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TRAFFIC POLLUTION: CONTROL POLICY AND RESEARCH TREND

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Abstract—This paper focuses on the control policies and countermeasures to prevent traffic pollution, and researches to enforce them. Traffic pollution, such as air pollution and road traffic noise caused by motor vehicles, continues to be one of the most serious and complicated environmental problems in major urban areas, and will remain so in the "Network Society" projected into the year 2000. The first step of regulating emission from vehicles, which depends on technical availablity, halfway succeeded, and the second step directed towards reduction of friction between traffic and residences in respective areas by means of Environmental Impact Assessment (EIS) and improvement of road structure and roadside environment is in progress. While the effectiveness of those countermeasures reached the plateau, a wave of urbanization and motorization overwhelmed and cancelled them. This lead to the third step of a more comprehensive planning policy cooperating with transportation and urban management. The fourth policy expected is an economic incentive policy, such as road pricing, that takes the place of conventional regulatory countermeasures.

1. PRESENT STATE OF TRAFFIC POLLUTION

1.1 *Environmental problems caused by traffic*

During those 10 years after the Organization for Economic Cooperation and Development (OECD, 1977) evaluation reported that "Japan has won many pollution abatement battles, but has not yet won the war for environmental quality," many steps have been taken to raise Japan to one of the countries with high environmental quality. But as the mechanism dominating its environmental situation changes, reflecting a rapid shift in its industrial structure from heavy industries to knowledge intensive and service industries, environmental problems step into another phase, from industry origin to an urban and residential one, from point source to non-point.

Traffic pollution, as well as the eutrophication of closed water areas and contamination by chemical substances, is likely to be the most difficult to solve pollution after the fading-out of pollution from "smoke stack industry."

Of the seven major categories of pollution defined in the Basic Law for Environmental Pollution Control [Japan Environment Agency (JEA) 1974a], traffic causes air pollution, noise, vibration, and offensive odors. In addition to these, intrusion of traffic threatens pedestrian safety, heavy traffic separates residential areas physically and socially, elevated highways intercept sunshine, and sparks from ignition jam electronic waves. Those also are side environmental impacts of traffic on the living environment.

The most serious problem is air pollution by motor vehicles in urbanized regions. Also, noise damage is important along roadways, near the Shinkansen railway, and in the periphery of major airports.

1.2 *Motor vehicles*

In general, ambient air quality in Japan has improved remarkably from its peak in the late 1960s, especially in terms of sulfur dioxide and carbon monoxide. As for the nitrogen oxide, nevertheless, little improvement has been observed, and only 17% of 282 automobile exhaust monitoring stations set on roadsides show full compliance with EQS (Environmental Quality Standard) for NO_2 (Table 1). Motor vehicles are the main source of the pollution, and JEA's survey shows that the contribution of motor vehicles to total NOx emission in 1983 rose to 69% in Tokyo Metropolis, 51% in Osaka, and 33% in Yokohama (JEA, 1985a). The target JEA set in 1978 to "achieve Air Quality Standard for NO_2 nationwide by March 1986" was unaccomplished, and the time limit was postponed until around 1990.

The main reasons of this failure came from (JEA, 1985a):

1. Unanticipated increase of motor vehicles with high NOx emission such as trucks,
2. Retardation in replacement of conventional vehicles to newly regulated production because of the prolonged durability of car usage,
3. Increasing use of direct fuel injection type diesel engine in mid-size trucks and buses that emit more NOx than subcombustion chamber type vehicles.

During the seven years since 1977, the share of diesel vehicles increased from 10% to 33% in small-sized trucks and 89% to 96% in regular-sized trucks, and the rate of direct injection engine in mid-size trucks increased from 30% to 70% in the past five years.

Particulate matter (diesel smoke), which accompanied this increased use of diesel engines, and dust generated by studded tires in snowy regions are other air pollution issues raised by motor vehicle use. Earlier regulation of carbon monoxide emission and lead additives worked successfully and there are almost no problems now.

Table 1. Compliance rate with environmental quality standards for NO_2

	1980	1984
Stations recording	%	%
over 0.06 ppm	89 (38.2)	75 (26.6)
between 0.04–0.06 ppm	107 (45.9)	160 (56.7)
under 0.04 ppm	37 (15.9)	47 (16.7)
Total number of stations	233 (100.0)	282 (100.0)

Automobile exhaust monitoring stations excluding those where the sampling inlets are located in the driveway. Source: JEA (1986a).

Environmental Quality Standards relating to roadside noise are set as shown in Table 2, but their compliance status is far from satisfactory. Out of 4,281 roadside monitoring points in 1986, only 15% fully satisfied EQS (Table 3) and 25% exceeded the "request" limit (i.e. the level at which The Governor can request the Prefectural Public Safety Commission to implement measures to prevent noise damaging to the living environment).

Road traffic noise is serious along roadways that pass through urban residential areas and along trunk roads that link the cities of the Pacific Coast, such as Tokyo, Nagoya, and Osaka. Circular Road No. 7 in Tokyo, where more than 70,000 vehicles per day pass through suburban residential areas, National Route No. 43 and Hanshin Express Highway, with 160,000 vehicles in Osaka and Kobe, and National Route No. 1 near Okazaki are some of those typical examples.

The compliance rate for roadside vibration exceeds 70%. The infrasound vibration problem, presumably coming from the connection of road bridges has been reported in some places but remains at the investigating stage.

1.3 *Shinkansen superexpress railway noise and vibration*

Since 1974, the Shinkansen railway has formed the main network of Japan's public transportation, and at the same time caused in some urban areas serious environmental impacts from its noise and vibration. The EQS related to noise caused by Shinkansen was established in 1975 as 70dB in residential areas. To attain this EQS, Japan National Railway (JNR) took countermeasures, such as strengthening the maintenance of tracks and cars and constructing noise barriers and soundproof works for dwellings along the railway. Still, the EQS compliance rate at the point of 50 m from the center of the track remains 20% to 50%.

Table 3. Compliance rate of environmental quality standards and exceeding rate of request limits (total 4,145 monitoring points)

	Environmental quality standards	Request limits
Completely complied in all four time divisions	15.1%	—
Complied in at least one of the four time divisions	36.4%	—
Below the request limit		74.5%
Exceeded in at least one of the four time divisions	—	22.0%
Exceeded in all four time divisions	48.5%	3.5%

Source: JEA, (1986a).

Near Nagoya City, where the Tokaido Shinkansen passes through densely inhabited areas, lawsuits were filed in 1974 by the residents demanding the suspension of the noise and vibration. After negotiation, an agreement was reached in 1986, assigning JNR to strengthen countermeasures. The later Shinkansens took enough consideration in design beforehand and have not caused so many problems yet.

1.4 *Aircraft noise*

Weighted Equivalent Continuous Perceived Noise Level (WECPNL) 70-75 was set as the EQS on aircraft noise in 1973, with plans to have it attained by 1983. But, with few exeptions in small airports, it is not yet accomplished. At Osaka and Fukuoka Public Airport and in some air bases located adjacent to residential areas, lawsuits were filed, demanding the prohibition of nighttime take-off and landing.

In 1975, the "Certification of Conforming to Noise Standard" system was instituted, which promoted introduction of low-noise jet aicraft and other flight operation countermeasures such as rapid take-off and landing, flight frequency adjustment, and noiseproof works for dwellings. These resulted in a reduction of the noise contour area over 75dB near Tokyo, Osaka, and Fukuoka Airport areas.

Table 2. Environmental quality standards for noise in areas facing roads (dB(A))

	Time category		
Area category	Daytime	Morning–evening	Night-time
A areas facing roads with 2 lanes	55	50	45
A areas facing roads with more than 2 lanes	60	55	50
B areas facing roads with not more than 2 lanes	65	60	55
B areas facing roads with more than 2 lanes	65	65	60

"Lane" refers to a longitudinal strip of road with uniform width requisite to allow a single line of cars to travel therealong safely and without hindrance. "A" area is mainly used for residence. "B" area is used for commerce and industry with considerable residences. Source: JEA (1986a).

Table 4. Countrywide situation related to traffic pollution

		Japan	West Germany	United Kingdom	France	USA
Per livable area	(1982)					
Nominal GDP	m$/km^2	12,920	5,110	3,360	1,930	570
Energy consumption (oil eq.)	ton/km^2	3,660	1,550	1,180	480	360
Cars owned	car/km^2	470	154	108	64	34
Population	man/km^2	1,450	386	358	158	50
Traffic volume per total area	(1984)					
Total traffic	m car	1,150	1,430	1,130	600	300
Freight traffic	× km/km^2	400	120	180	120	80
Air pollutant emission	(1980)					
per capita						
Sulfur dioxide	kg/man	11	52	83	66	102
Nitrogen oxide	kg/man	11	50	34	48	89
per GDP						
Sulfur dioxide	kg/m$	1.2	3.9	12.5	5.4	8.9
Nitrogen oxide	kg/m$	1.3	3.8	3.6	3.9	7.8
Ambient concentration of	(1984)	Tokyo	Mannheim	London	Dunkirk	Los Angeles
nitrogen dioxide	μg/m^3	59	56	79	52	86
Ratio of residents living in area with traffic noise more than 65 phon	(1984) %	31.0	9.3	11.0	13.0	7.0

m = 1,000.
Source: JEA (1987); OECD (1987).

This paper, hereafter, deals mainly with pollution from motor vehicles as the most common problem throughout the world.

2. BACKGROUND OF SERIOUS TRAFFIC POLLUTION

Traffic pollution seems to be one of the common problems in the contemporary world, although each country's problem has its own feature based on its own characteristics. Geographical restraint, recent rapid economic expansion, and urbanization and absence of centralized administrative organization in charge of traffic and environment make the problem in Japan worse than in other developed countries.

2.1 *Densely utilized land*

Out of the Japanese land area of 370,000 km^2, mountain and forest comprise 67%, and only about 20% of its land is livable. A population of 120 million with its high level of industrial activity in this small livable area make Japan the country of the most environmentally difficult land use in the world (Table 4) in terms of industrial production, energy consumption, and traffic volume. In spite of its effort to reduce discharge of pollutants to the lowest level in respective activities by applying first class pollution control technologies, and to change its industrial structure to an energy saving type, these constraints fundamentally define the Japanese environmental situation.

2.2 *Rapid industrial growth and urbanization*

In its economic growth periods of 1950–1960, industrial complexes were formed in the three big urban regions of Tokyo, Osaka, and Nagoya, and by 1970 industrial output in this area was four times as large as 1960. Also, 40% of the total population lived in those areas, which share only 10% of the total land. At present, more than 60% of the national population lived in densely inhabited districts (DID) and this migrating movement still continues and is projected to reach 70% by the year 2000. Population inflow to major urban areas, which showed a short leveling in the late 1970s after continuous surplus registered through 1960–1970, tends again to increase from 1980. A quarter of the total population has accumulated in the greater Tokyo region. Industrial structural change to service and information intensive industry spurred this concentration, and traffic volume that supports service industries also grew in pace with it.

2.3 *Rapid motorization and lagged road plan*

Parallel with high economic growth, motorization started and quickly gained on the western countries. The number of cars grew 10% annually in 1960–1970s, from 8 million in 1965 to 44 million in 1983. Insufficient coordination between road construction and urban planning corresponding to this rapid growth of vehicles and urbanization accelerated the chronic congestion, the invasion of vehicles into residential areas, and environmental pollution.

2.4 *Absence of administration to establish comprehensive policy*

Lack of unified administrative organization to control traffic pollution made this situation worse. For instance, not enough land along planned bypasses was acquired or properly zoned because of infrequent communication between road planners and local government, leading to objections by res-

[Basic Law for Environmental Pollution Control, 1967 JEA]

- Establishment of EQS
  - Air pollution
    - Sulfur Dioxide (1969/73)
    - Carbon Monoxide (1970)
    - Suspended Particulate Matter (1973)
    - Nitrogen Dioxide (1967/78)
    - Photochemical Oxidants (1973)
  - Noise
    - Area facing roads (1971)
    - Aircraft noise (1973)
    - Shinkansen Railway (1975)
  - Vibration (request limit)
    - Area facing road (1976)
- Emission Control
  - [Air Pollution Control Law, 1968 JEA]
    - Establishment of permissible limit of motor vehicle exhaust gas
  - [Noise Regulation Law, 1970 JEA]
    - Establishment of permissible limit of motor vehicle noise
  - [Road Vehicles Act, Ministry of Transport]
    - Establishment of technical standards for noise and air pollution control as a part of safty standards
    - Inspection at the time of periodical safety check
- Monitoring
  - [Air Pollution Control Law]
    - Monitoring at automotive exhaust gas stations by Prefectural Governments
  - [Noise (Vibration) Regulation Law]
    - Monitoring at designated areas by Prefectural Governments
  - [Road Traffic Law, rev. 1970 National Police Agency]
    - Governor's request to Public Safety Commission to impliment measures to prevent pollution
- Research and Development
  - JEA and local Governments in contract base
  - National Research Institutes under the Grant-in-Aid for Environmental Protection
  - National Institute for Environmental Studies and research institutes of local Governments
- Regional Pollution Control Plan
  - Designation of heavy polluted area that needs comprehensive control program
  - Formulation of pollution control plan by central and local Governments
  - Cost bearing by polluters
- Relief for Health Damage
  - [Pollution Related Health Damage Compensation Law, 1973 JEA]
    - Designation of regions and diseases
    - Certification of damage and decompensation rate
    - Cost bearing partly by motor vehicle weight tax
- Improvement of Roadside Environment, Airport and Shinkansen
  - [Law for the Improvement of Roadside along Trunk Roads, 1985 Ministry of Construction]
    - Designation of noisy roads requiring improvement
    - Formulation of improvement plan
    - Loaning of funds for land purchasing
    - Bearing part of expenditure to construct buffur structures
  - [Law relating to the Prevention of Injuries Due to Aircraft Noise for Public Airport, 1967 Ministry of Transport]
  - [General Principle for Measurement against Shinkansen Railway Noise, 1976 Cabinet Agreement]
- Environmental Impact Assessment
  - [Enforcement of EIA, 1984 Cabinet Decision]
    - EIA obliged to Governments related projects (express highway, national route, railway, airport)
    - Preparation of EIS by project promoter
    - Comments by Governor and Director General of JEA after public disclosure

[ ] related Law, enacted year and competent Ministry

Fig. 1. Legislative system related to traffic pollution control.

idents who bought the discounted roadside land for housing.

3. ADMINISTRATIVE IMPLEMENTATION

3.1 *Legislative system*

Traffic pollution control policies are based on the Basic Law for Environmental Pollution Control, and enforced on the basis of related laws and regulations by JEA and other competent Ministries and Agencies (Fig. 1). The main flow of control is:

1. Establishment of EQS;
2. Establishment of an emission control plan to attain the EQS on exhaust gas and noise based on the Air Pollution Control Law and Noise Regulation Law;
3. Enforcement of the permissible limit of motor vehicle exhaust gas and noise, based on the Road Vehicle Law, on newly produced models and inspection of conventional vehicles at the time of the periodical safety check;
4. Traffic control by the Prefectural Public Safety Commission according to the request of The Governor in case of serious pollution (this request has rarely been issued so far);
5. Environmental Impact Assessment of express highways and new construction of roads longer than 10 km;
6. Improvement of roadside areas suffering from serious traffic noise based on the Law for the Improvement of Roadside Along Trunk Roads.

Like other environmental problems, traffic pollution is so site-specific that local governments play a substantially larger role in integrating those countermeasures into a concrete control plan. Major local bodies organized divisions in charge of traffic pollution control. In JEA, the Office of Traffic Pollution Control started to coordinate the policies among governmental organizations in 1978.

In addition to those preventive procedures, the Pollution Related Health Damage Compensation Law enacted in 1973 covers the relief of about 100,000 health-damaged people due to air pollution. Twenty percent of the total funds come from the vehicle weight tax on the basis of the Polluter's Pay Principle. A 1987 amendment of this Law enabled the government to allocate a part of this fund to research to monitor damage and improve the roadside environment.

3.2 *Research organizations*

Agencies of Ministries and local governments promote and carry out research and surveys either with affiliated research institutes or with outside research organizations on a contract basis. Ad hoc committees and working groups organized by those governmental bodies assist their decision by indicating future policies (JEA, 1979, 1983), evaluating technical progress (JEA, 1976, 1979–1982), checking criteria (JEA, 1978), publishing technical manuals (JEA, 1982, 1986b), and so on. Academic research work in universities is reflected through these committees and working groups. Beginning in 1987, the Ministry of Education started two research groups in its Scientific Grant-in-Aid projects, which treat traffic pollution from planning and socioeconomic points of view, headed by H. Nakamura of Tokyo University and K. Iwata of Jouchi University, respectively.

4. TREND IN CONTROL POLICY AND RELATED RESEARCH

Traffic pollution occurs with friction between traffic and residences, so pollution is said to be observed neither along rural roads nor in isolated towns without heavy traffics.

As indicated by the formula:

$$\text{traffic pollution} = \text{traffic} \times \text{emission} \times \text{residence},$$

countermeasures available are classified as: (1) reduction of pollutant emission from traffic, (2) separation of the contact between emission from traffic and residence, and (3) reduction of traffic volume itself.

Another intrinsic formula, traffic $= f(\text{residence})$, makes the solution by means of (2) and (3) especially difficult.

The history of Japanese traffic pollution control and related research efforts followed this schema. The first technological step based on mechanical engineering almost succeeded, but was not enough by itself. Separation countermeasures, mainly based on civil engineering and urban planning, scored to some extent but are far from completion, and as those policies now reach a marginal point, the third one that treats the road and urban planning comprehensively, and the fourth that controls traffic volume itself, by regulation or incentive, are on the discussion table.

One peculiarity of transportation in Japan is its freight traffic. As there exists well-developed public transportation in urban areas, passenger cars now contribute relatively little to pollution. Another explanation comes from past regulating policies that have successfully emphasized passenger car technology. In major urban areas at present, more than 60% of NOx emitted from mobile sources, comes from freight trucks (JEA, 1985a), and noise from trucks is 5–10 times greater than from passenger cars, so the priority of regulation is moving towards trucks (JEA, 1983).

But material flow is essential to the logistics of urban residence, and "service" industry also means more frequent movement of commodities. In the Tokyo Metropolis Area, the frequency of freight dispatch increased during 1972–1982 in spite of a 12% decrease in total cargo flow volume. Moreover, the technical barriers seem to be relatively high in comparison with the passenger car case. Thus, this problem becomes even harder than before (Nishioka, 1986).

4.1 *Emission control*

In 1970, the Council for Transportation Policy set the goal for long-range planning to reduce exhaust gas emission to the EQS level, and the next year emission standards on hydrocarbons, nitrogen oxides, lead compounds, and particulates were established. Earlier regulation in 1968 and establishment of EQS in 1970 on carbon monoxide worked effectively, and ambient concentration registered at automobile exhaust monitoring stations nearly kept below one-fourth of EQS in this decade. But as an increasing tendency on nitrogen oxides continued, the Central Council for Pollution Control in 1972 set a stringent target, that should be reached by 1976, of a permissible limit of passenger car exhaust gas. This limit, 0.25 g/km average, the same level as proposed by Muskie in the U.S. Congress, was one-tenth of the existing level at the time. The Oil Crisis of 1973 raised controversies on the trade-off relation between energy saving and emission control that obliged the target to be extended until 1978. But efforts of automobile makers along with appropriate guidance of government (JEA, 1976, 1979–1982, 1980) achieved this difficult goal (OECD, 1986). This development worked effectively not only to prevent air pollution but also to save energy consumption that matched the high oil price era, and strengthened the Japanese automobile industry to compete with other developed countries. This is a good example of how environmental regulation can lead to technological innovation.

The tentative permissible level of 1975 and 1976 (Table 5) could be achieved relatively easily by means of engine modification, but to attain the 1978 goal, drastic change of engine design would have to be invented, and that challenge brought the innovation. The dominant systems for low pollutant emission today are the lean-burn method with exhaust gas recycle and ignition timing control (plus oxidation catalyst) and the three-way catalytic converter (Saitoh, 1985). Unleaded gasoline was necessary to avoid malfunction of the catalyst and so was introduced quickly in 1975 and almost all small cars use unleaded gasoline now.

Table 5. Comparison of permissible emission level of 1976

(g/km)	Japan	USA
Carbon monoxide	2.1	9.3
Hydrocarbons	0.25	0.93
Nitrogen oxides	0.6	1.93

Figures are average.
Source: JEA (1974b).

Recent regulation and research efforts concentrate on diesel engines to reduce nitrogen oxides, noise, and particulate.

Based on the EQS on roadside noise set in 1971, an advisory report to establish a goal for a long-range program was proposed in 1976. The first stage from 1979 regulated all vehicles to some extent, and the second stage strengthened the regulation stepwise with consideration of technical availability.

Another approach to reduce emission is to substitute electric power or methanol-fueled engines for gasoline engines. The Ministry of International Trade and Industry (MITI) carried out a six-year project from 1971 with ¥5,700 million promoted and contributed to electric vehicle technology (MITI, 1977). The results of this project were inherited by a private industrial organization, the Electric Vehicle Engineering Research Association, consisting of automobile and electric power-related companies. Tokyo Metropolis and Osaka Prefectural Government are continuing on-road tests, Kansai Electric Power Company uses electric vehicles for patrol, and the Transportation Bureau of Kyoto City operates six electric buses on one line (Japan Environmental Association, 1982). These development efforts, however, have not borne satisfactory results in a practical sense, mainly because of low battery capacity, uncertain economy, and a gasoline fuel provision system already firmly rooted.

The National Institute for Environmental Studies (NIES) is carrying on development of electric vehicles based on a new design concept (NIES, 1987b). Instead of a conventional concept only to replace the gasoline engine with an electric motor, a total design of the vehicle utilizes the advantages of electric power drive. Direct drive by outer rotator system, using a brushless direct current motor made of permanent magnetic coil, was applied to a prototype motorcycle and this concept extended to apply to passenger car design (Shimizu, 1986).

A methanol engine vehicle was developed by Ministry of Transport (MOT), mainly for the purpose of developing substitute fuel and at the same time reducing pollutants. Tokyo Metropolis is testing this vehicle on the road to confirm its pollution prevention capability (Iida, 1986).

4.2 *Moderating the friction between traffic and residence*

Although stringent regulatory policies for emission control have been set, air pollution in major urban areas and roadside noise still remains. Therefore, in addition to the emission control, site-specific countermeasures to separate traffic (and its emissions) from residential areas were developed next. In 1974, the Ministry of Construction (MOC) issued a standard for land acquisition and road maintenance to preserve the environment along newly planned roads, recommending separation of housing from traffic flow. In 1975, a policy of reducing total traffic volume in large cities was proposed, and some local governments (including Tokyo and Osaka) began to improve mass transit, introduce sophisticated traffic control systems, and support rational allocation of truck terminals (Nagai, 1985). An advisory report by the Central Council for Pollution Control. "On the Traffic Pollution Control Policy" (JEA, 1983), proposed to strengthen controls on heavy trucks, designate heavy-duty truck routes, enforce the Polluters' Pay Principle, upgrade roads and road facilities, and finally adjust roadside land use to separate traffic.

The 1980 Law for the Improvement of Roadsides Along Trunk Road (MOC, 1979) was enacted to enable the government to make loans to local bodies for improving roadside areas for noise resistance, such as by constructing buffer buildings. Until 1986, six routes totaling 81 km were designated under this law, and local administration are now in the process of design and negotiation with residents.

Environmental Impact Assessment (EIS) is one of the effective means for pollution prevention. The Cabinet in 1984 decided on the "Implementation of EIS," after more than five years of an unsuccessful effort by JEA to have it enacted as a law. By this decision large-scale projects, involving the national government for which significant environmental impacts are predicted, are assessed according to technical guidelines (MOC, 1985).

Some traffic control measures have been tried locally, such as removing through traffic by road design, promotion of bicycle use, and the introduction of new transportation systems (Japan Environmental Association, 1982). A ban on trucks in the town areas of Yamagata and Iwaki (nighttime only) worked effectively. Inducing trucks at night to use a toll expressway bypassing Fujieda City, by discounting the toll fee, is one of the few road pricing policies actually adopted, with little success reported so far. At Circular Road No. 7 in Tokyo and roads in Nagoya, heavy trucks are required to use only the central lane to lessen noise, but the effectiveness of this trial is still in question. By 1987, 90 cities completed and 250 cities were planning bypass construction (JEA, 1984).

Already 1,400 km of noise barriers have been constructed nationwide, and in recently built express highways (like Yokohama–Yokosuka and Joban express highway), tight noise barriers are applied using the upper plane as a public garden (Japan Environment Association, 1982).

To evaluate these roadside improvement countermeasures, research on mechanisms of pollutant diffusion and noise propagation were carried out.

The technical guidelines for EIS (MOC, 1985) adopted the Plume Model in the with-wind case and the Puff Model for the without-wind case. For the Implementation of Areawide Total Pollutant Load Control on NOx in 1981, a technical manual (JEA, 1982) was published, in which an empirical formula (JEA Formula) was proposed to estimate roadside air pollutant diffusion. Ambient air pollution concentration areawide is estimated by summing up linkwise pollutant concentrations (Osaka Prefectural Government, 1985). Accurate estimation of driving patterns is essential for this estimation; this still remains to be investigated (Nishida, 1986).

NIES developed a system to assist in effectiveness evaluation of roadside improvement alternatives such as setting back buildings, constructing depressed and elevated roads, and utilizing exhaust gas treatment. This precise air pollution simulation and display system, with its communication facility equipped with a video projector, serves to select the best and most feasible measures for a specific site with a consensus of experts and residents (NIES, 1987a).

Some preliminary developments have been made to treat NOx in roadside ambient air. NIES, jointly with Hitachi Zousen Technical Laboratory, proposes a chemical process to decompose NOx contained in lean (3–5 ppm) high-volume (500,000 Nm^3/H) tunnel gases. The point of this process is to reduce the air volume to be treated in a catalytic reactor to 1/20 by the use of an absorbent. It is still an experimental process, but as land prices in the metropolitan area are greatly increasing, newly planned roads are obliged to be depressed or tunneled, and this kind of gas treatment plant may become economically feasible in the near future.

Tokyo Metropolis, with the Pollution and Resource Research Institute of MITI, carried out a wind tunnel simulation to analyse air pollution on Yamatocho Crossing, where the worst air pollution in Japan is observed, and pointed out a "covering" effect of an elevated road that prevents swift diffusion of pollutants.

The effects of smoothing traffic by the construction of an overpass was estimated to be a 10% reduction of exhaust gas per vehicle in a joint study of JEA, the Ministry of Construction, and the National Police Agency.

As for the estimation of road traffic noise, a formula to estimate L_{50} (median of noise levels measured) developed by the Japanese Society of Sound and Vibration was adopted as standard reference for EIS (MOC, 1985). Supplemental factors experimentally measured are in practical use to compensate for error (Kanayasu, 1978).

The pollution prevention capability of roadside greenery is sometimes discussed. The noise attenuation capacity of a hedge is estimated to be 2–3 dB (JEA, 1986c), and the psychological effects may be more. Experimental research using an environment simulator carried in NIES indicates some plants have an absorption capability of NOx (NIES, 1987c) that suggests that roadside trees ease air pollution in some degree.

4.3 *Planning for comprehensive policy*

The policies indicated above may function well in a local context, but sometimes tend to be patchwork or "mole bashing," and only move pollution from one place to another. Moreover, in the long run, they serve, contrary to the initial purpose, to increase traffic and pollution from a regional point of view. A comprehensive analysis and planning procedure is necessary to set up more long-sighted anticipatory traffic pollution control that integrates land use policy, traffic and urban management policy, etc.

Major local governments have now started to establish long-term traffic pollution control plans (Tokyo Metropolis, 1982; Osaka Prefectural Government, 1982; Kobe City, 1986; Yokohama City, 1987). JEA guides this movement with research works of three years of discussion (JEA, 1986b).

In the planning process, regionwide recognition of pollution and damage is essential. Research work in this context is being carried on in two phases. One is to quantify the environmental impacts covering not only physical pollution but also environmental amenity and social impacts the traffic brings into the residential area.

Social survey methods are used to evaluate comprehensively the environment. The items to be evaluated are pollution, landscape destruction, solar interception, and social separation (Aoshima *et al.*, 1977, Shiozaki and Mimura, 1978, NIES, 1982, Sakai, 1986) and are scored by the residents individually or in group conferences (Harashina *et al.*, 1981). The surveys measured social impacts of road and social separation effects of traffic in neighbourhood communities (Ohta and Kubota, 1983), as well as tradeoff relations between convenience and environment, (Kawakami *et al.*, 1983). An analysis of one-week walking trip data of 200 persons by a graphic display system showed that the residents feel danger in crossing the road with traffic of more than 2,000 vehicles per hour (Moriguchi *et al.*, 1982).

Another phase is to integrate those results into one map to serve regionwide policy evaluation (Horie *et al.*, 1982). Computer systems play an essential and most effective role in this phase, because traffic pollution such as noise should be treated fully site-specifically and, at the same time, regionally, considering that impacts of countermeasure (like traffic control) affect not only that spot but also propagate widely. So to judge the effectiveness of policy alternatives, any device to see simultaneously micro and macro effects at a glance is very helpful for planners and decision makers (Nishioka, 1987).

With the help of a computer system, the Osaka Prefectural Government screened out roadside spots seriously suffering from noise with a criteria combining population, traffic volume, and road conditions (Osaka Prefectural Government, 1986). Kobe City developed a personal computer system to formulate city-level control policy (Kobe City, 1986), and NIES developed a graphic system for environmental evaluation of a prefectural-level road network (NIES, 1987a).

4.4 *Economic evaluation and incentive policy*

Economic evaluation of traffic pollution is necessary to assure equity between polluters and those suffering pollution, and to decide the amount of transfer price for an effective incentive policy. Such an incentive policy has not been much discussed so far in Japan. One plausible reason for this comes from the history of an environmental policy that refused to discuss environment and economy at the same level. (In the process of enacting the Basic Law, a harmonization clause between environment and economy was abandoned.) But as the effectiveness of regulatory policy reaches saturation, an incentive policy should be considered.

Morisugi *et al.* (1980) showed the equivalence of a series of methods applied to estimate the social cost of aircraft noise, and gave the theoretical base for an accountability of pollution. Iwata and Asada (1985) applied a property pricing approach to evaluate the justification of an existing special landing fee at Osaka Airport and concluded that it covers only 30%–50% of the marginal social cost. Koshi (1979) pointed out the underestimation of environmental and social cost of trucks, and the inequity of fuel tax (¥24.3/L for diesel fuel, ¥45.6/L for gasoline) and weight tax. Uchiyama (1983) applied land price analysis to measure the social cost of roadside noise. The only existing incentive is mitigation of automobile tax and acquisition tax applied to electric and methanol-fueled vehicles.

5. CONCLUSION

The 4th National Comprehensive Development Plan defines the Japan of the year 2000 as "A Network Society," where moving and exchange activities of man, material, and information will increase up to 1.4, 1.5, and 3.4 times more than in 1980. This forecast with increasing urbanization certainly brings the possibility of more serious friction between traffic and residences. Fifteen years' effort so far has proved that technical countermeasures are not enough to cope with this trend and that policy should move more to urban management, including rational industrial and land use planning, and should depend more on incentives than on regulations. Not only for environment but also for promoting convenience of traffic, transportation systems should be more tightly integrated into urban policy and planning, especially in Japan, where geographical conditions are not so favourable.

REFERENCES

Aoshima N., Kawakami S. and Katahira K. (1977) An analysis on significance of components in environmental evaluation system for highway planning. *Proc. JSCE* **263**, 97–105.

Harashina S., Iikura Y. and Nishioka S. (1981) Environmental evaluation of roadside residential area. *Annual Res. Report City Plan. Inst. Japan* **16**, 319–324.

Horie S., Sekine K. and Imanishi Y. (1982) Dynamic simulation system of urban road traffic and environment. *Proc. JSCE* **328**, 97–108.

Iida Y. (1986) On road test of methanol fueled vehicle. *Sangyo Kankyo* **15**(161), 73–77.

Iwata K. and Asada Y. (1985) Measurement of social cost for traffic noise—case study of the Osaka International Airport. *Kankyo Kenkyu* **55**, 124–132.

Japan Environmental Association (1982) Survey report on the traffic pollution control in model cities. Tokyo.

JEA (1974a) Environmental laws and regulations in Japan. Tokyo.†

JEA (1974b) Quality of environment in Japan (annual report). Tokyo.

JEA (1976) Motor vehicle emissions. Final report on motor vehicle nitrogen oxides emission control technology. Tokyo.†

JEA (1978) On the criteria for human health damage by nitrogen dioxide. Tokyo.

JEA (1979) On the traffic pollution problems—report from discussion group on traffic pollution control. Tokyo.

JEA (1979, 1980, 1981, 1982) Technical report on the motor vehicle pollution control (1st–4th). Tokyo.

JEA (1980) Air pollution and motor vehicle emission control in Japan. Automotive Pollution Control Division, Air Quality Bureau, Tokyo, p. 109.†

JEA (1982) Technical manual for total emission load control on nitrogen oxides. Tokyo.

JEA (1983) On the traffic pollution control policy—an advisory report from Central Council for Environmental Pollution Control. Tokyo.

JEA (1984) Survey on the effects of bypass as a reducing method of road traffic noise in urban area. Tokyo.

JEA (1985a) Mid-term prediction on the air pollution by nitrogen oxides in urban areas. Tokyo.

JEA (1985b) The status quo of road traffic noise and policies to be taken hereafter. Tokyo.

JEA (1986a) Quality of the environment in Japan (annual report to Diet). Tokyo.†

JEA (1986b) Planning manual for traffic pollution control. Tokyo.

JEA (1986c) Environmental research in Japan—annual report of research under Grant-in-Aid for Environmental Research. Tokyo.

JEA (1987) Quality of environment in Japan (annual report). Tokyo.

Kanayasu K. (1978) Compatibility of calculation models for road traffic noise. *Proc. JSCE* **278**, 75–84.

Kawakami S., Hirohata Y. and Kumagai E. (1983) Resident evaluation of trade-off between convenience of urban transport facilities and their environmental impacts. *Annual Res. Report City Plan. Inst. Japan* **18**, 475–480.

Kobe City (1986) Prediction of air pollution in the city area of Kobe.

Koshi M. (1979) Social cost of truck operation. *Economist* Oct. 16, pp. 32–36.

MITI (1977) Development of electric vehicle. Report from Agency of Industrial Science and Technology, Tokyo.

MOC (1979) On the countermeasures to prevent damages caused by road traffic noise and to promote appropriate and rational land use along specific trunk road in urban area. Advisory report from Council for Road Policy, Tokyo.

MOC (1985) Technical guideline on the environmental impact assessment for the public work projects competent to MOC. Tokyo.

Moriguchi Y., Harasawa H. and Nishioka S. (1982) Application of color graphic display system to the diagnosis on roadside environment. *Proc. 7th Annual Symposium Computer Appl. JSCE* 41–44.

Morisugi H., Miyatake N. and Yoshida T. (1980) A study of measurement of social cost of noise. *Proc. JSCE* **302**, 113–123.

Nagai Y. (1985) Development of traffic pollution control in Osaka Prefecture, *Kankyo Kenkyu* **54**, 88–96.

NIES (1982) Comprehensive evaluation of environmental impacts of road and traffic. Research report from the National Institute for Environmental Studies 35, Tsukuba.

NIES (1987a) Research on the effectiveness of countermeasures for preventing site-specific roadside air pollution by NOx, Tsukuba.

NIES (1987b) Technological assessment of electric vehicles from the environmental protection viewpoint. Research report from the National Institute for Environmental Studies 103, Tsukuba.

NIES (1987c) Studies on the role of vegetation as a sink of air pollutants. Research report from the National Institute for Environmental Studies 108, Tsukuba.

Nishida K., Murakami Y. and Yamakawa Y. (1986) Studies on driving pattern of vehicles in the city. *Kogai Taisaku* **22** (5), 45–50.

Nishioka S. (1986) Urban structure and material flow analysed from environmental protection viewpoint. *Kankyo Kenkyu* **60**, 63–75.

Nishioka S. (1987) Compromising planning procedures for the integration of living environment—a case study of traffic pollution control. *Proc. 15th Annual Symposium on Environmental Issues, JSCE* 92–98.

OECD (1977) Environmental policies in Japan. OECD, Paris.†

OECD (1986) Environmental effects of automotive transport. OECD, Paris.*

OECD (1987) OECD environmental data, compendium 1987. OECD, Paris.†

Ohta K. and Kubota H. (1983) Effects of residential road on the formation of neighbourhood community. *Annual Res. Report City Plan. Inst. Japan* **18**, 409–414.

Osaka Prefectural Government (1982) Research report on the countermeasures to prevent nitrogen oxides from mobile sources.

Osaka Prefectural Government (1985) Estimation of roadside air pollution by means of JEA Model.

Osaka Prefectural Government (1986) Report on the planning method on the traffic pollution control.

Saitoh T. (1985) History and future of automobile emission control techniques. *J. JSME* **88**(797), 71–76.

Sakai K. (1986) Study on evaluation road by roadside residents. *Annual Res. Report City Plan. Inst. Japan* **21**, 193–198.

Shimizu H. (1986) A development of an electric motor cycle. *Jidohsha Kenkyu* **8**(7), 8–12.

Shiozaki Y. and Mimura H. (1978) A survey of roadside environment along urban trunk way. *Annual Res. Report City Plan. Inst. Japan* **13**, 211–216.

Tokyo Metropolis (1982) Survey report on the countermeasures to reduce nitrogen oxides from mobile sources.

Uchiyama H. (1983) Measurement of social cost of roadside noise by means of land price analysis. *Proc. Annual Meeting JSCE* 231–232.

Yokohama City (1987) Traffic pollution control plan of Yokohama City.

†In English.