceptions are those aircraft which are due to be retired before the compliance deadline, based on an FAA evaluation of the intentions of airline managements. For the JT3D powered aircraft (B-707, B-720 and DC-8) the airline reaction is less obvious and the remaining aircraft with lifetimes beyond the compliance date could either be prematurely retired, sold or modified.

Given projections of the expected future composition of the airline fleet, the costs associated with three possible future scenarios are compared with those of a base case:

<u>Base Case</u>

No modifications or premature retirement. In 1985, and even in 1990, there would still be large numbers of noisy JT3D and JT8D powered aircraft.

	1976	1985	1990
JT3D	487	314	212
JT8D	1052	823	692

Case 1

JT3D aircraft - modify those with lifetimes extending beyond the compliance date.

JT8D aircraft - modify those with lifetimes extending beyond the compliance date.

B-747 - modify the small number not complying with FAR 36.

Case 2

As Case 1, except

JT3D aircraft - modify only 100, the remainder being prematurely retired or sold.

Case 3

As Case 1, except

JT3D aircraft - all prematurely retired or sold.

Thus, in all three cases, the JT8D powered aircraft and the B-747s are acoustically modified and the differences in the three cases only relate to the JT3D powered aircraft. A distinction is not drawn between premature retirement and sale, it being assumed that both courses of action prevent the aircraft from making any further noise contribution. If, however, other countries simultaneously enacted similar legislation, it would become very difficult to sell these aircraft. Whether or not this has been taken into account in this study is not clear.

Costs

Details of the main assumptions adopted in this study are given in Appendix 4. Given these assumptions, the study projects the net present value (at 10% discount rates) of the additional costs with respect to the base case for the period 1975 - 1995. These are summarised in Table 6.

TABLE 6

BEFORE TAX NET PRESENT VALUE OF INCREMENTAL CASH FLOWS RELATIVE TO THE BASE CASE 1975-1995
(Millions of 1975 Dollars)

Case	Net Present Value at 10% Discount Rate
100% Modified	439
Modify/Replace JT3D and Modify JT8D	228
Replace JT3D and Modify JT8D	-352

AFTER TAX NET PRESENT VALUE OF INCREMENTAL CASH FLOWS RELATIVE TO THE BASE CASE 1975-1995
(Millions of 1975 Dollars)

Case	Net Present Value at 15% Discount Rate
100% Modified	200
Modify/Replace JT3D and Modify JT8D	427
Replace JT3D and Modify JT8D	293

Note: All cases presume a purchase price of $23 million for new technology aircraft and a 6% annual increase in fuel prices after inflation. Positive net present values represent additional costs relative to the base case and negative net present values represent benefits relative to the base case.

The positive benefits associated with replacement are the results of the increased efficiency of the new technology aircraft. Fuel savings are the dominant aspect of this increase in efficiency. Maintenance and crew cost savings are also expected.

In Case 1, 100% modification, the negative net benefit to the airlines relative to the baseline is the result of an approximately 1% increase in out-of-pocket costs.

Thus, based on this comparison, the optimum means by which US airlines can meet the requirements of FAR 36 would appear to involve a combination of replacement and modification. All B-707 and DC-8 aircraft would be replaced by new technology aircraft, the latter being 30% more fuel efficient on a seat mile basis. It should be borne in mind however that the re-engining option was excluded for this study and, as explained earlier, it is now known that some B-707 and DC-8 aircraft are likely to be re-engined.

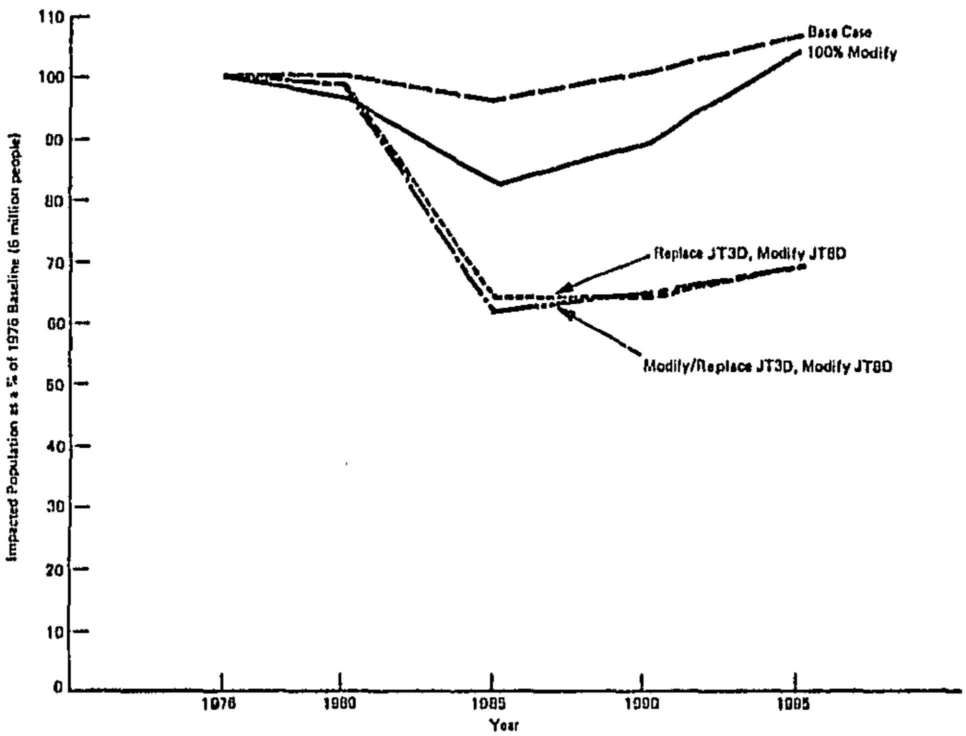
Using a similar approach a similar conclusion might be reached for ECAC airline fleets with respect to Annex 16 requirements. As mentioned earlier, the costs of early retirement are being investigated within ECAC but the results are currently not available.

Noise Benefits

Graph 2 shows the percentage change in the number of people exposed to a level of aircraft noise greater than 30NEF* for the base case and the three alternative cases. It can be seen that the replacement of JT3D powered aircraft and the modification of JT8D powered aircraft not only provides the optimal solution for the airlines, but also a relative effectiveness which compares well with the other options.

*NEF = Noise Exposure Forecast. This is equivalent to an L_{dn} level of approximately 65.

GRAPH 2



RELATIVE EFFECTIVENESS – IMPACTED POPULATION
(NEF 30)

3. NOISE ABATEMENT FLIGHT PROCEDURES AND AIRPORT NOISE CONTROLS

The opportunities offered by noise abatement flight procedures and airport noise controls have yet to be fully exhausted. Modest but worthwhile reductions in airport noise may be achievable at relatively low cost and within a comparatively short time-scale.

Some well documented examples exist of measures that have been adopted or considered. However, many of the examples relate to a specific airport (or aircraft type) and the conclusions on costs and benefits may not necessarily be applicable elsewhere.

Our approach in this report has therefore been to concentrate on what appear to be generally applicable conclusions.

Table 7 summarises the costs and benefits of various measures considered in an extensive US Study(14). (NB. The authors warn that the noise reductions shown are not necessarily additive.) The measures are discussed below under three headings:

a) Take-Off Procedures.

b) Approach and Landing Procedures.

c) Airport Noise Controls.

3.1 Take-Off Procedures

There are two types of noise problem associated with take-off: sideline noise and climb out noise. Each requires different noise abatement procedures.

For sideline noise, Hurlburt(15) concluded that reduced thrust take-offs are a technically feasible way of reducing sideline noise. Costs appear to be insignificant and there are savings in maintenance costs because of reduced engine wear.

For climb out noise, Hurlburt(15) identifies "power cut back" climb outs and "maximum angle (full power)" climb outs as two procedures currently in use. The choice between the two depends on the location of noise sensitive areas with respect to the departure runway, but flight safety standards often overrule such a choice. Power cut back after take-off reduces disturbance in residential areas crossed during the first few miles of a route, but the reduction in rate of climb worsens the situation for people

TABLE 7 : SUMMARY OF NOISE BENEFITS AND COSTS ASSOCIATED WITH MODIFIED FLIGHT PROCEDURES AND AIRPORT NOISE CONTROLS

Procedure/Control	Single Event Noise Reduction	Single Event Area Reduction (90 EPNdB)	Estimated Nationwide $L_{dn} \geq 65$ Takeoff or Landing Area Reduction	Estimated Nationwide $L_{dn} \geq 75$ Takeoff or Landing Area Reduction	Unit Costs
Take-Off Procedures					
Reduced thrust take-offs	0 - 2 dB	0 - 20% sideline only	1%		Possible engine wear savings
Power cutback departures	0 - 7 dB	0 - 15%	10%	6%	Probable fuel savings
Approach & Landing Procedures					
Reduce flap settings on approach	0 - 5 dB	0 - 30%	20%	5%	Probable fuel savings
Increased initial approach altitudes	0 - 10 dB	0 - 25%	10%		
3° ILS Glide Slopes	0 - 3 dB	0 - 25%	15%	15%	$50,000 per runway for system change $ 6,000 per runway for flight check Probable fuel savings
3.5° ILS Glide Slopes	3 - 6 dB	25 - 44%	35%	35%	$50,000 per runway for system change $ 6,000 per runway flight check or $200 per delayed flight Probable fuel savings
6°/3° Two Segment Approaches	0 - 17 dB	50 - 75%	64%	28%	$60,000 per runway for DME $31,400 per aircraft for glide slope computer (IFR only) $ 9,000 per aircraft for V-Nav as addition to R-Nav (IFR only) Probable fuel savings
Decelerating Approaches	0 - 3 dB	10 - 25%	15%	5%	Undetermined
Thrust Reverse Limitations	0 - 10 dB	0 - 75% sideline only	-	-	Possible brake wear cost
Airport Noise Controls					
Preferential Runways	0 - 30 dB	0 -100%			
Preferential Flight Paths	0 - 30 dB	0 -100%			
Night Curfews	-	-			
Aircraft Type Limitations	0 - 18 dB	0 - 94%	30%	30%	
Schedule Limitations	0 - 30 dB	0 -100%			
Trip Length Limitations	0 - 13 dB	0 - 85%			

living further away from the airport. Conversely, the full power procedures maximises noise in the immediate vicinity of the airport, but benefit people further away. This suggests that full power procedures might usefully be combined with SAM retrofit, the effectiveness of which is reduced by distance.

Detailed examples of the noise benefits for specific aircraft types are given by Hurlburt[16] and by Shapiro[17].

No significant costs have been identified that are associated with these modified take-off procedures. For power cut back take-offs there are substantial savings to be made. One airline[18] estimates that it saves a minimum of 4.5 million gallons of fuel and $1.6 million, and that the procedure significantly reduces engine wear and increases engine reliability.

3.2 Approach and Landing Procedures

The most promising procedures are briefly discussed below:

Low power/low drag approach

There is no unique version of this procedure but IATA recommendations exist describing the main features. The main principle is to minimise the drag (e.g. to avoid the extension of flaps and under carriage earlier than necessary). The lower thrust thus required results in a reduction in noise levels beneath the approach path.

Hurlburt (see Table 7) estimates a single event noise reduction of 0 to 5 dB. This is consistent with recent experience at London Heathrow[19] which indicates an average reduction of 3 dB.

There are no significant costs and the reduced power settings result in fuel savings.

Continuous Descent Approaches (CDA)

Using traditional approach procedures, aircraft fly lower than is necessary before intercepting the glide-path on which they land. The principle of the CDA procedures is that the glide-path is intercepted at a higher altitude. In USA this is aptly referred to as the "keep-'em-high" philosophy.

The noise reduction resulting from CDA comprises two elements, as described in a recent British paper[20]: "Over the area where the aircraft would traditionally be flying level to intercept the glide-path, CDA provides a reduction in source noise by virtue of the lower thrust required for descending flight. The second element of noise reduction is provided by the attenuation of noise on the ground resulting from the increased height of an aircraft performing CDA over that of an aircraft on the same track flying a level segment prior to glide-path interception.".

Hurlburt (see Table 7) estimates single event noise reduction in a range 0 - 10 dB. This is consistent with experience at London Heathrow[21]: "4 dB for CDA thrust benefit plus a further CDA height benefit varying from 0 to 5 dB depending on distance."

Costs are insignificant. Fuel consumption may be reduced[22] but not to the same extent as in LP/LD approaches.

Higher Glide Slopes

Increasing the slope of the glide-path from the conventional 3° entails a considerable noise reduction, because less power is required. However, ICAO[23], in guidance material prepared relating to the establishment of noise abatement operating procedures, states that glide-paths should not be above an angle of 3° because of safety considerations. Presumably therefore, this possibility is unlikely to be pursued. Costs and benefits are shown in Table 7.

Two Segment Approaches

In the case of this procedure the approach path is divided into two segments. In the steep segment (generally 6°) noise abatement is achieved as above with the transition to 3° normal glide slope occurring at an altitude sufficient to reduce the high rate of descent. The noise reduction is achieved by the combined effect of reduced power settings and higher altitudes.

This technique attracted considerable attention in the early and mid seventies(8, 24, 25, 26, 27), but very little progress appears to have been made in implementing this procedure.

For example, in USA it has now been ruled out by the FAA for reasons of safety(28). Costs and benefits are shown in Table 7.

Decelerating Approaches

In this procedure the aircraft starts its approach at a high speed and then thrust is reduced. Hurlburt(29) concluded in 1973 that it was technically feasible but: "had not proved adequate for widespread routine use". He suggests that this approach is best suited to aircraft with programmable automatic landing systems, which very few aircraft currently have. More recently a similar view was expressed to us in France(30) Costs and benefits are shown in Table 7.

Thrust Reverse Limitations

On landing it is common practice for the pilot to put the aircraft engines into reverse. This saves braking and tyre wear. Communities located alongside runways may find this particularly objectionable, because its sharp application makes it easily distinguishable.

Limitations on the use of this practice, particularly at night, would produce significant benefits in terms of sideline noise reduction (see Table 7).

The main costs are likely to be associated with additional brake wear and tyres. At some airports there may also be capacity implications, because thrust reversal can reduce the time spent on the runway and may be being used as a means of increasing runway capacity.

3.3 Airport Noise Controls

In this section we consider several noise abatement measures that are available to airport authorities and that are applicable at a local level. Emphasis is placed on measures against flying aircraft, rather than those against aircraft on the ground or other airport noise sources.

Their costs and benefits are very dependent upon local circumstances. Hurlburt (see Table 7) was unable to give any cost figures. IATA[31], however, have produced some very approximate world-wide averages that are useful for preparing order-of-magnitude cost estimates.

Noise Preferential Runways (NPR)

These are commonly used to direct flight paths away from noise-sensitive areas.

The main cost is that of aircraft diversion. IATA[32] assume:

1) that 20% of all aircraft movements at airports using NPR systems are significantly diverted;

2) that the duration of the average diversion for those movements diverted is 2½ minutes;

3) that the weighted average cost of flight time is $30/minute (1975 dollars).

Using these assumptions, an average cost per movement at airports using NPR systems would be $15 (1975 dollars).

Noise Preferential Flight Paths

These are also known as minimum noise routes (MNRs). As in the previous example, MNRs can minimise noise impact by routings which avoid noise sensitive areas. In its simplest form this could be a turn executed once a safe height has been achieved after take-off.

At some airports it may be preferable to share flights among several selected flight paths rather than concentrate on one[33, 34].

The main cost is that of aircraft diversion. IATA assume that the average diversion is 2 nautical miles (nm) and that, at the relevant stage of the flight, the aircraft speed could be 3.5 nm per minute. Using this assumption, an average cost per movement at airports using MNR systems would be $17 (1975 dollars).

Night Curfews

IATA[35] estimate that in 1975 there were 33 airports around the world known to impose a complete or partial curfew on jet aircraft movements at night. The number has undoubtedly increased since then. Examples of partial curfews include:

i) quotas, which define the maximum number of flights permitted;

ii) a night-time ban on noisy aircraft only, thus encouraging the use of new, quieter aircraft.

Sperry[19] considered the effectiveness of a national night curfew on United States airports. Assuming that 15% of all operations occur during the proposed curfew period (2200- 0700) a curfew would result in a reduction of the land area exposed to any NEF level by 60%.

A national curfew would affect maintenance, air cargo and passenger operations. This may be particularly serious with respect to long distance international flights where scheduling may be affected. The major impact would appear to be the costs associated with delays. Airline costs may also be increased through the purchase of additional aircraft and the hiring of crews to fly them.

Costs will vary from country to country depending on the degree of universality of the curfew regulations nationally and internationally. As an example Sperry[36] estimates the total costs of national curfew in the United States under the forementioned assumptions. The results are summarised in Table 8.

Sperry[37] assumed that there would be a 10% overall decrease in flight activity. However, IATA [38] estimated that a universal curfew (2300 - 0600) "... could result in an average loss in aircraft utilisation of about 15%, with a figure as high as 30% for individual airlines whose route network was predominantly long-haul multi-stop crossing several time zones".

TABLE 8 : SUMMARY OF CURFEW COSTS (Millions of 1973 dollars)

Year	Delay Times (000 minutes)	Airline Ops. Cost Increase	Airline Lost Cargo Revs.	Airline Delay Costs	User Delay Costs	Total
1974	5139.8	7.30	3.77	39.06	36.06	86.19
1975	5353.4	7.83	4.13	40.68	37.56	90.20
1976	5567.4	8.40	4.51	42.31	39.06	94.28
1977	5781.2	9.06	4.92	43.93	40.56	98.47
1978	5995.1	9.73	5.37	45.56	42.06	102.72
1979	6208.9	10.54	5.87	47.18	43.56	107.45
1980	6422.7	11.37	6.22	48.81	45.06	111.46
	TOTALS	64.23	34.79	307.53	283.92	690.77

*The assumptions applied in the construction of this table are as follows:

.On a national level, night flights represent approximately 15 percent of the total daily activity.

.With a night curfew, one-third of the night flights are rescheduled to daytime, resulting in a 10 percent overall decrease in flight activity.

.Half of this activity will not be replaced, and passengers will travel on non-curfew flights which will increase the non-curfew flight load factors.

.The remaining 5 percent affected aircraft movements may require airlines to purchase new equipment to compensate for decreased aircraft activity.

SOURCE: Ref. 36

As an example of how one airline is affected, see footnote*.

Aircraft Type Limitations

Some airport authorities (e.g. New York) restrict aircraft which create noise above a certain level. The main costs are likely to be borne by the airlines, e.g. reduced utilisation for the noisier aircraft types. No cost estimates have been made available to us.

Schedule Limitations

Hurlburt[40] cites the example of a Californian airport that limits the number of average daily departures. While cumulative noise exposure is reduced, the costs are borne by passengers in forms of reduced service, although the airlines presumably benefit from increased load factors. No cost estimates have been made available.

Hurlburt also discusses the possibility of restricting aircraft to a maximum take-off weight, in order to ensure that aircraft climb rapidly or to enable them to gain maximum benefit from a power cut back take-off procedure. The main implication is that aircraft will carry less fuel on take-off and more stops or more flights might be required. This would tend to increase cumulative exposure and offset some of the benefits gained.

Airline costs would presumably be affected. No cost estimates have been made available to us.

Measures Against Non-Flying Aircraft

Other measures not referred to in Table 7 include:

i) setting noise limits for the auxiliary power units used by aircraft while on the ground (for further details see ICAO[41]);

ii) restrictions on engine ground runups, following maintenance or inspection checks;

iii) walls surrounding ground-level noise sources, e.g. Dusseldorf, Schiphol, Frankfurt.

No cost estimates have been made available to us.

*British Airways[39] have recently argued that the London Heathrow curfew unnecessarily penalises the quieter commercial jets and that BA could earn up to £2 million ($4 million, 1978) more each year if quieter aircraft such as the Lockheed Tristar were allowed an extra hour's flying time at the end of each day.

4. PROTECTION

Since even the new generation of "quiet" aircraft are so noisy that at some airports the community noise levels will be unacceptable for many years to come, further abatement must be achieved along the path or at the receiver end of the source - path - receiver system. Examples include land use planning, barriers, insulation and relocation of inhabitants.

4.1 Land Use Planning

At new airport sites, land use planning offers a unique opportunity for preventing or minimising community noise problems in the future. The use of the land in the immediate vicinity of the airport site can be controlled in such a way that noise sensitive objects (houses, hospitals, schools, etc.) cannot be built there.

The cost implications are difficult to assess and will depend upon circumstances at the individual site. In some circumstances, an alternative use may be found for the land, (e.g. factory, warehouse) and the costs may not be significant. Alternatively the airport operator may have to buy a substantial amount of land, which then lies idle. However, no examples with well documented cost data have been brought to our attention.

4.2 Barriers

Since aircraft noise is predominantly overhead, there is very little scope for the effective use of barriers along the noise path. There are exceptions associated with ground level sources (e.g. auxiliary power units, engine testing), which have already been considered in the section on abatement at source.

4.3 Insulation

For reasons expressed elsewhere in this report, insulation is not an entirely satisfactory method of protecting the community against noise. Nevertheless it has had to be adopted at many of the major airports. The main factors affecting cost are similar to those for insulation against road traffic noise (Part A, Section 8.3), but the following factors also have to be taken into account:

a) aircraft noise is overhead, and therefore roof insulation is also required;

b) the reductions associated with aircraft noise are often higher than those for road traffic, and high frequencies are strongly represented.

In order to derive a cost per house, the window costs for road traffic noise should be used, to which should be added the costs of insulating overhead. These costs have been estimated[42] to be £40 - 180 per square metre ($80 - 160, 1978) depending upon the areas of attic floor and the number of layers of plaster board used.

For buildings other than houses there is very little data available. Table 9 summarises some recent data prepared by FAA[43] on the costs of soundproofing public buildings near airports.

TABLE 9 : COSTS OF SOUNDPROOFING PUBLIC BUILDINGS AGAINST AIRCRAFT NOISE (1977 DOLLARS)

	$ per m^2 of floor area	$ per building
US (estimates)	Approx 65	180,000[1]
Germany (actual)	Approx 65	
Canada (actual)		200,000
Japan		160,000

Note: (1) Schools - $5030 per room for 10 dB(A) reduction, $5750 per room for 20 dB(A) reduction

Hospitals - $2630 per room for 10 dB(A) reduction $3050 per room for 20 dB(A) reduction

Source: FAA (1977), Ref. 43.

4.4 Relocation

In cases where insulation is not considered to be a satisfactory means of protection, the only possibility remaining is to relocate the inhabitants. Two examples have been identified, where the costs are known.

The city of Los Angeles, California, has spent[44] over $124 million to acquire 2,673 homes since 1972, i.e. $46,000 per home. This includes three categories of cost:

- the acquisition price of the property;
- the differential cost between the old and the new property;
- the compensation for moving expenses.

In Denmark, consideration is currently being given to the future of Kastrup airport, Copenhagen. It is reported[45] that, if Kastrup is expanded, housing would have to be compulsorily purchased. Estimates indicate that house purchases would cost D.Kr. 250, 500 or 2,500 million ($44, $88 and $440 million), depending upon whether the noise limits were set at 75, 70 or 65 dB (Day/Evening/Night Level).

5. COMPARISONS OF ALTERNATIVE NOISE ABATEMENT PROGRAMMES

The alternatives for reducing aircraft noise have so far been considered in isolation (with the exception of the FAA Study on Aircraft Replacement/Jet Engine Retrofit, discussed in Section 2.4). Very few studies were brought to our attention that were able to help us compare the cost effectiveness of the various alternative noise abatement measures and to identify the most promising combinations of them.

Although single airport examples exist, these are unable to reflect all the costs and benefits that are involved. An optimal solution for one airport might not necessarily be an optimal solution for another airport or for the whole air transport system.

Two major American studies of the whole air transport system are of interest. The first study[7] for the US Department of Transportation (DoT) in 1974, considered the effectiveness of SAM and REFAN technologies and a change in landing procedures to the two segment approach. Both SAM modified JT3D and JT8D engines and combinations of SAM modified JT3D and REFAN modified JT8D engines were simulated. However, in each case the two segment approach was assumed to have been adopted. Since this procedure has now been ruled out by the FAA, we cannot be certain that the conclusions reached are now still valid.

The second[8] was undertaken by Wyle Laboratories on behalf of the US Environmental Protection Agency, published in February 1976. This covers a wider range of options than the DoT Study above.

However, it omits the possibility of early retirement of aircraft, which FAA has since demonstrated to be one of the most promising possibilities (see Section 2.4). For this reason, the findings are of only limited use for our purposes. It is worth recording however, that they concluded that house insulation was much less cost effective than the retrofit alternatives that they considered.

This conclusion contrasts with that of a study[46] at Schiphol Airport in the Netherlands, which compared the costs of retrofit for KLM (the main user of the airport) with potential cost savings in a house insulation programme if aircraft were retrofitted. The total retrofit costs (capital expenditure and operating costs) for KLM were estimated at approximately 90 million guilders at 1977 prices ($ 40 million 1978), whereas insulation cost savings would have been approximately half this figure. However this analysis for Schiphol understandably does not attempt to consider the benefits that would accrue from the retrofit option elsewhere in the air transport system, i.e. at other airports in the Netherlands and in other countries.

APPENDIX 1

AIRCRAFT TYPES LISTED BY ECAC/ANCAT[3] AND THEIR STATUS WITH RESPECT TO ANNEX 16

Aircraft that comply with the standards of Annex 16

This category consists mainly of these aircraft covered by the applicability clause of Annex 16, i.e. models newly developed since 1969 or having a by-pass ratio of two or more (and manufactured after 1st March 1972). Some aircraft in this category are of older design but nevertheless fulfil the requirements (the Fokker F 28, for example).

By Amendment 2 of ICAO Annex 16, individual aircraft of older design (which would not otherwise be affected by the Annex) are required to comply with Annex 16 if they are manufactured after 1st January 1976. In the USA somewhat earlier dates apply. However, because it was not possible to establish the consequences of the above, it was assumed by ANCAT that all individual aircraft of older design should be regarded as retrofit candidates.

Aircraft that can in principle be modified (retrofitted) to meet the standards of Annex 16

The second category is made up of the bulk of today's aircraft, propelled by the "second generation" of jet engines with low by-pass ratios. This category includes such types as:

Boeing 707	JT3D-1/-3B engines
Boeing 727-100/-200	JT8D-7/-9 engines
Boeing 737-100/-200	JT8D-9 engines
Douglas DC-8-51 to 63	JT3D-EB/-1/-7 engines
Douglas DC-9-14 to 41	JT8D-7/-9/-11/-15 engines
BAC-111-200 to 500	Spey 511 and 512 engines
VC-10 (Standard)	Conway 540 engines
VC-10 (Super)	Conway 550 engines
HS-125-400	Viper 522 engines
HS-125-600	Viper 601 engines
Caravelle-10R/-11R	JT8D-7 engines
Caravelle-10B3	JT8D engines
Caravelle 12	JT8D-9 engines

Notes: 1. Early 747 100 and 200 aircraft, although fitted with high by-pass ratio engines, did not meet the standard of Annex 16. Conformity could be obtained through an appropriate modification.

2. DC9s have been considered in the study as calling for retrofit, although there have been indications to the effect that some would meet Annex 16 standards without retrofit.

Aircraft that cannot be modified to meet the standards of Annex 16

These aircraft are those of the first jet generation. This category includes such types as:

Boeing 707 with JT4A and Conway engines(1)

Douglas DC8 with JT4A(2) and Conway engines(1)

Caravelle 3, 6 N and 6R(3)

HSA Trident(2)

All Convair jet aircraft(3)

HSA Comet(3)

HFB 320 and some other business jets

Notes: (1) Although the Conway engine is strictly a low-by-pass ratio engine, its characteristics are similar to those of a pure jet engine, and no retrofit kit has been contemplated for it.

(2) Though these aircraft are listed as "non-retrofittable", technically speaking some can be modified to reduce noise levels by a noticeable margin; Annex 16 levels will, however, not be obtained or will be obtained only with a considerable reduction of payload. Some information is available for these aircraft.

The decision whether to include those in a general retrofit scheme - and what to require - may have to be made on an individual type basis, taking into account the cost of the modification, its effect on the airport neighbourhood and the remaining service life of the aircraft. Most have already been phased out.

(3) Numbers of these types still in operation are too small to consider designing a modification kit.

APPENDIX 2

RETROFIT COSTS, ANALYSED BY COUNTRY AND AIRCRAFT TYPE

COUNTRY	Aircraft type	Number	Capital cost	Financial costs	Operating losses
Austria	DC 9	9	1 980	716	1 735
Belgium	B.707 C	6	6 180	1 133	1 200
Cyprus	-	0	0	0	0
Danemark	Caravelle 10-12	8	440	230	34
	DC 8-63	3	2 328	582	1 266
	DC 8-62	2	1 561	390	
	DC 9	10	2 200	660	1 540
Finland	Caravelle 10.B	8	800	248	1 200
	DC 8-51	1	1 075	324	900
	DC 8-63	3	2 055	618	2 475
	DC-9	8	1 760	528	1 232
France	B.707-B/C	14	22 110	8 859	42 943
	B.727.200	22	5 010	2 756	2 226
	Mercure	10	1 100	410	227
	Caravelle 12	5	774	155	111
	DC 8-55	2	1 390	417	4 140
	DC 8-60	5	4 675	1 401	
Germany	B.707-B/C	14	14 319	2 252	6 387
	B.727.200	14	1 723	271	738
	B.737.100	28	7 950	1 485	3 905
	BAC 1-11	14	3 242	946	4 167
	Caravelle 10.B	5	651	158	126

Source: ECAC/ANCAT, Ref. (3)

Costs are expressed in thousands of US dollars

COUNTRY	Aircraft type	Number	Capital cost	Financial costs	Operating losses
Greece	B.707-B/C	6	9 480	2 640	4 050
	B.727-200	6	1 380	370	260
Iceland	DC 8-60	3	2 250	826	2 850
Ireland	B.747	2	701	534	048
	B.707-C	4	4 400	2 246	736
	BAC-1-11	4	1 143	575	232
	B.737-200	8	1 761	1 333	2 744
Italy	DC 9	51	11 220	2 939	6 634
	DC 8-60	10	10 000	7 625	10 900
	B.747	2	1 000	550	1 200
Luxembourg	-	0	0	0	0
Netherlands	DC 8-50	4	2 865	902)	
	DC 8-60	11	8 284	2 752)	8 000
	DC 9	18	4 088	1 881)	
Norway	B.737-200	5	1 100	342	740
	DC 8-62	3	2 342	585)	
	DC 8-55	1	790	198)	1 013
	DC 9	10	2 200	660	1 540
Portugal	B.707-B/C	10	15 800	3 824	7 980
	B.727-100) -200)	9	2 070	725	540
Spain	DC 8	15	11 250	3 256	7 125
	DC 9	35	7 700	2 307	5 390
	B.727-200	16	3 680	1 790	1 345

COUNTRY	Aircraft type	Number	Capital cost	Financial costs	Operating losses
Sweden	B.727-100	3	690	117	69
	DC 8-63	2	1 552	388)	
	DC 8-62	3	2 342	585)	1 521
	DC 8-55	1	790	198)	
	DC 9	15	3 300	990	2 316
Switzerland	Caravelle 10	4	616	92	56
	DC 8-50	1	1 070	267	600
	DC 8-62) -62 F) -63) -63 CF)	9	6 750	1 500	3 100
	DC 9	23	5 060	1 265	2 852
Turkey	DC 9	9	1 980	594	1 395
	B.727-200	4	920	468	360
United Kingdom	BAC 1-11	64	19 802	7 522	23 410
	Super VC 10	11	16 552	3 353	18 303
	Trident 2 E	15	11 114	2 530	10 472
	Trident 3 B	26	19 147	6 405	27 049
	B.707-120/320B	23	25 581	7 910	23 051
	B.720-B	4	4 439	1 730	5 349
	B.727-100	5	650	178	618
	B.737	11	2 876	1 180	2 901

SUMMARY OF COSTS AND NOISE LEVEL REDUCTIONS, ANALYSED BY AIRCRAFT TYPES FOR ECAC COUNTRIES

	Number of Aircraft	Cost per Aircraft (Million 1975 dollars)				Total Cost $ million 1975
		Capital (including down time)	Operating Losses	Financial Costs	Total	
2 Engines						
DC-9	188	0.22	0.16	0.07	0.44	83
BAC 1-11	82	0.30	0.34	0.11	0.74	61
B-737	52	0.26	0.20	0.08	0.54	28
Caravelle	30	0.11	0.05	0.03	0.19	6
Mercure	10	0.11	0.02	0.04	0.17	2
3 Engines						
B-727	79	0.20	0.08	0.08	0.37	29
Trident	41	0.74	0.92	0.22	1.87	77
4 Engines						
DC-8	79	0.80	0.50	0.29	1.59	126
B-707 [(a)]	81	1.26	1.13	0.38	2.77	224
Super VC-10	11	1.51	1.66	0.31	3.47	38
B-747	4	0.43	0.31 [(b)]	0.27	1.01	4
TOTAL	657					678

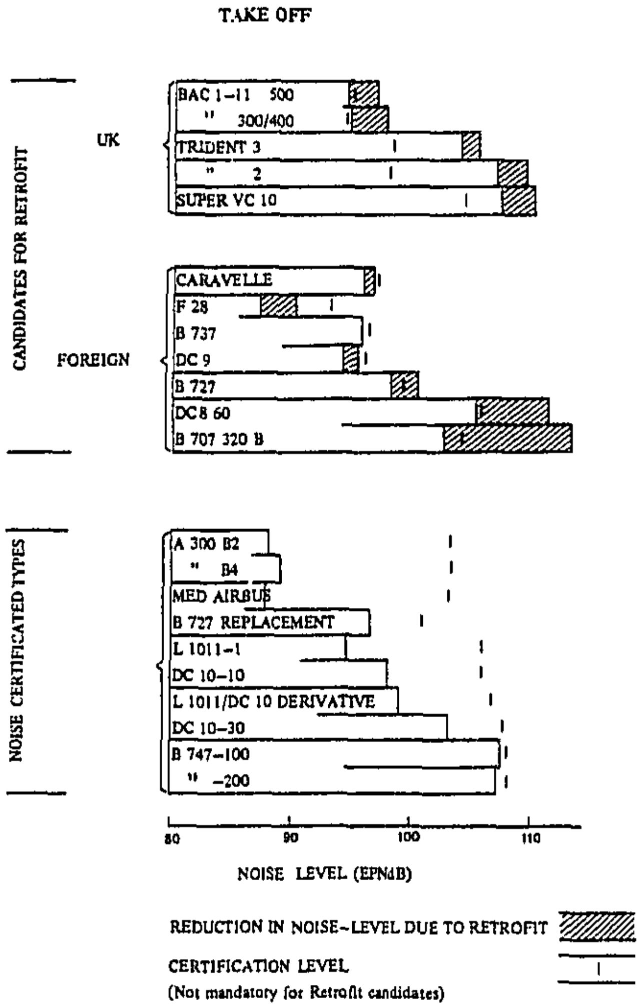
(a) Includes 4 B-720

(b) 2 at 0.02; 2 at 0.60.

Source: These averages are derived from the table on the previous page

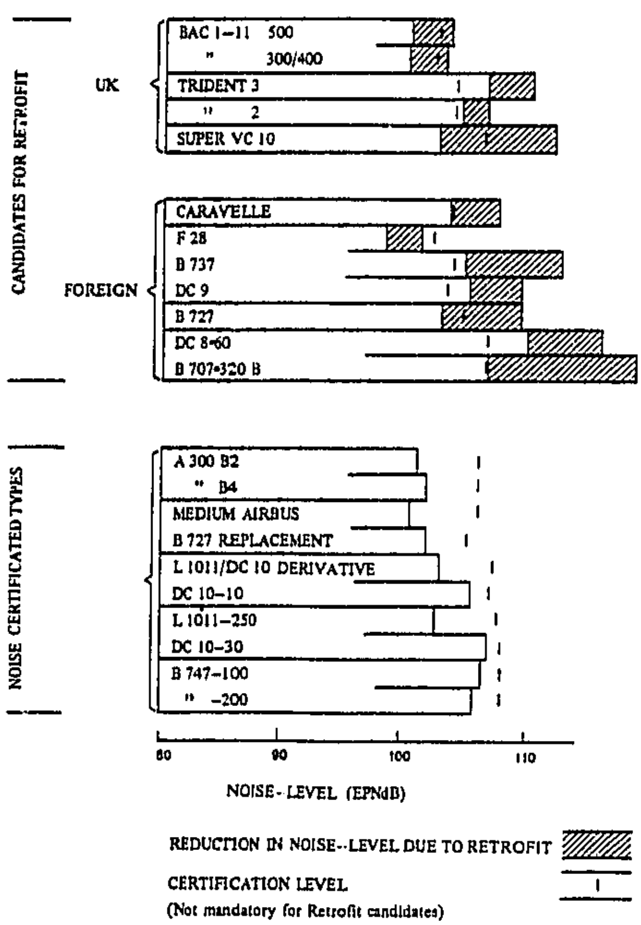
APPENDIX 3

AIRCRAFT NOISE LEVELS BEFORE AND AFTER RETROFIT



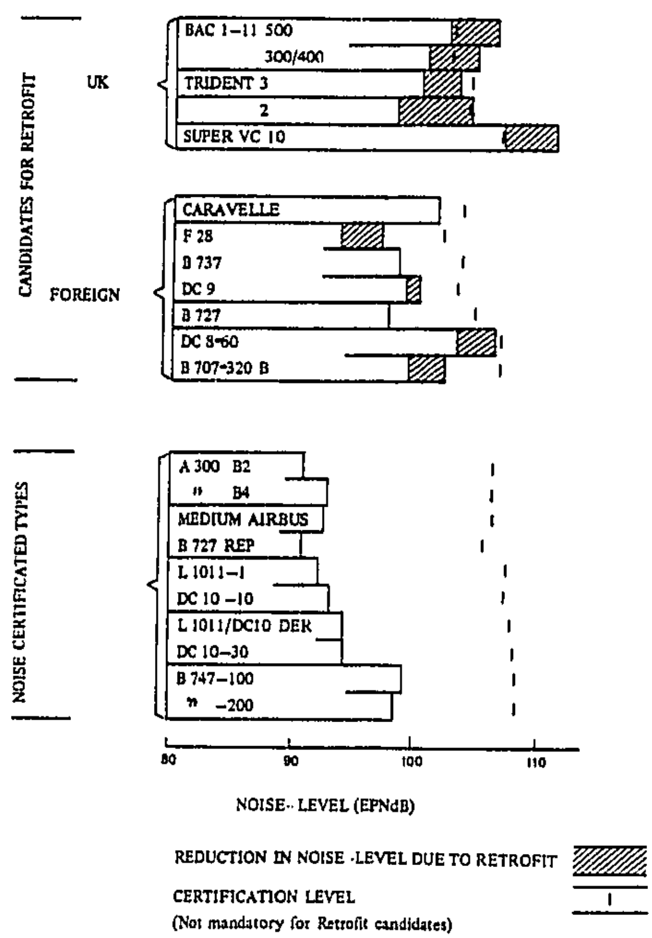
Source: Ref. (4)

APPROACH



CANDIDATES FOR RETROFIT
UK
BAC 1-11 500
" 300/400
TRIDENT 3
" 2
SUPER VC 10
FOREIGN
CARAVELLE
F 28
B 737
DC 9
B 727
DC 8-60
B 707-320 B
NOISE CERTIFICATED TYPES
A 300 B2
" B4
MEDIUM AIRBUS
B 727 REPLACEMENT
L 1011/DC 10 DERIVATIVE
DC 10-10
L 1011-250
DC 10-30
B 747-100
" -200
80
90
100
110
NOISE-LEVEL (EPNdB)
REDUCTION IN NOISE-LEVEL DUE TO RETROFIT
CERTIFICATION LEVEL
(Not mandatory for Retrofit candidates)

SIDELINE



CANDIDATES FOR RETROFIT
UK
BAC 1-11 500
300/400
TRIDENT 3
2
SUPER VC 10
FOREIGN
CARAVELLE
F 28
B 737
DC 9
B 727
DC 8-60
B 707-320 B
NOISE CERTIFICATED TYPES
A 300 B2
" B4
MEDIUM AIRBUS
B 727 REP
L 1011-1
DC 10 -10
L 1011/DC10 DER
DC 10-30
B 747-100
" -200
80
90
100
110
NOISE LEVEL (EPNdB)
REDUCTION IN NOISE LEVEL DUE TO RETROFIT
CERTIFICATION LEVEL
(Not mandatory for Retrofit candidates)

APPENDIX 4

COST ASSUMPTIONS USED IN THE FAA RETROFIT/EARLY RETIREMENT STUDY

The following notes relate to the study described in Section 2.4.

This type of analysis depends heavily on the assumptions underlying the fleet projections. For example, passenger demand was assumed to grow at 6% per annum. This allows for a certain rate of development of new technology quieter aircraft consistent with airline needs independently of government action. Costs were divided into capital cost and operating costs. Capital costs of aircraft purchase sale and modification were included in the analysis with due regard to interest payment and taxes. The operating cost analysis was conducted both before and after taxes, and only used "out-of-pocket" items such as fuel and maintenance.

The table below shows the price assumptions for the capital analysis and gives the assumed cost of SAM modification for each aircraft type in 1976 dollars.

THE COST OF NEW AIRCRAFT AND SAM MODIFICATION ($ 1975)

	Plane Price	Modification Price (per plane)	
New Technology Aircraft	$23 million	727	$0.225 million
L-1011/DC-10	$25.9 million	707 Case 2: Case 1:	$2.6 million $1.9 million
727	$10 million	747	$0.25 million
DC-9/737	$ 6.5 million	DC-9/737	$0.27 million
707	$14.7 million		
747	$32.7 million		

A range of prices is shown for the B-707 since the cost of modifying that equipment is reported to be dependent upon the number of B-707s being modified.

The table below shows the assumed change in annual operating cost owing to modification of the B-707/DC-8, and the relative cost per seat of the new technology aircraft.

BASELINE OPERATING COSTS DATA (OUT-OF-POCKET ITEMS ONLY)

Aircraft Types	Cost per aircraft year (000)	Number of seats per aircraft	Annual Cost per seat (000)
B-707/DC-8	3,800	145	26.2
B-707/DC-8 w/Acoustic modification	3,850	145	26.6
DC-10	5,120	250	20.5
B-727	2,780	125	22.2
New Technology	3,690	200	18.4

Source: FAA, Ref. (9)

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PART C : INDUSTRIAL NOISE

CONTENTS

1. MEASUREMENT AND PREDICTION

Before discussing methods of industrial noise abatement, it is first necessary, as in the other two parts of this report (road traffic, aircraft), to comment on the appropriateness of the methods of measurement and prediction that are used for this particular type of community noise nuisance.

1.1 Measuring Single Moments of Noise

The unit most commonly used for industrial noise is dB(A). This type of noise often has strong low frequency components which, as explained in Part A (Section 1.1) may be more annoying than dB(A) measurements indicate. It is therefore important to be aware of the possible distorting effects of working exclusively with this unit. These are similar to those identified for road traffic noise (see Part A, Section 1.1).

1.2 Measurement of Noise over a Period

The most commonly used method for industrial noise is Leq, measured in dB(A). This is the same measure as is used for road traffic noise and the implications have already been discussed (Part A, Section 1.2).

1.3 Measures of Community Annoyance

There are no measures of community annoyance against industrial noise and so the situation is similar to that for road traffic noise (Part A, Section 1.3).

1.4 Prediction

Given the location and the power levels of noise sources in an industrial plant, sufficient is known about the propagation of sound for reasonably accurate predictions of community noise levels to be made.

A point worth recording, for the purposes of this report, is that a reduction of X dB(A) near to the source will not necessarily produce the same reduction at long distance. In practice the community noise levels are likely to be reduced by less than X dB(A) because the high frequency components will already have been substantially attenuated by distance.

2. NOISE ABATEMENT AT SOURCE

2.1 Data-Base Problems

In order to present cost data for any type of noise, we have to be able to achieve the following three steps, by some means or other:

i) identify the sources (numbers, types);

ii) determine the noise reductions required;

iii) estimate the costs of these reductions by different methods.

For example, for aircraft noise we know approximately how many aircraft of different types need to be quietened and the approximate costs of bringing their noise levels to within those laid down in Annex 16.

For aircraft noise and road traffic noise these steps can be achieved with some confidence. But, for industrial noise there are severe data base problems that have so far limited researchers in their attempts to draw general conclusions on the costs of abatement (although some well-documented individual case studies are in existence).

Problems of source identification

Source identification poses the first problem. A choice has to be made between describing costs in terms of:

a) pieces of equipment; and

b) whole industrial plants or sites.

Most of the available cost information relates to the more noisy individual pieces of equipment(1). However, the interactions between sources at a plant limit the usefulness of such data, for the purposes of our report.

Example

> Consider a point near a plant where the community noise load is 40 dB(A), caused by two individual pieces of equipment:
>
> A makes a contribution of 39 dB(A)
>
> B makes a contribution of 33 dB(A)
>
> Suppose that studies on equipment A have shown that it can be reduced by 16 dB(A), for 1600 cost units. If this were carried out in isolation, the contribution made by A would be reduced to 23 dB(A), i.e. well below that of B. Consequently the total noise load would drop to that of B, i.e. from 40 to 33 dB(A).
>
> Thus for 1600 cost units, the community noise load would be reduced by only 7 dB(A), rather than by the 16 dB(A) that might be anticipated from the information available on the individual piece of equipment.

The alternative is to concentrate on whole plants or sites. Here the problem lies in the fact that no two industrial plants are identical and therefore conclusions based on one plant may not be valid if applied to another.

What Reductions?

The extent to which the noise load from any particular plant or site needs to be reduced will of course depend upon its location. It is therefore dangerous to assume that all plants of a certain type (e.g. refineries) will require an identical reduction in noise load of, say, 5 dB(A). Whereas an isolated refinery may not need to be quietened, a similar one located near a major housing area may require a 10 dB(A) reduction.

Therefore, in order to estimate costs at a regional or national level, an inventory is necessary of all the noisy plants and of the noise reductions required at each one. For understandable reasons, such an inventory exists in only a very few countries (e.g. the Netherlands).

What Costs?

The third problem is how to relate abatement costs to reductions in community noise load. Clearly the size of plant will be an important determinant of cost and therefore a relationship may exist between cost, expressed as a percentage of fixed assets, and dB(A) reduction.

Figure 1 illustrates the problems that surround any attempt at determining such a relationship. Appendix I gives details of an attempt by Metra in 1976 to present results from industrial noise studies in such a format. However, the variability in the results only served to underline the problems described in Figure 1. It was concluded that a lot more detailed information will have to become available before satisfactory relationships of this type can be established.

2.2 Nationwide Cost Studies

Despite the problems outlined above, attempts have been made in some countries to determine the cost of abatement at source for all noisy plants within a particular country. Two have been brought to our attention (Netherlands, Sweden). In both cases the aim was to assess the likely national costs of reducing noise at source in order to comply with proposed community noise legislation. Although the total cost figures in themselves are of limited interest outside the respective countries, some of the findings are useful for the purposes of our report in that they help to identify those industries that would be faced with the largest cost.

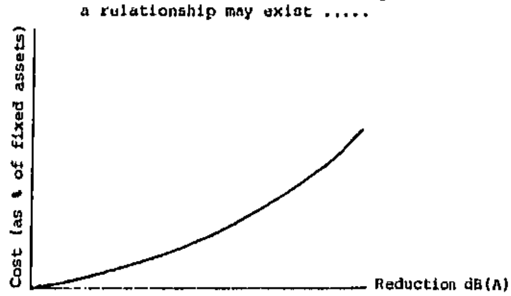
Netherlands

In 1976 Metra were commissioned by the Netherlands Ministry of Public Health and Environment to perform case studies at a number of industrial sites,[2] in cooperation with the companies involved, to investigate how these sites would be affected by the proposed Noise Abatement Bill. Following these detailed case studies, it was agreed that it would be useful to attempt a "grossing up" exercise to determine the possible total cost of compliance for the Netherlands as a whole. Metra emphasised that the results must be treated as "tentative" given data source difficulties.

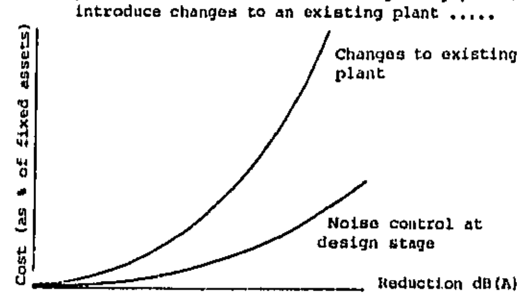
FIGURE 1

THE RELATIONSHIP BETWEEN COST AND REDUCTION IN COMMUNITY NOISE LOAD

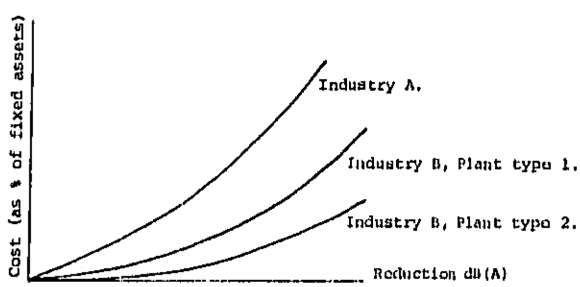
1. At any plant, each additional dB(A) saved costs more. For similar plants a relationship may exist .....



3. .....and for any plant type, it is cheaper to incorporate noise control at the design stage, than to introduce changes to an existing plant .....



2. .....but, differences should be expected between industries, and perhaps between plant types .....



4. ..... and for any existing plant, the cost will depend upon the extent to which noise abatement measures have already been taken.

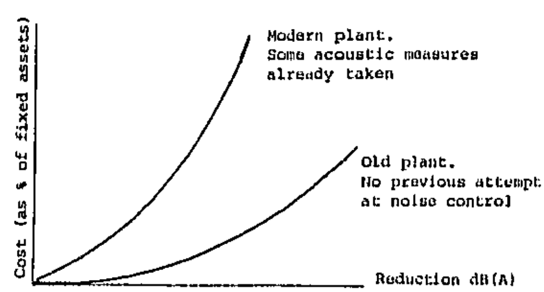


Table 1 summarises the costs of reducing noise at source, analysed by industry. It is assumed that all industrial sources would be silenced so that the community noise load would be reduced to below 55 dB(A) during daytime, 50 dB(A) during the evening and 45 dB(A) at night. The assumptions made on the proportion of sites that generate a community noise problem were based on a site inventory prepared by the Ministry. Assumptions on the cost of silencing noisy plant (expressed as a percentage of estimated asset value) were based on the findings of the detailed cost studies.

The right hand column of the table shows that two industrial categories account for 75% of the source abatement costs. These are "chemicals/petroleum" (40%) and "metal industries" (35%). Utilities, foodstuffs and paper industries will also incur substantial costs.

To a certain extent these figures reflect the concentration of chemicals/petroleum industry in the area surrounding Rotterdam. We would not expect this sector to be quite so important in most other OECD countries.

Sweden

Almost simultaneously with the Netherlands study, Ingemansson Acoustics were undertaking a similar study for the Swedish Environmental Protection Board[4]. The community noise levels that were required were the same as those in the Netherlands except that zones for vacation houses and recreational use were given an additional 10 dB(A) protection.

A case study approach was adopted and the results were "grossed up" to determine the cost of compliance for the whole of Sweden. The results are summarised in Table 2. As might be expected in Sweden, the pulp and paper industry would be faced with the highest costs (46% of the total). Mechanical engineering (30%) is the second largest.

TABLE 1 : THE COSTS OF REDUCING NOISE AT SOURCE IN THE NETHERLANDS, ANALYSED BY INDUSTRY

INDUSTRIAL CATEGORY	Assumed Proportion of Noisy Sites (see Note 1)	Assumed Silencing Cost (see Note 2)	Resultant % of Total Cost (see Note 3)
Chemicals/Petroleum	50%	1.5%	40%
Metal Industries	40%	2%	35%
Utilities	(a)	(a)	7%
Foodstuffs	33%	1%	6%
Paper	50%	(a)	6%
Building Supplies	50%	1%	2%
Woodworking	20%	1%	< 1%
Textiles	15%	1%	< 1%
Printing Leather and Rubber }	(a)	(a)	3%
TOTAL			100%

(a) = Estimated differently

Note 1: Proportion of sites that generate a community noise problem (% weighted by the number of employees).

Note 2: Cost expressed as a percentage of the estimated value of the assets.

Note 3: Total cost = 880 million guilders (1976) = US $ 420 million (1978)

TABLE 2 : THE COSTS OF REDUCING NOISE AT SOURCE IN SWEDEN, ANALYSIS BY INDUSTRY

INDUSTRIAL CATEGORY (see Note 1)	Percentage of Total Cost (see Note 2)
Pulp and Paper	46%
Mechanical Engineering	30%
Iron and Steel	12%
Chemicals	10%
Mining	3%
TOTAL	100%

Note 1: Utilities were not included in this study

Note 2: Total Cost = 500 million Sw.Cr. (1977)
= US $ 120 million (1978)

2.3 Individual Industries

The previous section has identified the industries that are likely to have to bear most of the costs of abatement at source. Some of the noise sources in these industries are pieces of equipment that are common to most industries (e.g. electric motors), but the main sources tend to be equipment items whose use is less widespread and may even be unique to a particular industry. Examples include blast furnaces and sinter plants in a steel works; furnaces and airfin coolers in a refinery; large valves in gas distribution systems; and chippers in paper factories. Each industry therefore faces a different set of noise abatement problems. For further details of how their problems are being tackled, see references (5) to (20) for chemicals/petroleum, references (21) to (24) for metal industries; references (25) to (30) for pulp paper industries, and references (31) to (46) for utilities.

Although some of these references do include cost data, they are mostly of limited use, other than as interesting case studies. It is difficult to draw conclusions on costs, from such data, that would be applicable elsewhere.

Petroleum Refinery Sources

An exception is the work by Bolt, Beranek and Newman on the costs of noise abatement in refineries.(9) Its purpose was to determine the nationwide cost of compliance with proposed regulations on employee protection. It was assumed that all primary sources except pumps and cooling towers would require noise control treatment. Sources that contribute to community noise, but that do not seriously annoy employees, were also excluded (e.g. flares).

Table 3 gives a brief description of each noise source, the typical noise levels produced, the most appropriate abatement methods and estimated costs per equipment item.

Table 4 considers a "typical" refinery (250,000 bbl/day), makes assumptions about the number of equipment items that such a refinery would have and gives the costs for quieting the whole refinery, based on the costs per equipment item in Table 3.

TABLE 3 : PETROLEUM REFINERY: NOISE SOURCES, LEVELS, POTENTIAL SOLUTIONS AND ESTIMATED COSTS (1975) Dollars)

Equipment	Sound Level in dB(A) at 3ft.**	Possible Noise Control Treatments	Estimating Average Cost of Noise Control Treatment
Air Coolers	87-94	Aerodynamic fan blades, decrease rev/min and increase pitch, tip and hub seals, decrease pressure drop	- $ 4000/unit
Compressors	90-120	Install mufflers on intake and exhaust, enclosure of machine casing, vibration isolation and lagging of piping systems	Centrifugal units ≥5000hp $10000/unit Centrifugal units <5000hp $ 6000/unit Reciprocating $ 8500/unit
Electric Motors	90-110	Acoustically-lined fan covers, enclosures and motor mutes	>25-100hp $ 1000/unit 100-200hp $ 2000/unit 200hp requiring total enclosure $ 4000/unit
Heaters and Furnaces	95-110	Acoustic plenums, intake mufflers, ducts lined and damped	$250/million Btu/hr*
Valves	<80 to 108	Avoid sonic velocities, limit pressure drop, and mass flow, replace with special low noise valves, vibration isolation and lagging	$1000-2000/unit
Piping	90-105	Inline silencers, vibration isolation and lagging	$4-16/linear ft**

*Million B.t.u./hr heat dissipation **3ft. = 0.91 metre

TABLE 4 : "TYPICAL" REFINERY EQUIPMENT AND COSTS FOR NOISE CONTROL (1975 Dollars)

Equipment	Assumed Number of Units	Unit Cost for Noise Control	Total Cost for Noise Control
Air Coolers	150	$ 4,000	$600,000
Compressors:			
Centrifugal ≥5000hp	8	$10,000	$80,000
Centrifugal <5000hp	12	$ 6,000	$72,000
Reciprocating	14	$ 8,500	$119,000
Electric Motors:			
25-100hp	800	$ 1,000	$800,000
100-200hp	300	$ 2,000	$600,000
Large Motors requiring Total Enclosure	20	$ 4,000	$ 80,000
Heaters	4000 million Btu/hr	$250/million Btu/hr	$1,000,000
Valves	40	$ 1,000	$40,000
Valves	10	$ 2,000	$20,000
Piping	7,500 ft	$4/ft	$30,000
Piping	6,000 ft	$8/ft	$48,000
Piping	3,000 ft	$16/ft	$48,000
TOTAL (excluding pumps, cooling towers, flares)			$3,537,000

NOTE: "Typical" : Production capacity is 250,000 bbl/day

1 ft. = approx. 0.3 metre

Details are not available of the noise level reductions anticipated for each source. The authors explain that they assumed that sources would be reduced by "the maximum technically feasible amount".

3. PROTECTION

In the absence of adequate abatement at source, the community can be protected from industrial noise by land use planning, barriers or insulation.

3.1 Land Use Planning

Many potential community noise problems have been avoided in OECD countries by land use planning techniques. This has been achieved either by preventing industry developing on a particular piece of land or by not allowing houses to be built there. In making decisions of this kind, there may be cost implications for the industrial plant (e.g. changes in transport costs, land costs, etc.).

These costs are very dependent upon the local circumstances and therefore any cost conclusions that might be drawn are likely to be only of limited value. However, no examples with well documented cost data have been brought to our attention.

3.2 Barriers

A barrier can in principle be introduced at any point along the path between a noisy piece of equipment and a community requiring protection. For maximum effectiveness it should be introduced as near to the equipment as possible. Examples include acoustic enclosures around motors, and even acoustic walls around large sources such as furnaces (see Japanese examples, Refs. (11, 15)).

In these circumstances the barrier is the responsibility of the plant operator, i.e. it is a method of noise abatement at source.

Very few examples of barriers against industrial noise, erected <u>outside</u> plant boundaries, have been brought to our attention. This is mainly due to the reduced effectiveness of distant barriers, particularly when industrial noise sources are located at heights well above ground level (e.g. airfin coolers).

3.3 Insulation

The costs of insulation against industrial noise are similar to those for insulation against road traffic noise (see Section 8.3 of the Road Traffic section of this report).

For a comparison of the costs of (i) insulation and (ii) abatement at source, see Section 4 below.

4. COMPARISONS OF ALTERNATIVE NOISE ABATEMENT METHODS

We have so far only considered the various industrial noise abatement methods in isolation. However, they should not be considered to be mutually exclusive since, in certain circumstances, different methods might be combined to produce the most cost effective solution.

In order to identify the most promising combinations, we need first to have good measures of the costs and effectiveness of the various abatement methods. However, as we have already seen, the data in most cases is inadequate. It is not surprising therefore that very few studies appear to exist that compare alternative noise abatement methods or that suggest how they might be combined.

4.1 Source Abatement versus House Insulation

The Metra[2] study in the Netherlands compared the cost of abatement at source with that of insulating dwellings and examined the interaction between the two types of cost at several case study sites. The results were "grossed up" for the Netherlands as a whole. Cost calculations were carried out on the basis of two extreme applications of the proposed Noise Abatement Bill:

Firstly that all industrial sources would be silenced so that the community noise load would be reduced to below 55 dB(A) during day-time, 50 dB(A) during the evening and 45 dB(A) at night. Under these circumstances it is estimated that the total cost for immediate conversion of the existing equipment would be 880 million guilders at 1976 prices ($ 420 million 1978) and should be in the range 0.5 to 2.0 times this figure.

Secondly it was assumed that there would be no abatement of industrial sources and that the dwellings affected would be insulated to compensate. If the internal level required were 40 dB(A) during day-time and 30 dB(A) at night, the total cost for insulation is estimated at 86 million guilders at 1976 prices ($ 41 million 1978) and should lie in the range 0.5 to 2.0 times this figure.

Thus abatement at source was estimated(3) on average to be about ten times as expensive as house insulation. It must be stressed however that this rule of thumb is not applicable in all circumstances.

In practice the cost resulting from the application of the Bill would almost certainly lie between these two extremes. This is because it is intended that source abatement be applied where it is most appropriate, but if not, houses will be insulated instead. Reasons for not insisting on source abatement could be, for example, that suitable measures are not technically feasible, that they would conflict with safety considerations, or that they would be excessively expensive in comparison with insulation costs. It was estimated that the result of treating those larger sites which affect only few houses, purely by house insulation, would reduce the cost of source abatement by some 300 million guilders to approximately 600 million guilders at 1976 prices (US $ 420 million 1978), with a virtually negligible cost of house insulation to compensate.

The costs of source abatement mentioned above refer to the costs of silencing the existing equipment. There will of course also be noise abatement costs associated with new plants and with extensions to existing plants, but these were not taken into account. The costs above also assume that equipment will be silenced overnight. However, the Noise Abatement Bill allows for the possibility that the measures will not be carried out overnight, but instead be extended over a period of time. This means that not all of the existing plant will require silencing before it is replaced with modern quieter plant, so that cost will be reduced substantially.

APPENDIX I

EXAMPLES OF PLANT COSTS (See Section 2.1)

Figure 2 displays the results of an investigation by Metra in 1976. The figures are taken from case studies[2] undertaken in the Netherlands by Metra, and from other material available at that time. Costs are expressed as a percentage of fixed assets. In many cases the figures are in the form of a range and so the results are presented as a line rather than a single cross. In one case both the sound level reduction and the percentage costs cover a range and this is represented by two crossing lines.

Each individual result can be identified by the number attached to it, which is explained in more detail below.

1. Steel works

   Cost 1.7%. Reduction is for 5 dB(A) at one place and 10 dB(A) at another.

2. Paper factories

   Cost is 2% to 3% depending on the method used to estimate fixed assets. Reduction is 10 to 15 dB(A) depending on which factory is concerned.

3. Petrochemical plant

   Cost 0.2% for 3 dB(A) reduction from existing situation. This is probably conservative because assets have been valued at historic costs.

4. Petrochemical plant (as 3)

   Cost 0.4% for 5 dB(A) reduction from existing situation, comparable with (3) above.

5. Petrochemical plant (as 3)

   Cost 3% for reduction of 10 dB(A) for the new plants for expansion on their own.

6. Chemical plant

   Cost 0.75% for reduction of 7-10 dB(A), based on past abatement experience.

7. Chemical plant (as 6)

Cost 0.3% for 1-2 dB(A). Anticipated cost and result for further measures. This should be above average cost because cheaper measures have already been taken.

8. Small refinery

Cost 0.7 to 1.0% for 10 dB(A) reduction. Note this applies to new plant rather than existing and while below average is not markedly so.

9. Breweries

Cost 1% for 10 dB(A) - a rule of thumb suggested by a Dutch acoustic consultant.

10. Large Refinery

Cost 0.17% for 8-10 dB(A). Data from an article in Oil and Gas Journal[12].

11. Diesel engine testing

Cost 0.9% for 8 dB(A) reduction. Asset value could include assets which are not concerned with the noisy manufacturing activity, therefore percentage may be too low.

12. Petrochemical plant

Cost 1.9% for 6 dB(A) reduction.

The result of fitting a straight line to these points is:

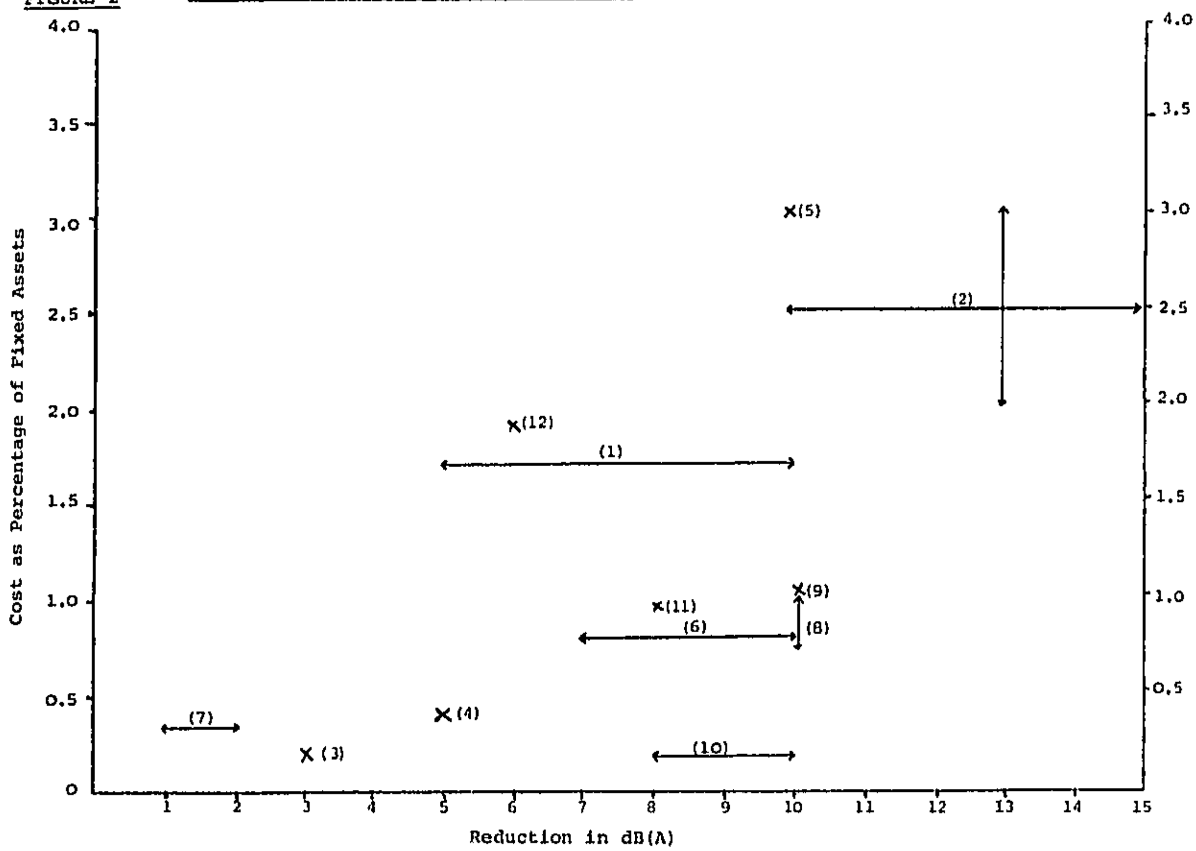
Cost percentage = - 0.107 + 0.164 (reduction in dB(A))

or approximately 0.15% for every dB(A) reduction.

The correlation coefficient is 0.56, but rises to 0.71 if points (10) and (12) are excluded, for which the relationship is:

Cost percentage = -0.32 + 0.195 (reduction in dB(A)).

FIGURE 2 : Noise Reduction versus Cost Percentage



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