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The Sustainable Development of U.S. Air Transportation: The Promise and Challenge of Institutional Reform

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Biography

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Abstract

Sustainable development is a concept that has had great influence on natural resource policy, however to date it has had limited influence on transportation. This article examines how well U.S. air transportation practice meets the goal of sustainability, and finds current practice to be unsustainable. Forecasted trends suggest this problem will get worse. Neither current pollution control policies nor technological progress are sufficient to solve the problem. Reduced use of air travel could, however the goals of mobility and speed of travel would be inhibited. Taxes could reduce the external costs caused by air pollution, however there are administrative and political barriers to this. Institutional reform seems to be the logical solution, and the process to achieve this reform is described.

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"An unquestioning attitude towards future growth in air travel and an acceptance that the projected demand for additional facilities and services must be met, are incompatible with the aims of sustainable development." (U.K. Royal Commission on Environmental Pollution, 1994)

Introduction

This paper applies the concept of sustainable development to air transportation. It begins by explaining the concept of sustainable development as applied to transportation and identifies four dimensions of the issue: environmental, financial, economic, and social. It then applies these dimensions to the aviation industry and identifies the problems in each dimension. Following that, current policies and proposed reforms are discussed in four areas: pollution control policies, technology, reduced use, and internalization of externalities. The next section discusses the potential for an institutional perspective to offer new solutions and argues that an integrated set of policies is necessary and that institutional change is required for long-term reform. A final section concludes.

What is Sustainable Development?

Sustainable development is a concept that has had great influence on ecology and natural resource policy recently, however to date it has had limited influence on transportation. Transportation professionals in the public and private sector need to understand this concept as it will influence proposed transportation developments in the future. With the maturation of transportation systems, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) declared that emphasis should shift from building infrastructure to ensuring that it serves economic and social goals. The concept of sustainable development provides insights on how to make that transition.

Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development [WCED], 1987). An environmentally sustainable transport system is defined as "one where transportation does not endanger public health or ecosystems and meets the needs for access consistent with (1) use of renewable resources below their rates of regeneration, and (2) use of non-renewable resources below the rates of development of renewable substitutes" (United Nations Economic and Social Commission for Asia and the Pacific [UNESCAP] and Asian Institute of Transport Development [AITD], 2001, p. 11). A third condition that has been added is: "the rate of pollution emissions does not exceed the assimilative capacity of the environment" (Black, 2004). Another definition of sustainable transport is the provision of the same level of transport and mobility with non-declining values of total capital (including natural capital[1], human capital, physical capital and financial capital) (Black, 2004).

The four dimensions of sustainability are: environmental, economic, financial, and social. When applied to transportation they can be more specifically operationalized as follows:

- *Environmental:* Limiting the use of natural capital to levels that can be replaced by natural regeneration. Integration of environmental concerns into transportation and land use planning and development would attempt to improve the management of all types of capital. This may call for a re-thinking of current policies affecting transportation mode choices, user fees, land zoning, and other regulations.
- *Economic:* Transportation must be cost-effective and achieve the highest social return on physical and natural capital. This may be achieved in some cases by stimulating market competition and in other cases by increasing the efficiency of practices for financing and

managing transportation assets.

- *Financial:* The activity attracts sufficient funds to cover capital and operating costs in the long-term.
- *Social:* Balancing the consumption of natural capital with improvements in the standard of living and the quality of life, in particular poverty reduction. Further, this perspective emphasizes ensuring access for the poor to the transportation network, and ensuring gender equity in service provision.

Sustainable transportation development therefore, attempts to balance the demand for mobility with a full consideration of the value of resources used up in producing these services. Not only should the cost of building and operating transportation facilities and vehicles be included, but also the cost of increased pollution, noise, health effects and lost opportunities as a result of the development. Ignoring these factors would cause development to lead to lower economic growth and a reduced quality of life. Finally, this broad view of efficiency should be balanced with the goal of equity implied by social sustainability.

Sustainability Issues in Aviation

In applying the four dimensions of sustainability outlined above to the aviation industry, the problems in the industry are mainly environmental concerns, although there are related economic, financial and social problems. These problems are likely to be exacerbated in the future as air traffic increases. It is projected that from 2002 to 2022 worldwide passenger traffic will increase by over 250 percent and the number of passenger aircraft will increase by 190 percent. Worldwide air freight transport and the fleet of freight aircraft is projected to grow even faster. Aviation fuel use is projected to increase by 3 percent annually, doubling by 2050 (Whitelegg and Cambridge, 2004). In the U.S., the Federal Aviation Administration (FAA) has estimated that domestic air travel will grow 3.6 percent annually between 2000 and 2011, for a total increase of 48 percent (National Research Council [NRC], 2003). Balancing this projected increase in mobility with a desire for long-run sustainability will be a great challenge.

ENVIRONMENTAL

The main environmental problems of aviation are caused by emissions, noise, health, and to a lesser degree, land use. Emissions have impacts at both the global and local levels. Aircraft emit greenhouse gases (carbon dioxide and nitrous oxides) which are one of the causes of global warming. Condensed water vapor at high altitudes may also exacerbate the greenhouse effect, although there is some controversy among scientists about this. Water trails and condensation trails (contrails) also contribute to trapping heat in the atmosphere. Nitrous oxides also contribute to smog, and to acid rain affecting forests and wetlands (Dempsey, 2000).

Although these emissions are small relative to those caused by surface transportation, they are significant and growing fast. It is estimated that aviation is currently responsible for 3.5% of the anthropogenic greenhouse gas emissions, but these emissions are injected at high levels of the atmosphere and have a higher radiative forcing impact (NRC, 2003; Whitelegg and Cambridge, 2004). The implication is that these emissions cause three times as much global warming than if they were emitted at the ground level. By 2050, aviation's share of greenhouse gas emissions is projected to grow to between 4 and 15 percent (NRC, 2003; Whitelegg and Cambridge, 2004).

The degree of climate change induced by greenhouse gases is a matter of some uncertainty. However it is clear that global temperatures have been rising steadily. "It has been estimated that if we continue at our current rate of carbon dioxide pollution alone, average global temperatures to rise by 1.5 to 4.5 degrees [Celsius] over the next 40-50 years" (Dempsey, 2000, p. 651). The climate change induced by the emission of greenhouse gases has an immediate financial impact on economic risks, and therefore insurance costs. “The insurance industry has already put the total cost of economic damage arising from climate change risks (storms, floods, etc.) up to $600 billion over the next 10 years” (Whitelegg and Cambridge, 2004, pp. 44-45).

Emissions also have local effects which affect the health of those working at airports and those living nearby. The health effects include higher incidence of asthma and pulmonary disease (Whitelegg and Cambridge, 2004; Dempsey 2004). Various other chemicals used at airports for de-icing, fueling and maintenance also use environmental capacity and create health hazards (Dempsey, 2000). Further contributing to the problem is ground transportation to and from airports. In the U.S. most of this transportation is by private auto. As a comparison, in Switzerland 65 percent of such trips are by public transport (Whitelegg and Cambridge, 2004).

Aircraft also cause noise which has a local impact and is associated with health problems, specifically cardio-vascular disease, impaired hearing, depression, irritability, chronic tinnitus and sleep disturbance (Dempsey, 2000). The health effects are even more acute for children, and apparently include increased heart rates, increased stress, impaired attention span and memory function, and impaired reading performance (Whitelegg and Cambridge, 2004). Noise effects have been estimated to reduce property values by about 0.6 percent per decibel of day-night average sound level exposure (NRC, 2003). Current noise regulations restrict operations that can cause congestion, delays, higher costs and higher fares (NRC, 2003). While there has been substantial progress in the reduction in aircraft noise, the pace of noise reduction is forecast to decrease while the rate of increase in air traffic increase is expected to accelerate, causing the problem to worsen, especially at high-traffic airports.

Another obvious health effect is deaths and injuries in travel and provision of transportation. As Black (2004, p. 12) writes, “[i]t should be an accepted premise that a transport system that kills off its users is not sustainable." Also animals killed in flight, on runways, by the emissions, or in the process of producing and transporting fuel contribute to the problem.

ECONOMIC

One of the fundamental ironies of transportation, especially in the U.S., is that the negative externalities caused by transportation are *subsidized* by long-standing policies while elementary economic theory suggests that for efficiency reasons they should be taxed instead. All modes of transportation are directly and indirectly subsidized yet we wonder why there is too much traffic, pollution and noise. The just-in-time inventory policy of many retail businesses is a good illustration: Dempsey (2000) cites the example of garments made in Korea that are flown overnight to New York for sale in retail outlets the next day. The jet that flies in the goods produces 20 times more carbon dioxide per ton-kilometer than would a truck transporting the same goods from North Carolina, and the difference in mileage is more than ten times, resulting in an increase in greenhouse gas emissions by over 200 times. Yet none of these environmental costs are reflected in the price of the garments. The absence of an appropriate price signal for the use of environmental capacity leads to wasting natural capital, and perhaps an inappropriate relocation of the manufacturing activity.

Airport capacity is another capital asset that is undervalued in the current U.S. system. In 2000, 13 of the 50 busiest U.S. airports were at capacity, with estimates that by 2006, 19 more will be. Three-quarters of the delays in capacity expansion at these airports are due to environmental issues (NRC, 2003). Yet there are no congestion charges assessed on airport use.

Despite the pressing nature of these problems, the high degree of competitiveness of the commercial air travel industry has made it very difficult for airlines to fund research on emissions reductions and noise abatement. Pure research is a pure public good, so there is not a sufficient incentive for business to fund research to address the problem. Despite this, airline companies realize that the cost increases and reduced consumer demand caused by environmental problems are a serious and looming threat to their industry. Therefore, it may well be in the best interests of the airlines to have federal (or international) regulations and taxes imposed to reduce the environmental problems they cause. One source said, “To the extent that the growth of an airport leads to growth in flights, and the emissions from those flights, the administrative provisions of the Clean Air Act may act as a de facto limit on the size and operations of an airport in a given district that has not attained its air quality goals” (Barbara Lichman, quoted in Dempsey, 2000, p. 678). Uniform regulations are important to an industry that by its nature is not constrained by national boundaries. As the National Research Council found,

> Currently, there are essentially no financial incentives for industry to develop and deploy environmental technologies that go beyond regulatory requirements. In fact, spending resources that go beyond regulatory requirements can put airlines at a competitive disadvantage... The environmental impact ... would be reduced if equipment manufacturers, service providers, and consumers directly faced the full cost of their activities, including environmental costs. (NRC, 2003, p. 41)

The World Business Council on Sustainable Development (WBCSD), a coalition of 170 international corporations drawn from 35 nations wrote, “[f]or all our companies, long-run success depends on the future viability of mobility. It is our collective view that the mobility sector will not be healthy over the long term unless mobility is made sustainable” (World Business Council on Sustainable Development [WBCSD], 2004, p. 6). The WBCSD called on governments to provide the necessary incentives to justify business production of vehicles and fuels that could meet sustainability criteria.

FINANCIAL

Financial incentives in the U.S. aviation finance system are problematic in several ways. Ticket taxes, flight segment taxes, fuel taxes, excise taxes on international flights and domestic cargo are the main sources used to support the Airport and Airway Trust Fund (AATF). The AATF in part funds the Airport Improvement Program (AIP) which gives grants for noise abatement and reduction, improvements in capacity, safety, and security. It is appropriate that fuel, cargo, and international flights should be taxed, as these are proxies for pollution emissions. However the rate of the fuel tax is low, and the proceeds of these taxes are then used in part to extend the systems, leading to increased travel and increased pollution.

Second, passenger facility charges (PFC) allow airports to charge each passenger departing from, arriving at, or passing through their airport between $1 and $4.50. The funds are used to supplement AIP grants or for debt repayment. PFCs do not create a close link between the costs of the projects they fund and the benefits received by the passengers paying for them. Further, they are assessed on a per passenger basis, despite the fact that an empty plane pollutes almost as much as a full plane. While such a charge could be used to address sustainability goals, it should be assessed per plane, rather than per passenger.

Third, the structure of federal aid to airports uses pre-determined matching rates in distributing funds. As Gramlich (1994) has pointed out, these matching rates tend to be too high and the restrictions on funds too inflexible. This leads to building too much of certain types of infrastructure and too little of other types. Fourth, landing fees are generally assessed based on aircraft weight. However aircraft weight is not well-correlated with emissions, creating improper price signals. Finally, congestion fees are not employed in the U.S. with the exception of small fees assessed on general aviation in a limited number of airports (American Association of Airport

Executives [AAAE], 1998). This approach is used in Europe and serves as a model for reform.

SOCIAL

Social equity concerns in aviation are focused on access, and the effects of noise and pollution on different populations. The WBCSD (2004) called for a narrowing in the gap between the poorest and richest nations, and between the poor and the middle class within nations. This would enhance the access of the poor to mobility, although it may do so at the expense of higher traffic levels. Noise and local emissions tend to have disproportionate effects on this population, with the greatest harm done to those working at airports and living near them. Also children seem to be more adversely affected than others. This harms a relatively powerless group of persons, and exacerbates inter-generational equity. The contribution of aviation to global warming adversely affects persons in low-lying costal areas, and other areas and industries where the impact of climate change is greater.

In summary, then, many of the practices of the U.S. aviation industry do not achieve the four dimensions of sustainability outlined here. Some of these shortcomings are technological while others are administrative. On the face of it, the latter might seem to be easier to solve than the former, but those with experience in attempting to reform policy and administrative practice may see it the opposite way.

Current Solutions

CURRENT POLLUTION CONTROL POLICIES

There are several agreements and laws that seek to address the sustainability problems of aviation. These include both international treaties and federal legislation, which are briefly reviewed here. The Kyoto Protocol in 1997 set goals for reductions in the emissions of carbon dioxide, methane and nitrous oxides by 2008-2012. This protocol has been ratified or acceded to by more than 140 nations, with the notable exception of the U.S. However international aviation emissions are excluded from the Kyoto Protocol, in part because of the difficulty of apportioning the responsibility to reduce these emissions. The result is a classic example of the problem of common pool goods, resulting in the "tragedy of the commons." Because there is no governing body with sufficient power, all parties have an incentive to over-use natural capital dissipated by emissions, potentially leading to a degradation of natural resources because of a misalignment of incentives.

The U.N.'s International Civil Aviation Organization (ICAO) is a legal authority that drafts treaties and agreements related to air law for approval by diplomatic conferences. In 1993 the ICAO reduced aircraft standards for nitrous oxides emissions by 20 percent, and in 1999 they lowered these standards by another 16 percent (Dempsey, 2000). However, according to Button (2004, p. 20), the ICAO has, "limited powers to enforce even the measures that may be needed to fully embrace global environmental factors into international policies."

Several major pieces of legislation are relevant to policy in this area (Dempsey, 2000). Some of the most important are:

- The Federal Airport Act of 1946, which authorized federal aid to airports,
- The National Environmental Policy Act of 1969, which created the environmental assessment and environmental impact statement processes,
- The Airport and Airway Development Act of 1970, which established the AATF,
- The Noise Control Act of 1972, which gave the Environmental Protection Agency (EPA) and the FAA a role in formulating aircraft noise standards,
- The Airline Deregulation Act of 1978, which deregulated the airlines,
- The Aviation Safety and Noise Abatement Act of 1979, which gave the EPA and the FAA

jurisdiction to monitor and regulate aircraft noise and emissions,

- The Airport Noise and Capacity Act of 1990, which required a phase-out older aircraft which were noisy and emitted high levels of pollution, and
- The Intermodal Surface Transportation Efficiency Act of 1991, which declared the policy of the U.S. government to develop a transportation system that is "economic efficiency and environmentally sound ... that will move individuals and property in an energy efficient way" (cited in Benfield and Replogle, 2002, p. 10638).

The roles and duties of federal agencies are also important. The National Aeronautic and Space Administration (NASA) is the only federal agency conducting research on commercial aviation pollution. NASA also takes the lead in research on aircraft noise. The FAA has programs concerned with noise regulation and aircraft certification. They fund noise abatement through the Airport Improvement Program (AIP) and the Passenger Facility Charge (PFC) program. And, as mentioned above, the EPA has responsibility to formulate, monitor and regulate emissions and noise standards.

NASA has set as goals the reduction of noise levels by 50 percent by 2007 (compared to 1997 levels) and 75 percent by 2022. For carbon dioxide, the goal is a reduction of 25 percent by 2007 and 50 percent by 2022. For nitrogen oxide, the goals are 70 percent by 2007 and 80 percent by 2022 (NRC, 2003). However the National Research Council has found that the current level of funding for federal research is too low to achieve this goal on schedule (NRC, 2003, p. 15 and p. 33). At the same time, spending on noise abatement through the AIP and PFC programs from 1991 to 2001 was seven times that spent on noise reduction research and technology, and this ratio has more than doubled since then (NRC, 2003).

While substantial progress has been made over the last 35 years towards sustainability goals, obviously the current structure of laws and agency powers leaves aviation short of a sustainable path of development.

TECHNOLOGY

Historically, technology has greatly reduced the pollution caused by aircraft. Fuel efficiency has been improved by advances in engine technology, airframe design, and operations. It is estimated that future improvements in technology can reduce fuel consumption by 1 percent annually per revenue-passenger-kilometer over the next 15 to 20 years. However the projections are that commercial traffic will increase by 3 to 5 percent over the same period. For cars and trucks, alternative fuels such as natural gas or hydrogen are a possible technological advancement, but there are a variety of problems associated with storage, weight, cost, availability and infrastructure in using these fuels on aircraft (NRC, 2003).

Technology has also made important historical advancements in reducing the noise of airplanes. Technological change, phase-out of older aircraft, and operations improvements have made aircraft quieter by an estimated 3 decibels per decade over the past 40 years.[2] While traffic has increased by a factor of 6 from 1975 to 2000, the number of people affected by noise in the U.S. has been reduced by a factor of 15, indicating the important improvements that have been made. However further reductions are expected to be small because the fleet is relatively new and no phase-outs of aircraft are anticipated. Also spending on noise reduction research and development has fallen (NRC, 2003). Thus traffic levels are expected to outpace technological improvements for both air pollution and noise, making the current situation less sustainable.

REDUCED USE

Another solution is obviously to travel less, or to travel by modes that pollutes less. The emission of carbon dioxide caused by airplanes is much greater than the same per-person kilometer travel by other modes. Dempsey writes that it, "is between four and eight times that of travel by automobile, more than ten times that of travel by bus, and twenty-two times that of electric-powered train" (Dempsey, 2000, pp. 653-654). For freight travel, these magnitudes are even larger: twenty times that of truck travel and 240 times that of rail.

Whitelegg and Cambridge (2004) argue that in Europe, substantial reductions in emissions and noise are possible by shifting trips of from air to rail. They estimate that 45 percent of European flights are less than 500 kilometers, which can be shifted to rail. Some of these trips can be shorter by rail than by air, since rail centers are nearer to commercial areas than airports.

Here, the goals of mobility and speed on the one hand often conflict with sustainability on the other. All the indications are that traffic will increase even if the incentives are corrected. That said, it is certainly possible to reduce some unnecessary travel or divert travel among modes at the margin. As Wachs (2004) points out, American attitudes have been changed by public education efforts in numerous areas: reduced smoking, increased recycling, reduced drinking and driving, and the promotion of "safe sex"; it is not unthinkable that similar educational campaigns or incentive realignments could reduce the use of energy and environmental capacity in air transport.

TAXING THE EXTERNALITIES

The problems of air pollution and noise caused by aircraft are clearly a negative externality. The traditional economic solution to this problem is to tax the externality. Doing so would both discourage air travel at the margin, and produce revenue that could be used for mitigation expenses, research, or other uses. Further, if aircraft that pollute more than others face the highest taxes, this will stimulate a shift to less-polluting aircraft. The U.K. Royal Commission on Environmental Pollution (1994, p. 75) has stated, "the demand for air transport might not be growing at the present rate if airlines and their customers had to face the costs of the damage they are causing to the environment."

The European Union has articulated the principle that the polluter should pay for their environmental damage. They have adopted a policy of tariffs on airport infrastructure, and taxes and duties on trucks (Whitelegg and Cambridge, 2004). A variety of pollution charges have been suggested by researchers: (1) emission charges, (2) landing and take-off emission charges, (3) fuel charges, and (4) ticket charges (Bleijenberg and Wit, 1998). Brockhagen and Lienemeyer (1999) of the Dutch Centre for Energy Conservation and Environmental Technology determined the level of emissions charges that would be necessary to reduce global warming to achieve the standards of the Kyoto Protocol. The charge for carbon dioxide would be 0.3 Euros per kilogram of fuel consumed, and for nitrogen oxide 14.31 Euros per kilogram. For a one-way flight from London Heathrow to New York on a Boeing 747-400 with 310 passengers, this charge would amount to a total of 28,764 Euros, or 92.8 Euros per passenger.

Conventional economic analysis has long argued for internalization of the externalities of pollution, noise and congestion caused by transportation. For example, the U.N. Economic and Social Commission for Asia and the Pacific (2001, p. 56) concluded that, "the internalization of externalities is a fundamental requirement in devising transport pricing policies to promote sustainable development." And yet this strategy is only beginning to be implemented in Europe, and is not used in the U.S. Clearly one reason why this solution has not been pursued is because the polluters and those who use their services are politically powerful and well-mobilized, while those affected by the pollution are generally politically weak and disorganized. A second reason is the large amount of information required to administer an efficient pricing system. Third, as Verhoef and Pels (2002) point out, the assumptions required for a "first-best" solution are rarely met because of other economic distortions. Second-best solutions pose several questions and require complex economic models of the transport system.

Despite this, a variety of pricing alternatives are possible. The first-best solution of setting price equal to marginal cost is one. Others include: price discrimination, two-part tariffs, and "Ramsey prices" where users pay according to the inverse of their elasticity of demand. The feasibility of these options should be explored.

Institutional Reform

The limitations of the solutions presented above suggest a more fundamental need to reform the institutions that has lead us to this situation. Current policy has created a structure of institutions and incentives that is the more fundamental cause of unsustainable practice in the provision of air transportation. This cannot be changed with one single action, but rather the institutional structure needs to be recast in a way to reinforce progress toward sustainability goals. Others have noted the importance of institutional structure in developing sustainable transportation policy. The WBCSD (2004, p. 27) wrote, "[m]oving towards sustainable mobility will involve paying as much attention to institutional frameworks as to the inherent potential of any vehicle technology or fuel or the theoretical 'effectiveness' or 'ineffectiveness' of any particular policy lever or action."

Rietveld and Stough (2002), Rietveld (2002), and Connor and Dovers (2004) use North's (1990) model of institutions and transaction costs to examine the structure of exchange. Any given structure of institutions creates a set of incentives to which actors respond. Their responses determine the cost of transactions and therefore which exchanges will occur. This will create a path dependency, where institutional structure continues to evolve in response to the incentives it creates. Efficiency does not necessarily result from the existing institutional arrangement. Economic growth can be retarded in an economy where the transaction costs of potentially

Pareto-efficient trades are prohibitively high. Institutions such as weakly-defined property rights, incorrect price signals, or inappropriate vertical or horizontal organization lead to high transaction costs and can lead an economy onto a path where efficient trades are not made and long-term growth will be lower. As Rietveld and Stough (2002) point out, there are several examples of this in air transportation:

- The Kyoto Protocol does not include international aviation emissions in their limits, and also the U.S. and other nations are not party to the agreement.
- International agreements on taxation prohibit taxing fuel for international flights.
- Research and development leading to pollution reduction may be too costly for businesses in a low profit-margin industry such as commercial air transportation. Further, the public good nature of research makes it likely to be under-supplied by the private sector.

Connor and Dovers (2004) suggest two approaches that benefit from the institutional insight: Strategic Environmental Assessment (SEA) and Property Rights Instruments (PRI). SEA follows the logic of environmental impact statements, and systematically evaluates the environmental consequences of policy, weighing them equally with economic and social concerns. It can enter at various phases of the process: planning, policy formulation, legislative consideration, and cumulative assessment. SEA has been implemented fully or partially in several countries in Europe and the British Commonwealth. PRI are familiar to economists concerned with the problems of common pool goods. The approach is to establish entitlements to resource use, such as the capture of value from these rights and the ability to trade them. Property rights may be identified for various elements of resource use: access, withdrawal, management, exclusion, and alienation (the right to sell or lease the resource). Neither of these tools could address the greenhouse gas problem, because no strong international governance exists to enforce these rights.

Indeed, the absence of the U.S. from the Kyoto Protocol is a classic case of a free-rider refusing to pay for a common pool good. However both could be applied to local emissions problems and noise pollution.

Despite the complexities of creating a comprehensive solution to a global problem, there are examples of successful implementation. Connor and Drovers (2004) detail the evolution of environmental policy in the European Union, and show how institutional structure can be changed in a complex federal system. The key features they identify are (1) a reiterative framework, where principles, policies and implementation procedures are regularly revisited and revised as appropriate, (2) the use of formal and informal networks to involve a variety of actors on a number of levels, and (3) a combination of both top-down and bottom-up processes of political change. These features have helped create a more integrated set of policies, where environmental policy is not seen as separate from other policies, where policies are matched with the appropriate level of government, and where political and bureaucratic capacity is stable and fosters continued policy learning.

While the U.S. has not achieved this level of advancement in sustainable development, the EU example shows one way that this can be achieved. To accomplish this in the U.S. would require doing so in a way consistent with our political, economic, social, and cultural institutions. The path dependence of institutional development shows that models are not easily transferred from one nation to another.

Sustainable transportation policy will maximize the wealth possible from all forms of capital. Incentives that waste of any form of capital lead to lower long-term growth and a lower future quality of life. The goal of institutional reform should be to maximize the efficient use of these capital resources incorporating production costs, external costs and transaction costs.

Achieving this efficiency will not be done by a single policy approach because different institutional structures create different costs and incentives. Some current policies have moved in this direction, such as the environmental impact statement process, and the subsidization of research and development in emissions reductions and noise reduction and abatement. The critical next steps are to examine the details of these administrative processes with an eye to improving long-run efficiency and equity of resource use. Doing so can make air transport more sustainable in the long run.

Conclusion

No single approach will solve these complex, global problems. However a variety of reforms are suggested by these problems. They are a starting point on the path towards a more sustainable air transportation system. Generally, they call for correcting the structure of incentives to reflect the full value of all capital assets. More specifically, these recommendations are offered:

- Fuel taxes, cargo excises, PFCs, landing fees, and segment charges need to be reformed to better reflect the costs of noise, emissions, congestion, and other resources used.
- The AATF should be reformed to create a closer link between costs caused and benefits created, and should shift its goal from system expansion and improvement to balancing mobility goals with resource preservation.
- High subsidies under the federal AIP program that give airports incentives to expand capacity that they may not have built otherwise should be reduced.
- Cost-benefit analysis should be used to calculate the matching rates for AIP grants, with flexible rather than fixed matching rates equal to the ratio of the external benefits (those enjoyed by persons outside the local area) to the total benefits of the project.
- Federal funding for noise reduction research and emissions reduction should be increased.

- Fuel used in international flights should be taxed.
- The Kyoto Protocol, or something similar, should be enforced internationally with appropriate implementation powers.
- U.S. institutions of governance need to be strengthened to achieve the goal of sustainability. The EPA, FAA, and NASA are the logical agencies to be asked to pursue these goals.

While some of these reforms go against long-standing policies, in an era of increasingly scarce resources they provide an alternate approach to move towards a more sustainable development of air travel.

Major improvements are possible in air transportation's contribution to society by eliminating wasteful and destructive incentives. Doing so in conjunction with technological improvements would reduce global warming and increase the contribution of air transportation to economic growth and social stability.

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Notes

[1] Natural capital is defined as living systems and ecological services (Hawken, Lovins and Lovins, 1999).

[2] A reduction of noise levels by 10 decibels is a 50 percent reduction.