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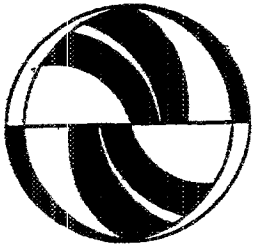
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## **Environmental Protection**

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Chapter 15

## ENVIRONMENTAL PROTECTION

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### 1. Introduction

Environmental protection is a major concern of modern societies, and transport is a major source of environmental damage. So it should not be surprising that environmental protection has played a central role in transportation policy and decisions, and that considerable resources have been devoted to mitigating adverse environmental impacts.

Environmental protection can be analyzed from different points of view, including technical, legal, ecological and political. Here we focus secondarily on engineering and primarily on economic perspectives, with acknowledgment of their shortcomings. The engineer seeks technical solutions and designs technical devices to abate environmental damage, the economist seeks the best use of societal resources and identifies actions that yield the highest return for investments and other initiatives.

In market economies, prices are the primary mechanism for allocating resources. The difficulty, however, is that environmental impacts are largely outside the marketplace. When I drive a car, I make noise, I disturb my neighbors, but I do not pay for that damage, and my neighbors are not compensated in any way. If I was obligated to pay compensation – what economists call the polluter-pays principle – I would make less noise. Unfortunately there is no market for that “good” – or, more accurately, “bad”, there is no natural mechanism to ensure a proper balance between the demand for silence and the supply of silence. The same applies to air and water pollution, climate change, esthetics, loss of wetlands, loss of biodiversity, and most other forms of environmental damage.

This absence of markets for environmental damage is a clear case for public action, public authorities must devise mechanisms to respond to this market failure. Economics is a powerful tool, but because environmental effects are

outside the marketplace, public action must be manifested in the creation of secondary markets or as administrative actions by government. Economists argue that these actions should be guided by economic principles. But, contrary to natural market mechanisms, which are relatively non-manipulable, devices created by public authorities are subject to discretion and can be more easily influenced by the strategic action of the private interests at stake.

While economics provides a powerful framework for guiding and designing actions to reduce environmental damage, the shortcomings noted above have led to other approaches playing a more dominating role in recent decades.

Government first actively intervened on behalf of environmental protection in the 1960s. First, regulatory programs were adopted to reduce air pollution, followed by fuel use regulations in the USA and Japan in the 1970s. The regulatory system that evolved was a creation of lawyers and engineers whose disciplinary paradigm was one of right and wrong. It was founded on highly specific rules of conduct and design, resulting in an approach that has come to be known as "command and control." While the various regulatory activities affecting vehicles and fuels are not strictly command and control – they contain some flexibility – the overriding framework continues to be one of directives that restrict the behavior of vehicle and fuel suppliers.

Most rules were premised on technological solutions and followed engineering principles of "best available technology." Examples include rules specifying the amount of pollution a car is allowed to emit, attributes of fuels (use of oxygenates, lead, etc.), allowable types of engine technologies (e.g., bans on two-stroke engines), required inspections of vehicle emissions, and bans on car use in city centers.

As part of a larger debate over the role and effectiveness of government intervention, conventional wisdom in both the political and the professional arenas is gradually shifting from an embrace of command and control to greater use of market instruments and greater emphasis on flexibility. Examples include use of tradable credits (for vehicle emissions), fuel taxes, vehicle taxes, tolls for use of high-occupancy vehicle lanes, and voluntary agreements with industry to reduce CO<sub>2</sub>.

The perception exists that command and control rules are appropriate and effective when externalities are large and little effort has been expended. But after decades of efforts to reduce emissions, the marginal costs for further reductions can be large and the marginal benefits relatively small. It is widely accepted that the most cost-effective approach is to grant more flexibility to industry, though much of the environmental community remains skeptical. They fear that flexibility will result in industry finding loopholes to avoid action, and that market instruments will create environmental "hot spots" (often where residents are poor and less politically influential) and will not be as effective at changing behavior as regulations and rules.

These general considerations will be developed and woven into the following sections. In Section 2, we categorize environmental damage, Section 3 provides a review of economic tools to cope with environmental damage and criteria for when and how to use them; in Section 4, we describe how these tools are applied to general transport policy, infrastructure design, and vehicle design and use, and in the concluding section, we provide a general assessment, stressing shortcomings, successes, and future prospects for environmental protection.

## 2. Categories of environmental damage

The transport sector encompasses a wide variety of activities and facilities, from infrastructure building to vehicle use. Environmental damage includes the following:

- (1) Esthetic effects resulting from new infrastructure and vehicle use. These effects are pervasive and highly subjective. They are usually viewed as negative intrusions, but in some cases can be positive, as when users gain access to previously inaccessible scenery.
- (2) Habitat and community fragmentation, for animals, plants, and humans. Animal and plant migration is inhibited by the building of road and other infrastructure, exacerbating the difficulty of responding to environmental threats and changing climate.
- (3) Soil and underground water pollution from construction and use of road and fuels infrastructure (leakage from fuel tanks and pipes, water runoff from roads, particles).
- (4) Water pollution from tanker collisions, spills, and discharges, including such dramatic accidents as Exxon Valdez or Amoco Cadiz.
- (5) Noise and vibration caused by all vehicles in the water, on land, and in the air. Road vehicles are most troublesome in dense urban areas, recreational (off-road) vehicles in pristine areas, and airplanes near airports.
- (6) Air pollution, primarily from vehicle exhausts, but also from upstream production of energy and manufacture of vehicles and facilities. The principal concern is with road traffic, because of the large volume of pollution emitted and because it is in close proximity to people. About half of the air pollutants emitted in urban areas are from vehicles. Air pollution damages human health, as well as vegetation and buildings.
- (7) Climate change caused by large emission of greenhouse gases, especially CO<sub>2</sub>. About 20–30% of greenhouse gases in OECD countries are from transportation, largely from fossil fuel combustion in cars and trucks. Climate change effects have been small so far, but the continuing buildup of these gases is creating a growing threat.

In this chapter, we limit our focus to air pollution, noise, landscape and barrier effects, and climate change. These environmental impacts attract the greatest attention of decision-makers, and have received considerable study.

### **3. Economic tools to cope with environmental damage**

A central issue is the extent to which public intervention to protect the environment is appropriate, and if so, what type of intervention is most effective. A celebrated theorem (Coase, 1960) tells that the use of natural market procedures, realized as bargaining, leads to an efficient result under some conditions:

- (1) no transaction costs,
- (2) perfect information, and
- (3) all parties at stake are involved in the bargaining.

It is clear that these conditions are rarely satisfied in transport activities. Usually transaction costs are high, due to the large number of parties involved – the many people exposed to environmental risk and the many vehicle operators causing them. Perfect information is not available to all, those exposed are often not aware of the extent of damage until much later, and vehicle operators have even less information. And many parties at stake often do not participate in the bargaining, as with taxpayer financing of infrastructure. For these reasons there is a strong case in favor of public intervention for environmental protection. This public intervention can follow various channels, which, following a classification close to Button (1999) can be characterized as follows:

- (1) Direct public management. This approach is widely used for many types of modal and intermodal terminals (airports, buses, rail) and guideways, but there is a growing movement toward selective privatization.
- (2) Regulation of actions by individuals and organizations, such as limiting emissions from cars and noise from airplanes (often referred to as “command and control”).
- (3) Economic instruments. These include mechanisms that alter price signals, such as fuel taxes, congestion fees, and payments for scrapping old polluting cars, and mechanisms that create property rights and new markets for environment goods, such as marketable credits for emissions, so that the Coase theorem could operate, and bargaining leads to an efficient result.

Policymakers and researchers carry on a continuing debate as to which tools to use for which problems in which situations. First-order criteria include the following:



- (1) transaction costs (cost in money and time for information to be used in implementation, management, and control),
- (2) accuracy and side-effects (e.g., an increase of petrol tax is quite an inaccurate way to master air pollution and has side-effects on car size),
- (3) equity and distributional effects (taxing old cars and subsidizing accelerated scrappage are equivalent in terms of pollution abatement, but the distributional consequences of these two measures are quite different),
- (4) collective efficiency (the economic optimum is not suppression of environment damage, but abatement to the point where the marginal cost of abatement is equal to the sum of the marginal willingness to pay of the people who suffer from it)

There are very few general findings about the advantages and drawbacks of the tools of public intervention vis-à-vis these criteria, and of those, virtually all are abstract and broadly theoretical. Certainly, economic instruments are more efficient than regulation under conditions of perfect information and without transaction costs, they allow for better decentralization of decisions and give more incentive to foster efficient technologies. And there are also some results relying on the choice between price and quantities regulation on the degree of uncertainty of costs and willingness to pay.

But economic instruments have more clear and distinct effects on redistribution and equity than regulations. Taxes for instance directly hurt the user's wallet,<sup>\*</sup> while traffic regulations just impose time delay, and emissions regulations provide all drivers with a technologically improved car.

Adoption of any particular instrument implies a variety of trade-offs that are difficult to measure and foresee. Is it more important to reduce environmental damage at least cost to society or in a way that is deemed equitable? Even the definition of equity is elusive and difficult to measure, does it mean that costs are borne by those who are more affluent, or by those residing in the respective region, or by those more willing to pay to reduce the damage?

Equally problematic is the difficulty of designing and adopting instruments that elicit the desired effect without causing secondary effects. For instance, how should one reduce air pollution from vehicles? Some efficient devices such as catalytic converters increase energy consumption and greenhouse gases a small amount, and noise abatement devices increase the weight of the vehicle.

Consider also that vehicles emit a variety of pollutants. Some pollutants are of more concern in some locations (carbon monoxide near intersections), at sometimes of day (ozone when the sun is shining), and when people are outdoors. Moreover, emissions are highly sensitive to how a person drives (hard

<sup>\*</sup>It can be shown that in many cases, road pricing has a negative direct effect on the user's surplus, and that the collective positive effect is due to the increase of government taxes.

accelerations cause 100–1000 times more pollution than simple cruising) An economist might argue that the ideal instrument in this case of air pollution is a tax that registers how much of each pollutant is emitted, exactly when, and the number of people likely to be exposed (perhaps using GIS and satellite data) – and that the fee is immediately communicated to the driver on the vehicle's instrument panel so that the driver has the information to alter his/her behavior For this market instrument to operate efficiently, someone must calculate the value (or damage) of each pollutant at each location at each time of day, the technology must exist that accurately measures each pollutant on a real-time basis and some means of actually billing each driver (or vehicle owner) must exist Some day, this idealized market instrument may be possible due to the availability of new information and measuring technologies, and better understanding of pollutant damage For now, this is no more than a dream

Another difficulty in creating taxes and regulations that meet economic efficiency objectives is the uncertain environmental consequences of transport Indeed, there is not even agreement on the health effects of pollutants and their importance relative to other social goals For instance, consider the case of diesel engines Diesel engines are about 10–20% more efficient than gasoline engines, and therefore emit that much less CO<sub>2</sub> They also emit less CO and hydrocarbons than gasoline engines, but higher levels of NO<sub>x</sub> and particulate matter In Europe, this trade-off is considered acceptable, even desirable In the U.S.A. however, and increasingly in Japan, diesels are much less popular and regulators are taking a far more aggressive stance against them The different regulations and policies are due in part to uncertainty about the health effects of particulate matter It is now widely agreed that particles are the most threatening air pollutant to human health, but it is uncertain how much comes from diesel engines, whether the chief culprits are the very fine particles (with diameters in the nanometer range), and whether these fine particles are and will be reduced by new diesel emission control technology

It is clear from this quick review that environmental protection is a matter of political decision – concerning trade-offs between equity and efficiency and various other social goals, and judgments about uncertainty Researchers are becoming more sophisticated about quantifying damages and costs, and this information is finding its way into the policymaking process but continuing uncertainties and conflicts mean that many decisions about environmental protection will continue to be based primarily on political factors Private interests and lobbies use uncertainty to push governmental decisions toward their objectives The story of environmental protection can be read as a struggle between pressure groups But in a larger sense, the debate can be characterized as one of competing philosophies, values, and paradigms

Another perspective, which we do not pursue further but which is fundamental to understanding the debate over environmental protection, is one put

forth by ecologists. They believe that humanity's anthropocentric approach is inappropriate. We need to see humans as just one species within a larger ecological system, and that doing so would entail much more emphasis on preserving a sustainable balance between humans, plants, and animals. This perspective seems to be gaining more support over time.

Institutional mechanisms have evolved to ensure that externalities and public goods are taken into account – they include various governmental entities as well as non-governmental organizations (NGOs) that advocate the interests of those without direct economic interests, and even the interests of other species.

As there is no clear solution to any particular problem and a variety of forces and interests are at work, it should not be surprising that the equilibrium may be quite different from one country to another. It also explains why debates over environmental protection are often so disjointed, more than with most public decisions, they are the outcome of many partial struggles rather than the result of a comprehensive and coherent process.

#### **4. The targets of environmental protection**

We categorize the transport sector into three areas of activities:

- (1) general transport policy,
- (2) infrastructure design, and
- (3) vehicle design and use.

##### *4.1 General transport policy*

The transport sector is a complex mix of subsystems, often referred to as modes (buses, rail, airplanes, cars, etc.), all influenced to varying degrees by governmental entities. A major share of government resources and attention are devoted to transport because transport activities have major social costs and benefits. Governments at all levels constantly struggle over levels of support for different modes – for instance, to invest in more rail lines or more roads, or subsidize more buses or build more parking. Central to these policy decisions are widely held beliefs that road transport, especially cars, is a grave environmental threat, that more resources need to be devoted to collective transport, and that infrastructure pricing should be used to divert passenger and freight traffic away from cars and trucks.

This policy is explicit in many European countries, it is for instance the goal of pricing reforms supported by the European Union (European Commission, 1995,

1996) In urban areas, especially during the past few decades, the underlying premise of urban transport policy in virtually all cities of the world, including the U S A , has been to enhance transit. In Europe it is the result of a long process begun about 30 years ago, premised on the belief that travelers could be readily diverted from cars to collective transport. Considerable public investment has gone into transit in Europe and the U S A , in both cases, though, the mode share of transit has continued to drop. Policy-makers in Europe, but not the U S A , are now shifting their emphasis from transit enhancement to suppression of car use. They are using various devices to decrease urban space dedicated to cars, to the benefit of pedestrians, bicycles or buses.

Support for rail and collective transport is explicitly justified by environmental arguments for reduced noise and air pollution. But social-cost studies show that measurable environmental damage is not sufficiently high to justify such policies (Greene et al , 1997). It can be said that strong public support for environmental protection is often a statement of distaste for the visual intrusion of cars and roads, delays caused by congestion, and a concern for what is often seen as a deterioration of community. This point is illustrated by the high cost of changes in the layout of infrastructure resulting from public hearings and the small benefits, especially in the case of noise abatement. In any case, pro-transit and pro-rail policies have had mixed success. Almost everywhere, transit has been losing market share to cars. U S cities, except for large city centers, are largely resigned to the marginalization of transit. European cities, which are older and denser, are making a stronger effort to slow or even stop the shift to cars. For interurban travel the dynamic is more complex. Great Britain, for instance, has in the past placed a moratorium on new road construction, and lies well behind other European countries such as France, where motorway construction continues at roughly the same pace as ten or twenty years ago, while TGV expansion is slowing after peaking around 1990.

A similar story can be told for freight transport, with rail continuing to lose market share to trucks almost everywhere. This shift has slowed in those cases, especially in the U S A , where rail operators have been most aggressive at partnering with trucking companies in using containers and encouraging intermodal shipments.

Transport pricing initiatives have also proceeded quite unevenly. Road pricing initiatives failed in The Netherlands, for instance, while urban collective transport prices have in general increased in recent years. Of course, it must be recognized that in Europe the price of collective transport was very low, resulting in large public subsidies, and that petrol taxes are high compared with the U S A . No ecotaxes have been adopted, except in Sweden. Several attempts have been made to bring road tolls nearer to social costs, but these efforts are justified by congestion cost externalities, not environmental costs, and have mainly consisted of differentiating tolls by time of day.

## 4.2 Infrastructure design

Infrastructure facilities can be designed and built to mitigate environmental damage, especially esthetics, soil and water pollution, noise, and barrier effects.

Landscape preservation relies on various devices and practices, including more esthetic designs of facilities, tunnels to avoid ecologically sensitive and esthetically attractive landscapes, and planting of attractive and native plants. It is common to devote 10% of the total cost of an infrastructure project to landscape preservation, and even more when historic buildings, scenic sights, or fragile ecosystems are nearby.

Barrier effects are reduced by building bridges and tunnels, specially designed for particular kinds of animals. The same is done for human beings, especially in urban areas, to maintain connection and community in neighborhoods. It is not possible, however, to eliminate the barrier effects caused by infrastructure. In the case of human pedestrians, the construction of tunnels and bridges often creates uneasiness, requires more travel time, and disrupts daily life.

Noise abatement is an important task that can be performed in part through infrastructure design. The three important means are soil movements, noise barriers, and tunneling, this last solution is the most expensive and is normally used only for dramatic situations of high noise levels involving large numbers of people.

Infrastructure investments are routinely subjected to cost-benefit analysis. It would seem normal that design decisions involving environmental protection would also be subjected to such criteria. This is rarely the case. First, cost-benefit analysis is not able, in the current state of the art, to cope with soil pollution, barrier effects, and landscape impacts. In the latter case, it is possible to value the effects through stated-preference methods but the results are often not reliable and are highly sensitive to the local situation. It is not possible to draw general rules nor rely on findings from similar situations.

The unique monetizable effect is noise, and the practice of incorporating noise valuations in cost-benefit analysis is now becoming widespread. Unfortunately it suffers several drawbacks. First, as noise is a very local phenomenon that varies widely according to topography, it is difficult to measure it precisely in the early stage of the decision process of new infrastructure. Noise is better assessed during the last stages of the process, when the final track is fixed, the execution schemes are completed, and bargaining is in progress with the local bodies (neighbor associations, local political authorities, etc.). But it often happens, at this stage, that the bargaining power of these local bodies is tremendous. They are able to delay or postpone construction, they can use political threats, and they can inflict huge costs on the infrastructure providers. For these reasons it appears that ex post noise cost determinations, derived from observations of past decisions, are much higher than the cost of noise derived from willingness-to-pay methods – the

ratio can be one hundred to one in the case of suburban highways, rail tracks, and new airports (It must be acknowledged that the explicit argument about noise often covers implicit arguments about landscape, esthetics, visual intrusion, or barrier effect, as indicated earlier )

#### 4.3 *Vehicle design and use*

The transport sector contributes about half the urban air pollution and about 20–30% of greenhouse gases in most OECD countries. Most of the pollution and the majority of greenhouse gases are from road vehicles. This general statement camouflages many variations, however. Some modes have a larger effect in some countries, for instance, in the U S A , air transport has a much greater effect than in most other countries, and transit a much smaller effect. The technology mix can be very different, with most European cities having a much higher proportion of diesel engines than the U S A or Japan. And the relative magnitude of emissions varies greatly and they have very different geographical reach. For instance, cars contribute as much as 90% of total carbon monoxide emissions in a city, but the health effects reach only about 50 m from the pollution source. On the other hand, greenhouse gas emissions from vehicles have a global reach.

In general, the quantity of air pollution emitted from a vehicle has been reduced dramatically in the U S A and Japan during the past few decades, by about 75–95%, depending on the pollutant and taking into account actual in-use emissions over the life of the vehicle (Pickrell, 1999), and overall air pollution has also been slowly improving. In Europe, progress has been slower but is catching up, with strict new rules in place. Indeed, in all OECD countries, rules and institutions and enforcement mechanisms are in place to reduce vehicle emissions significantly below current levels. Air quality improvement is a major success story in the U S A and Japan, and likely to be a big success story in Europe as well.

The situation with greenhouse gases is more problematic. Emissions of these gases, mostly carbon dioxide, have been increasing by about 1–2% per year in most countries, and somewhat faster in transport, despite the series of international protocols and agreements to reduce greenhouse gases. A voluntary agreement between the European Union and European automakers to reduce CO<sub>2</sub> emissions by 25% (per veh-km) between 1995 and 2008, and similarly stringent fuel economy standards in Japan suggest that past trends could be countered in those areas. In the U S , proposals to tighten existing fuel economy standards continue to gain attention but standards have been frozen for cars since the late 1980s and for light trucks since the early 1990s.

When governments first intervened in the 1960s and 1970s to reduce emissions (and energy use in the U S A and Japan), the initiatives contained a balance of technology and behavioral strategies. Over time, though, air quality regulators

have gradually turned more to technical solutions – mostly through promulgation of increasingly stringent performance standards – and less to behavioral strategies aimed at reduced driving and speeds. In the U S A , “travel demand management” strategies first adopted in the 1970s to reduce car travel (for environmental and infrastructure efficiency reasons) now receive little attention, and 55 mph speed limits imposed in 1975 on all U S motorways to reduce energy use, have now been relaxed (in some states rural speed limits have been completely abandoned)

Government regulation of vehicle emissions is highly formalized and structured. The paper flow between automakers and regulators contains minutiae on the design and conduct of emission tests and advises them of changes in reporting requirements, test procedures, and control technology. In most cases, a uniform standard is specified that each and every car, bus, and truck must meet. Initially, emission standards were established for three pollutants: carbon monoxide, hydrocarbons, and nitrogen oxides (plus standards were established for lead content of fuel), and later standards were developed for particulate matter and other toxic chemicals. Compliance is verified by running a sample of vehicles through a standard driving cycle.

Standards have been tightened intermittently, based on subjective judgments of the severity of ambient pollution problems and of what manufacturers were capable of achieving at reasonable cost. The strength of this uniform-standard approach is simplicity and apparent ease of enforcement.

Government intervention to reduce fuel consumption has been somewhat more flexible and less strict. No standards exist for heavy- or medium-duty trucks and buses. In the U S A since 1978, light-duty vehicles supplied by each manufacturer have been required to meet an average standard. Compliance is measured by average fuel consumption across all vehicles sold in a particular year (divided into four separate groups of cars, light trucks, and imported and domestically produced vehicles). Japan has a long-standing set of fuel consumption rules that were recently tightened and redesigned to require roughly 23% improvement between 1995 and 2010 for each category size of gasoline-powered cars (and somewhat less for light trucks and diesel vehicles). Europe has never adopted fuel economy standards, but has relied on high fuel taxes to restrain fuel consumption. In 1998, however, automakers under pressure from the European Union, agreed to reduce CO<sub>2</sub> emissions of light-duty vehicles by 25% (per vehicle) by 2008. Various monitoring protocols were adopted but the program is voluntary and no rules or enforcement mechanisms were put in place.

## 5. Conclusion

As humans gain wealth, they seek access to more goods, services, and activities and seek to do so with greater safety, security, comfort, and convenience. Growing

affluence translates into growing vehicle use (until or unless fundamental changes are made in the transport sector). More vehicles mean more resource consumption and greater stress on environments. The two fundamental responses are to alter the vehicles so that they have less impact on the environment, and to reduce vehicle usage. In the U.S.A., the greatest emphasis has been on rendering vehicles more benign, in most other OECD countries at least equal attention has been given to reducing vehicle usage.

The greatest successes have come in air pollution, eliminating lead in most OECD countries and greatly reducing vehicle emissions virtually everywhere. The result has been substantial improvements in air quality in most of the U.S.A. and Japan, and good prospects for doing so in Europe. The rules and institutions are in place, often with strong public support, to maintain these initiatives. Even so, given the expanding car stock, these air pollution successes will continue only if existing initiatives continue to be strengthened.

A similarly positive story can be told for noise pollution, though in this case government played a relatively minor role. The strongest force for change was vehicle owners, who demand and are willing to pay for quieter vehicles. Nevertheless, in dense settlements the problem of noise continues to be serious.

Improvements can also be noted in esthetics, landscaping, and barrier effects. With growing affluence comes more attention to esthetics, and a shift from pure functionalism to greater attention to beauty. Roads and other infrastructure built recently are far more attractive than those built decades ago, and landscaping along guideways is far more attractive and ecologically sound. Greater efforts are also being made, especially in Europe, to mitigate the fragmentation effects of infrastructure, with animal tunnels and bridges provided at key locations.

The greatest threat posed by expanding transportation systems appears to be climate change. Other impacts – air pollution, esthetics, noise – are local and reversible within fairly short time frames. In contrast, the effects of increased emissions of greenhouse gases are large and nearly irreversible. As more knowledge is gained, nations of the world are demonstrating greater resolve to reduce greenhouse gas emissions.

In a broader sense, transport continues to be at the center of debates over the future of our cities. The desire for more access and space leads to urban sprawl, as housing lots and office parks expand in size and number. What is the role of the auto in urban growth, and is it positive or negative? These questions are not easily answered, because values and preferences vary greatly, and because the process of urban development is complex, involving many forces and interests. Nevertheless, many public advocacy groups, as well as many researchers, indict the auto for not only consuming large amounts of resources and degrading the physical environment, but also for its role in loss of an urban esthetic, loss of community, and marginalization of the poor, old, and disabled. Many believe the only solution is to sharply curtail the use of vehicles.



These debates and these efforts to reduce the adverse effects of vehicles will continue. But what to do and how? The answer is not so clear, not even for the most well-defined and best-studied problems, such as air pollution. How much more effort should be devoted to reducing air pollution? How much effort should be devoted to each pollutant? How important is air quality relative to other goals such as reduction of greenhouse gas emissions?

The difficulty is insufficient knowledge of scientific phenomena, insufficient understanding of human values and preferences, uncertainties about technology development, fragmented policy and regulatory approaches, poor analysis and poor use of analytical tools, and undue influence by well-endowed interest groups. For broader issues such as climate change and urban community, the challenges are especially daunting. In the end, there are no unique and distinct answers. Clearly, though, decisions can be much better informed and environmental impacts can be reduced at less cost.

Consider again the case of air pollution. While carmakers have succeeded, in response to regulatory requirements, in dramatically reducing emissions of some pollutants, new medical research suggests that recently targeted pollutants, such as carbon monoxide and reactive hydrocarbons, may be less damaging than ultrafine particulate matter which has received less attention. Have regulatory efforts been misguided? Have resources been allocated inefficiently? We shall not know until better scientific knowledge is available, better sharing of this knowledge takes place across scientific disciplines, and better measurement and analytical tools are developed. What we do know is that better integration of governmental initiatives would lead to more coherent and desirable policies – if only we knew how to design those instruments to be efficient, effective, and equitable, to have low transaction costs, and to be politically implementable. Similar stories can be told for noise and other environmental effects.

Looking toward the future, the climate change problem is probably most important. It inspires several questions. Will we be able to cope and adapt if the most pessimistic prognoses are realized? It is quite clear that measures now under review are inadequate to cope with the scale of the problem. A positive view is that humans have always discovered new tools and technologies to overcome problems which hitherto seemed unavoidable. But new solutions often lead to unintended and unanticipated consequences. Prudence is in order.

In the end, though, it is useful to remember that extraordinary progress has been made along all dimensions of policy, practice, and science, with knowledge, political commitment, and sophistication growing everywhere. The bad news is that many resources have been misallocated, many problems have worsened, and new challenges need to be confronted. Given the huge progress of recent decades, it is not inappropriate to believe that the current positive trajectory can continue. But it will require continued political and scientific commitment.

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