CONFERENCE I RESOURCE PAPER

Transportation, Sustainability, and Land Use

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There is now a consensus for radical change in transport policy.
—Prescott (*1*)[1]

Transportation has always been based on values. For most of the 20th century, these values have revolved around (*a*) road improvements ("getting us out of the mud"), (*b*) speed (reducing the friction of time on access), and (*c*) improved access to land. Opening up new lands for development and improving the road system to accommodate the automobile were clear national priorities. We can be proud of our success in meeting these goals for building America's infrastructure in the 20th century.

As we greet the 21st century, however, we confront a new set of values for our infrastructure and for our society. In 1999, land consumption no longer has the high value that was placed on it in 1899. Speed has been achieved but, as distances have extended between destinations, travel times have not significantly shortened. We are "out of the mud" in all but the most remote locations. The challenge now is to ensure that our extensive transportation system does not sink back into it.

New values are now constraining our devotion to speed and to cheap land access. Sustainable development is a phrase that encompasses several of these new values, including conservation, efficiency, choice, and community. Perhaps most significant for transportation, consumption of our natural environment as an economic development strategy was replaced by conservation of our natural environment as an economic development strategy upon enactment of the National Environmental Policy Act of 1970 (NEPA). Gradually, as the profound significance of NEPA took hold, the values of conservation have seeped into public and private economic behavior at all level of organization and activity.

The transportation sector has been slow to recognize this paradigm shift in values. State departments of transportation (DOTs) initially used the social, environmental, and economic analyses that were required by NEPA to identify methods of project mitigation, without questioning the core objectives of transportation service delivery. This approach became increasingly untenable as the very process by which transportation problems were identified and solutions were devised came under increasing scrutiny. The "no build" option was increasingly pressed upon transportation planners, as were pricing solutions, traffic calming, transportation-control measures, and other demand-side strategies. Planners were asked to look at the system, not just the project, when considering NEPA's mandate.

Sustainable development and transportation for sustainability are the ultimate manifestations of this shift in values. Transportation must now be "embedded" within concepts of sustainability; there is no independent justification or political mandate for unsustainable transportation. As stated by the Canadian Institute of Planners, sustainability is now "the intent and central operating principle of planning." (*2*) This principle includes transportation planning. This is what John

Prescott meant when he said that it is time for radical change in transportation policy.

Transportation and Sustainability: Planning Dilemma

It is one thing to adopt sustainability as a policy goal, but it is quite another thing to implement or even define it. Nevertheless, sustainable development is rapidly moving from the policy arena to becoming a statutory and regulatory mandate. The 1992 Rio "Earth Summit" on environment and development and the 1997 Kyoto Protocol on climate change impose specific targets for the control of greenhouse gases, of which U.S. transportation activities are estimated to be the largest single source in the world.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) placed nontransportation objectives, such as social equity, environmental quality, and community integrity, on an equal footing with mobility as a desired output of transportation decision making. The Transportation Equality Act for the 21st Century (TEA-21) made ISTEA's shift to sustainability more explicit by creating a community-and system-preservation pilot program. The mandate for change is clear.

The Clinton administration has also made sustainable development an administration priority with the creation of the President's Council on Sustainable Development in 1993, which continues to promote the concept across all federal agencies. The U.S. Department of Transportation (USDOT) responded with the creation of a Livable Communities Initiative within the Federal Transit Administration and, most recently, with the creation of a task force on climate change. In January 1999, Vice President Gore announced a $1-billion "Livability Agenda," which included $50 million to improve coordination between transportation and land use planning.

Finally, sustainable development is also a "critical issue" in transportation research (*3*, p. 13). The Transportation Research Board (TRB) has published a research report on the long-term effects of motor vehicle transportation on climate and ecology (*4*). A new, permanent TRB Committee on Transportation and Sustainability is under active consideration, and a study panel is reviewing how transportation can be not only a significant part of the problem of global warming but part of the solution as well. A special TRB report of the social impacts of our national highway program has recently been published, and a new interest in transportation policies that support sustainable development is evident among many of America's trading partners (*5*).

State and local actions to promote sustainability are also increasingly specific. In November 1998, more than 200 state and local growth management initiatives were on the ballot, and 81 percent of them passed. At least 21 state and local laws and ordinances now require compliance with sustainable development goals, essentially limiting growth to the ability of existing public facilities and services to accommodate such growth (*6*, p. 37). A recent survey of 102 city and county transportation agencies in the San Francisco Bay Area found that more than 40 agencies were already integrating concepts of sustainable transportation into their transportation planning processes.

Quality of life is now an organizing principle for grassroots transportation activists and a way for diverse community groups to address common concerns about how transportation services are delivered (*7*). The interactions between transportation infrastructure or regulatory initiatives and the three dimensions of sustainability (economic, environmental, and social) are now a focus of research within the World Bank (see Figure 1).

These developments present challenges to the transportation planning community. Increasingly, planners are confronted with statutory and regulatory directives to act in support of sustainability goals, yet they are provided with neither (*a*) the power to act, (*b*) the analytical tools that are needed to support such action, nor (*c*) a clear statement of desired outcomes. Is sprawl (however defined) good or bad? Is mobility, as measured by increased average speed or increased vehicle miles traveled (VMT), still a public policy objective? How should transportation efficiency in the production and distribution of goods and services be measured within a context of sustainable development? These are the types of questions that are raised by placing transportation in the context of sustainability.

Ironically, the transportation planning community is being pressed to take action in support of sustainability at a time when the political environment is making planning for sustainability increasingly difficult. Examples of these constraints include the following:

- The price of gasoline, the most obvious variable cost of driving that can affect transportation behavior, is at a post-World War II low.
- Sales of sport utility vehicles and trucks, both with low gas mileage, now outpace the sale of automobiles.
- The primary performance measures for transportation—VMT and level of service—are still measures of consumption, not of access. If these are not the right performance indicators for transportation, what are?
- While transportation policy has now clearly shifted from an emphasis on construction to an emphasis on system preservation, transportation planning is still conducted within a planning structure that is designed to increase access to land, primarily by increasing physical

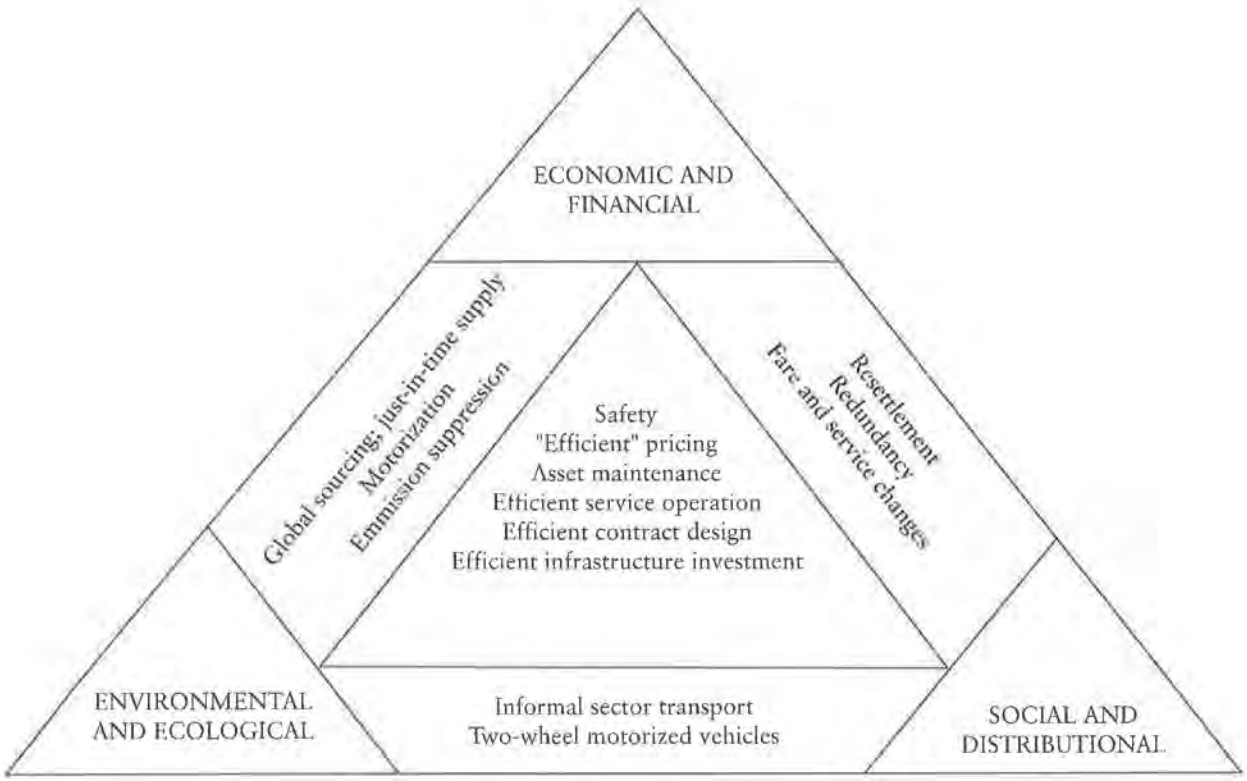

FIGURE 1 Three dimensions of sustainable development synergies and trade-offs (*8*).

capacity. Projects are still the primary output, not an efficient, sustainable transportation system.[2]

- The "tragedy of the commons" applies. The benefits of the existing planning paradigm are captured by individuals (through reduced travel time and increased access to land), whereas costs are felt at the community level (social and environmental costs, primarily). Conversely, the benefits of actions toward sustainability are captured at the community level (improvement in system efficiency), whereas the costs are heavily assigned to individuals (by internalizing the full environmental and social costs of travel). This makes political consensus on sustainability truly difficult.
- Legislative earmarking is an increasingly popular strategy for dictating the outcome of the transportation planning process as choices become more difficult.

These present constraints on the ability of transportation to advance sustainability goals are also burdened by an historical truth about transportation: Urban form has always been a function of the dominant transportation technology in place at the time an urban area experienced its greatest growth. Sustainability, with its emphasis on land conservation, represents a fundamental challenge to this historical imperative. Specifically, it presumes that transportation technology can be managed to support, instead of drive, public objectives on land use, landscape design, and urban form. This is a very tall order. TRB's *Special Report 231* provides a good discussion of research needs on transportation and urban form (*9*).

Scoping and Definitional Issues

The purpose of this paper is to stimulate ideas for planning research that will help integrate transportation planning with notions of sustainable development. Ideas from other countries, especially from European countries, on promoting transportation and sustainability will be referenced. However, the scope of these ideas for planning research is national, because that is the context of transportation planning in the United States.

This paper focuses on efforts by transportation planners to recognize, and respond to, primarily intergenerational impacts of transportation on natural resources. This is basically the approach taken by the TRB study panel in its *Special Report 251: Toward a Sustainable Future* (*4*). The report includes such issues as climate change, ecosystem integrity, long-term air

quality issues, and irreversible resource depletion.[3] It does not address actions for sustainability in transportation that are beyond the purview of transportation planners, such as materials management, which includes disposal of transportation materials (e.g., used asphalt and construction materials) or transportation supply (e.g., tires, used motor oil, leaking underground storage tanks, and junk cars). We deal here with the planning context within which the development and management of transportation infrastructure occur, period.

This paper does not cover research needs on transportation technology (e.g., Partnership for a New Generation Vehicle, electronic toll collection, the "hypercar," and new fuel technologies) that can promote sustainability goals. That is a job for technology research, not planning research. Regardless of what technological breakthroughs occur that benefit sustainability goals (primarily in materials and fuel technology), changes in our collective behavior regarding how we use transportation services will be needed (*10*).[4] For that reason, research on how transportation technology can be used to improve transportation planning for sustainability is covered in this paper.

Finally, the seven consolidated planning factors of TEA-21 cover a broader range of objectives than can be addressed in this paper. They include everything from planning for global competitiveness to increasing the safety and security of the transportation system. All efforts to integrate sustainability into the transportation planning process must be measured, not only by the degree to which they advance specific, measurable benchmarks or indicators of sustainability, but also by the degree to which they defeat or advance these other policy objectives. In this context, sustainability refers to efforts to achieve these objectives in a sustainable fashion. Global competitiveness and safety are relative goals (there is no way to be 100 percent safe or 100 percent globally competitive) and are therefore constrained by principles of sustainability in the same manner as other community goals.

Integration of Sustainable Development Goals into Transportation Planning: Taking Stock

Overview

Measured by outcomes, we are not doing a very good job integrating sustainability objectives into transportation service delivery. If consumption of transportation services per capita is used as a rough indicator of directional progress toward sustainability, nearly every indicator is trending downward.[5] Congestion is increasing; safety and security are still major problems (especially if the safety and security of nonusers are considered); the environmental footprint of transportation infrastructure continues to expand at an alarming rate; emissions and energy use per capita continue to rise (as does VMT per capita); and access and choice are declining, particularly for those too old, too young, too poor, or too disabled to have access to an automobile.

This generalized failure of transportation service delivery to advance sustainable development objectives applies across all sectors (economic, social, and environmental) and within all time frames. It also applies at all levels of system analysis: neighborhood, community, regional, state, and national. Why?

The answer to this question is complex. However, some core assumptions of transportation planning, as predominantly conducted, contribute to this dilemma. The first assumption that postulates that problem identification is nonpolitical and technical is wrong. It is a function of many, sometimes conflicting, human aspirations and policy responses to those aspirations. Deciding which aspirations require action, and what type of action, is a nonlinear process that requires broad public involvement. Technical analysis can inform this process, but not control it.

The second assumption postulates that transportation is a derived demand, which means that demand is solely a function of the desire for access to a place, not of the cost of getting there. According to this assumption, making transportation cheaper by keeping gas prices low and roads both toll-free and designed for speed will not induce more travel. Economists know this is false—that making any product cheaper will increase its use. Transportation models do not know this.

The third assumption, which is a corollary to the previous assumption, is that transportation is a function of land use (i.e., land use alone determines travel demand) and does not influence land use itself (by providing cheap access to land). This statement is also false. Most transportation planners recognize this fact but claim that, because they do not control land use, they do not have to plan for it. It is also very hard to develop transportation models that have feedback loops to recognize the impact of transportation access on land use. As a result of these arguments, this assumption is largely ignored.

The fourth assumption theorizes that nonmotorized transportation trips (primarily walking and bicycling) need not be included in surveys of transportation behavior because they are difficult to count and, therefore, should not be included in transportation models. The exclusion of such trips is why so few sidewalks and bicycle paths were included in transportation projects over the last 50 years, until mandated by ISTEA. Yet, people want places to walk and bicycle, so they identify the lack of such places as a transportation problem.

Not all transportation planners make these assumptions, but they are the majority view, and they certainly dominate transportation models. Bicycling and walking do not appear on the National Personal Transportation Survey, which is the primary survey conducted by USDOT to measure personal travel behavior, the results of which are fed into models to estimate future travel demand. It is little wonder, therefore, that nonmotorized modes are largely ignored in both problem identification and project development. This is not sustainable.

Although we cannot address all the challenges that are faced by planners in promoting sustainability goals, two particular problems that are augmented by these assumptions inhibit progress toward sustainability: land use and climate change.

Land Use

Two issues deserve prominence here: ecosystem fragmentation and sprawl. The ability of the transportation infrastructure to cause permanent damage to wildlife and plant populations is extensively covered in TRB's *Special Report 251: Toward a Sustainable Future* (*4*). In response to the threat to ecosystems that are identified in this report, TEA-21 explicitly directs USDOT to conduct a study on transportation and ecosystem preservation.[6] No action has yet been taken on this mandate.

No planning factor, including system planning, requires planners to conduct research on road-related habitat fragmentation beyond the project level. The transportation footprint is now so ubiquitous within urban regions that the ability of transportation investment and management strategies to retrofit the system for habitat integrity is incredibility difficult (*11*). Nevertheless, progress in this area is being made in Europe where the population (and infrastructure) is significantly more dense (*12*). Options are available, and TEA-21, with specific funding to reconnect habitats of endangered species under the Transportation Enhancements Program, has signaled that not only research but action is expected in this area. This development presents a planning challenge.

Sprawl is an another incredibly difficult subject. Vice President Gore recently observed that it is now not unusual that "a gallon of gas can be used up just driving to get a gallon of milk." [This remark was delivered at the announcement of the American Institute of Architects' Livability Initiative (*13*).] Despite this increased sense of frustration with spread-out development, little agreement exists as to (*a*) the definition of sprawl, (*b*) whether sprawl exists regardless of how it is defined, and (*c*) if sprawl does exist within some agreed-on definition, whether its effects are harmful or helpful to long-term sustainability goals.

However, a recent TRB report provides guidance on this subject, including a working definition (spread-out, leapfrog development, both commercial and residential), and rough measures of consensus on both (*a*) the concerns raised by sprawl, and (*b*) whether sprawl is, in fact, causally linked to that concern (*6*). This study reveals that there is general agreement in a few areas that are directly related to the contribution of transportation to sprawl, including (*a*) more VMT, (*b*) more automobile trips, (*c*) higher household spending on transportation, (*d*) loss of prime agricultural lands and environmentally fragile lands, and (*e*) loss of modal choice (transit is less effective and efficient).

As agreement emerges on the causes and consequences of sprawl, decision makers will increasingly demand options for action. Research is needed to help transportation planners respond to concerns for which there is a will to act. With the ability of the transportation infrastructure to permanently consume land, including prime farmland and environmentally sensitive areas, this issue promises to be on the transportation planning agenda for years to come.

A third and final aspect of land use and sustainability is gaining increased public visibility: land as history and the consumption of land as the consumption of our history. A striking indicator of history as a nonrenewable resource that we are consuming at an unsustainable rate is the rapid, recent involvement of the historic preservation community at all levels of transportation planning—advocacy and even litigation. From Civil War and Revolutionary War battlefields, to historic transportation corridors (e.g., Erie Canal and Natchez Trace), and now to landscape preservation, the historic preservation community has clearly moved beyond buildings to claim land preservation as a central component of our national heritage (*14*). The transportation planning community must integrate this new concern about protecting history at the system (community, landscape, or regional) level as a new sustainability objective.[7]

Climate Change

As mentioned earlier, climate change, or global warming, is now a national concern. President Clinton signed a document that called for U.S. reductions in greenhouse gases to a level of 7 percent below 1990 emissions, a very difficult task. U.S. transportation emissions of greenhouse gases are now estimated to be the largest single source of such emissions in the world, and transportation's share of total U.S. greenhouse gas emissions continues to climb, now totaling about 33 percent. Controversy over this issue is highly likely to constrain the selection, location, and management of transportation projects into the indefinite future.

That said, global warming presents a unique challenge to transportation planners. Unlike land use, an area in which both the concerns and the solutions are locally driven, global warming is a national, and even an international, concern that appears to have very little ability to generate political will for action at the local level. Even in low-lying states, such as Florida, where the potential long-term effects of climate change are the highest (e.g., floods, hurricanes, droughts or fires, spread of tropical diseases), there appears to be little political will to act. Given the lack of political will to address climate change, what is the transportation planner to do?

Much literature exists on this issue, and it comes to a striking consensus. Nothing can be done at the local level as long as the issue is perceived as climate change alone. Instead, transportation planners that seek to reduce greenhouse gas emissions at the system level must focus on other regional concerns, such as land use issues that were described earlier, brownfield redevelopment, or livable communities through improved transportation choice, that have collateral benefits in reduced greenhouse gas emissions (*15*). [Additional information on greenhouse gas emissions is provided by a Federal Highway Administration (FHWA) report on transportation and global climate change (*16*).] Smart growth, energy efficiency, community livability, and "healthy cities" initiatives, which promote infrastructure that invites, not discourages, outdoor, nonmotorized human activity, are local strategies with collateral benefits in terms of reducing greenhouse gases.

In this regard climate change presents a fundamental challenge for sustainable development, because it requires a focus on system performance instead of on project development. The ability of climate-change strategies to advance multiple sustainable development objectives at the system level sets this issue aside from traditional transportation problem solving. Research is needed on how to make the leap from single-objective to multiple-objective planning at the system level.

Natural Resources, Community Development, and Other Derivative Sustainability Issues

Beyond land (including ecosystem integrity, protection of special areas and landscapes, and historically significant lands) and climate change, sustainable development becomes a medley of place-based aspirations. Some nonclimate change—air quality issues are truly intergenerational. These issues include ground-level ozone, which can alter natural plant cycles, and other emissions that can have cumulative and long-lasting effects on the function and biological composition of ecosystems (*4*). These long-term effects present another level of complexity to transportation planners that seek to promote sustainability.

Planning Research: New Agenda for the 21st Century

ISTEA and TEA-21: Approach to Sustainable Transportation

ISTEA was a "paradigm shift" in transportation policy, from construction to system preservation, from single- to multiple-outcome planning, and from project planning to system management. TEA-21, on the other hand, is perceived as "fine-tuning" this new direction. Although TEA-21 was indeed an endorsement of the new direction taken by ISTEA, it includes several new tools that can be used for moving transportation toward a more sustainable foundation. Many of these tools are untested and therefore present good areas for planning research. These tools include

- Transportation System and Community Preservation Pilot Program (best practices research);
- Cash-out parking innovations (ability to affect commuting mode choice);
- Expanded commitment to Congestion Mitigation and Air Quality and Transportation Enhancement programs;
- Broader flexibility on moving funds between projects and programs;
- Expanded commitment to intermodalism; and
- Charge to expand sustainable transportation technologies through intelligent transportation systems (ITS).

Each of these new tools should be evaluated by transportation planners for its ability to improve system integration and system performance and, therefore, the overall sustainability of transportation service delivery.

Characteristics of Sustainable Systems

Sustainable development is as much about attitude as it is about technical knowledge. It requires a new mindset about outcomes, not in terms of projects but in terms of functions. Key ideas expressed in ISTEA and TEA-21 include (*17*)

- *Plan for multiple outcomes*—Plan for multiple outcomes, not for single objectives, such as how to provide access, air quality, energy efficiency, and minimum physical disturbance. Sustainable systems are conservative. They seek to mimic natural systems that have evolved symbiotically over millenniums and, therefore, are nat-

urally in balance. "First do no harm" is a principle of sustainability.

• *Think like a system*—Think like a system is another mindset of sustainability. It is not a particular "hot spot" that is the main focus of planning, but how the entire system is operating. Is it efficient? It is resistant to shock? What happens when part of the system "crashes," such as in a flood or earthquake? Are there backup systems? How resilient is the system, that is, how fast does it adapt to changing circumstances? These are the types of questions that "thinking like a system" engenders. Planning for sustainable transportation systems must ask the same types of questions.

• *Develop indicators*—Benchmarking is a key ingredient of sustainability. Performance measures that reflect sustainability objectives must be developed. A particular number or ratio does not necessarily represent achievement of a sustainable system. Those numbers and ratios must change as the environment within which they operate changes. However, they must be able to demonstrate directional movement. For example, acreage of developed land per capita within a metropolitan region may be an appropriate indicator of sprawl, although there is no "ideal" ratio that represents sustainability. The directional signals that each community establishes for moving toward sustainability, informed by data on the environmental, economic, and equity consequences of such movement, that drives the process.

• *Provide flexibility, choice, redundancy*—Sustainable systems should not be brittle but flexible in all aspects. Flexibility in choice of mode, in siting, in design, in funding sources, in institutional arrangements, and in avenues of participation, to name a few. Flexibility implies real-time feedback on performance and a bias toward incrementalism.

With these characteristics in mind, what are the major opportunities in planning research to bring the transportation planning process more in line with notions of sustainability? Research ideas in five areas include process, models, indicators, institutions, and technology. Together, these proposals underscore the paradigm shift needed in transportation planning to resolve the conflicts between the way we plan our transportation infrastructure and our sustainability goals.

Process Research

The process—the rules and regulations under which transportation planning takes place—is not conducive to the production of sustainable outcomes. This observation applies to all levels of transportation planning: systems planning and management, project planning, and design and operation. Each of these areas deserves analysis.

Systems Planning and Management

A predicate for transportation planning for sustainability is the development of mechanisms for system management. However, the transportation planning process is not designed to provide for operational control. ISTEA initially required the development of transportation management systems in six areas: highway pavement, bridges, highway safety, traffic congestion, public transportation facilities and equipment, and intermodal transportation facilities and equipment. Each of these management systems, if guided by a set of performance indicators, could significantly advance sustainability objectives (*18*, pp. 123–141).[8]

Unfortunately, system management was not easily integrated into the existing system planning structure. Lack of data for system management, inflexibility in both statutory mandates and planning structure, lack of organizational capacity both at the federal and state levels, lack of training, short timelines, and other factors resulted in poor compliance or outright resistance (*19*). In 1995 amendments to ISTEA, the management system mandate was made discretionary. By the end of 1996, only 24 states were implementing all 6 management systems, and performance continues to be spotty. Research is needed to provide planners with the tools that they need to develop operational control over transportation system management. A study by Lindquist provides a good analysis of why ISTEA management system provisions failed (*20*).

Some state and local agencies have responded to the need for real-time management of transportation systems by setting up transportation management centers (TMCs). About 140 TMCs are presently in operation, but they focus primarily on single systems (mostly highway) and work mostly on incident management and customer service (e.g., "talking billboards"). Planning research could study ways to make these TMCs work on a multimodal basis and to measure and operate transportation systems for sustainability. A summary of TMC progress to date is presented in *NCHRP Synthesis of Highway Practice 270* (*21*).

Project Planning

Project planning, as presently conducted, fails to promote sustainability goals. Although ISTEA applied the needed financial rigor to the project-selection process through the requirement that the Transportation Improvement Program (TIP) be financially constrained

within available funding sources, it did nothing to improve the quality of project selection. The reason is that, even though planning factors were improved, the project-selection process was not connected to the planning factors. The failure of this existing TIP process to produce projects that reflect the values in the planning factor, and what to do about it, is described in the *ISTEA Planner's Workbook* (22).

One solution to this problem is to apply screening criteria that eliminate clearly unripe or ineligible projects. Good screening criteria have the ability to control the tempo (timing) and sequence (phasing) of projects, and therefore can incorporate sustainability objectives such as promotion of in-fill projects, system efficiency, and control of sprawl.[9] [More information on this subject is provided by *TCRP Report 39* (6, p. 5).] This approach requires political discipline in project selection, which can be encouraged, if not imposed, by good planning.

In addition to screening criteria, which primarily address project timing and sequencing, planners can develop scoring criteria that rank meritorious projects against sustainability objectives. For example, because a characteristic of sustainability is multiobjective functionality, projects that serve several functions, including improved access and mobility, should do better in the scoring criteria than those projects that serve only one goal. Planning for multiobjective outcomes is a key needed improvement in transportation planning and project selection. A good analysis of how ISTEA and TEA-21 highway funds can be used to advance environmental objectives as well as transportation objectives is provided by a report titled *The Road to a Cleaner Environment: How to Use Highway Funds to Enhance Water Quality, Wetlands, and Habitat Connections* (23).

Design and Operation

Transportation for sustainability can also be approached through the "three Ds of sustainable transportation," which include density (siting of transportation improvements), diversity (choice of mode), and design. Transportation systems can be evaluated on the basis of all of these "three Ds." However, once selected, projects must focus on design and operation.

There are many ways for improving project design to advance sustainability goals. NEPA analysis is conducted primarily to inform project location, not design. However, there are many ways to turn a project from generating negative to positive sustainability indicators at the design stage, especially if the project, once constructed, is added to a system that is under strong operational control. The statute on federal aid highway design was amended in 1995 to make it clear that the design guidelines developed by the American Association of State Highway and Transportation Officials (AASHTO) can be waived to promote "context-sensitive design."[10] Former AASHTO President Francis François observed that "aesthetic, community-sensitive design is where our nation wants to go, and we should go with them." (24) More information on this subject can be found in a FHWA book on flexibility in highway design (25).

Land Use and Sustainability

As mentioned earlier, land use and sustainability is a key issue in transportation planning. How can the issues be integrated into the transportation planning process? For what types of land use should we be planning? What can transportation do to promote such land uses? What planning research is needed to inform these questions?

There are several ways to approach land use and transportation at the several levels of government. One way is the state approach through smart growth statutes (Maryland) and concurrency requirements between development and public infrastructure to support such development (Florida). Another method is through regional schemes, such as urban growth boundaries (Oregon) and tax-based sharing (Minneapolis area). [Carson presents a critique of the urban growth boundary in his report *Paying for Our Growth in Oregon* (26). A critique of Carson's report is at www.friends.org/rccarson.html.]

A final method used to approach land use and transportation is through local strategies for conforming the local comprehensive planning process to sustainability goals. Lindquist (20) provides an excellent analysis of how to integrate transportation planning for sustainability into the local comprehensive planning process.

It is not the intent here to analyze these different approaches to coordinating transportation and land use decision making. It is important to point out that the transportation planning process is being increasingly constrained at all levels of government by statutory and regulatory prohibitions on the consumption of undeveloped land. Because access to undeveloped land has been a driving justification for transportation improvements during the entire 20th century, this is obviously an area of great conflict for planners.

Process Research for Sustainability

- Data, capacity, and training needs for effective transportation system management for sustainability;
- Improvements in timeliness of transportation planning and regulatory processes to support sustainability,

including strategies to apply real-time indicators of performance to project and system planning;

- Context-sensitive design for sustainability—best practices;
- Urban growth boundaries—their effectiveness in capturing the true cost of transportation service delivery;
- Transportation and land use—approaches to integrated planning at the local, regional, and state level;
- Transportation planning for efficient use of land—best local practices;
- More behavioral research, including how advertising affects modal choice;
- Planning for multiobjective outcomes;
- Regulating project tempo and sequencing through planning for sustainability;
- Planning for sustainability—new tools from ISTEA and TEA-21;
- Sustainable transportation and the three Ds—density, diversity, and design; and
- Zoning codes and sustainability, especially how zoning affects infrastructure financial burden and options for reducing this burden through sustainability.

Performance Indicators for Sustainability

If the goal is to develop a transportation system that is sustainable at the intergenerational time scale, we need a set of indicators that will measure performance against sustainability objectives over time. Conventional indicators of transportation system health do not include indicators of sustainability. We must move away from indicators of how well vehicles move and toward a set of indicators that reflect how efficiently people can access what they want and need.

Indicators for sustainable transportation would identify not only the ability of the transportation system to deliver access but also the impact of the transportation system on the larger system. Such indicators provide a feedback loop that reflects the overall health of our communities. Target levels of impact are less of an objective than is direction of movement. Taken as a set, such indicators could provide signals when positive trends turn to negative trends, and vice versa. This approach would allow the entire transportation system to be managed on a real-time basis for its contribution to sustainability objectives.

The basic research task is to identify an appropriate set of indicators and proper ways in which to measure each one. Often, the mere presence of information is enough to alter individual behavior. Some guiding principles for all indicators of transportation system performance for sustainability include the following (*27*):

- *Relevant:* What is the indicator measuring? Is the measure of performance particular to transportation or does it link transportation to performance of the larger system?
- *Value-based:* Because each indicator measures the health of some sector of the transportation system, the community must value that measurement. Otherwise, it will be disregarded.
- *Attractive to the media:* Changing behavior is difficult. If indicators are understandable to the media, the job will be easier.
- *Statistically measurable:* Some useful indicators are very difficult to measure. Bicycling and walking trips are an example. Transportation demand models must figure out a way to account for such trips and to measure latent demand should adequate bicycle and pedestrian facilities be developed in conjunction with appropriate land uses.
- *Reliable:* We must be able to trust what each indicator is showing. This means that the indicator must be accurate as well as consistently measured over time.
- *Leading:* The best indicators will be leading, providing information about a trend while there is still time to act. Carbon emissions are an example.

The value of indicators is that they help us understand linkages between various parts of the system. All of our systems are linked together in complex chains of cause and effect. Some may reflect more or less strong associations; therefore, a weighting system may be necessary.

Communities in the United States and around the world have begun to use indicators to evaluate the health of environmental and social systems and to monitor progress toward sustainability. These indicators cover a wide range of topics: environmental, economic, social, cultural, and political. The indicators allow these communities to compare current conditions to desired performance and to evaluate trends over time. For example, the Maryland Department of Natural Resources and the Delaware Department of Natural Resources and Environmental Control have developed formats that specify the use of various indicators (*28*). Seattle, Washington, keeps track of miles of pedestrian-friendly sidewalks and miles of bike lanes. Portland, Oregon, has developed a pedestrian environment factor (PEF) that measures neighborhood characteristics, which make them more or less amenable to walking.

Once developed, indicators can then be incorporated into the visioning, planning, budgeting, and project-selection processes. Use of indicators will force us to focus on purpose instead of on process. What we seek, however, is a moving target; therefore, the development of indicators will always be a work in progress.

The indicators can be divided into those that are specific to the transportation system and into those that reveal the impact of the transportation system on some

larger social or environmental system. Indicators must also be scaled to the appropriate geographic level. Finally, an indicator that looks good at one level of analysis (e.g., walking or bicycling modal split in a neotraditional community), may not look as good at another level of analysis (regional transportation impact if the community is located at the urban fringe).

The following indicators of transportation system performance, with these qualifications, are being tested around the country:

- Transportation performance indicators
  - Access to goods and services
  - Portion on transportation costs that are internalized
  - Ability to maintain what we have already constructed
  - System's resistance to shock or redundancy resiliency
  - Adaptability in the face of rapid technological change
  - Extent of facilities that are available for nonmotorized transportation (i.e., miles of sidewalk per capita, and miles of bicycle lanes and trails per capita);
  - Vehicle-fleet mix
  - Mode split
- Environmental performance indicators
  - Land consumption (i.e., rate of consumption, developed land per capita, and acreage of protected open space per capita)
  - Air quality
  - Water quality
  - Transportation energy use per capita
  - Loss of prime farmland or environmentally sensitive areas (i.e., absolute acres, rate of loss, and loss due to transportation improvements).
- Social indicators
  - Health and fitness in terms of infrastructure footprint
  - Safety and fatalities
  - Neighborhood or community health indicators, such as crime
  - Distributional effects—public transportation expenditures per capita compared to such factors as average household income, ethnicity, and location (urban, suburban, rural). The disconnect between those who benefit and those who pay is a significant destablizing factor to the sustainability of our transportation systems.

Of course, the most relevant indicators are ratios, comparing one measurement with another to demonstrate a correlation. Our knowledge base is far from complete in terms of knowing which ratios are most relevant for measuring the overall contribution of transportation systems to notions of sustainability.

Planning Research on Indicators

- What are the best practices for measurement of transportation system performance for sustainability at the neighborhood level? Community level? Regional level? State level? National level?
- How do we integrate indicators over different geographic scales so those indicators that show a positive correlation to sustainability at one level do not show a negative correlation at another level?
- How do we integrate indicators of transportation system performance for sustainability with indicators of performance for the total system (social, environmental, and economic)?

Technology and Planning for Sustainability

As noted earlier, the environmental footprint of transportation in any given urban area has historically reflected the dominant transportation technology at the time of its greatest growth. Thus, Boston and Philadelphia still reflect the land patterns dictated by the maritime trade; Chicago was built around railroad technology; New York was built around transit; and Los Angeles was built around the automobile (along with most "edge cities"). Technology, facilitated by land development subsidies, has been the destiny of urban form and, increasingly, the form of our countrysides as well. (An excellent source of information and contacts on transportation technology for sustainability is the Transportation Technologies for Sustainable Communities Project at www.transact.org.)

In recent years technology has been increasingly used to counteract its own adverse environmental impacts. Thus, new ways of capturing nonpoint sources of pollution from highways have been developed, along with the development of

- Catalytic converters for tailpipe emissions;
- New techniques for disposal of highway construction materials;
- New ways to improve fuel efficiency;
- "Hypercars" made of light composite materials that are indestructible and recyclable, powered by fuel cells with no apparent emissions; and
- ITS to improve the efficiency of the relationship between the car, the driver, and the road.

Under this game plan, the solution to the problems of technology is more technology.

Technology also affects sustainability by providing remote access to places that were previously only accessible by private or public transit. The effect of electronic commerce (e-commerce) on shopping mall sales is a

prime emerging example of this trend. The real estate industry recently increased its estimate of projected bankruptcies for shopping malls by 15 percent on the basis of the competition they now face from e-commerce. In response, many malls are now promoting themselves as tourist destinations, as well as retail outlets, in a vigorous effort to retain traffic through their facilities. E-commerce may well have profound effects on transportation behavior, especially in suburban areas.

Technology is certainly a powerful tool to improve system efficiency and all its component parts. However, although essential, technology alone is not sufficient. Behavior must change as well, both in terms of how we move around and how much we move around, if we are to move the indicators of sustainability in a persistently positive direction. How can planners use technology to move system performance toward sustainability? Three possible answers to this question are discussed in the following paragraphs.

First, technology has the power to inform choice. Advanced Travel Information Systems include many promising ITS technologies that allow system managers to provide travelers with improved choice of mode. These technologies also provide the means to achieve that choice by providing real-time feedback on the effect of those choices on the environment, the community, and the pocketbook. Recent studies indicate that more information does not necessarily affect behavior, which may have something to do with the type and timeliness of information provided and the existence of available options. If the system itself is so rigid that modal "lock-in" occurs, no amount of information will change behavior (*29*).

Second, the power of technology for measuring system performance is a powerful new tool for moving transportation system investment and management toward sustainability. The computing power of desktop computers now allows planners to characterize system performance in ways that are unimaginable, even a few years ago. For example, sources and flows of transportation system investments, both capital and operations, can now be tracked relatively simply at the local, regional, and statewide level. Such tracking can reveal anomalies between where new investments are made and the documented surveys of system need, between who benefits and who pays, and between sources of system inefficiency and actions taken to reduce such inefficiencies. By using existing data sets and a few computers, planners have the capabilities to take the politics out of pothole management.[11]

Third, technology can be used to improve public transit efficiency. An unhappy fact about transit is that often the rolling stock is so old, or so fuel-inefficient, that on a passenger-mile basis it is less sustainable than single-occupancy driving. It is untenable for public advocates to promote greater modal choice when such choices have declining sustainability trends.

Just because ITS and other transportation-related technologies can be used to promote system sustainability does not mean it will happen. According to a Congressional Budget Office report on use of federal ITS funds, just 1.2 percent of the funds have been spent on projects with "environmental concerns," whereas 65.3 percent of the funds have been spent on travel management projects that move cars and trucks around the highway system faster and more efficiently (*30*). Although this is not necessarily an inefficient use of ITS technology, given limited resources, more sustainable applications of ITS technology may be appropriate.

Planning Research on Uses of Technology for Sustainability

- How can advances in computing power be used to plan for transportation system sustainability?
- How can ITS technology be used to improve overall system sustainability?
- How can ITS technology be used to expand consumer choice and affect consumer behavior to promote sustainable outcomes?
- How can technology improve operational performance of public transit to move overall system performance toward sustainability?

Model Improvements for Sustainability

Models have guided transportation planning for nearly half a century and have not evolved substantially over the years. There is room for improvement both in the depth with which the models treat the movement of goods and people as well as in the breath of the domain they address. Modeling for sustainability is a prime focus area for transportation planning research.

The traditional transportation four-step modeling process was developed at a time when the emphasis of transportation planning was on infrastructure development. (The four steps were trip generation, trip distribution, mode split, and trip assignment.) The basic questions asked were "Where should the new roads be placed?" and "How many lanes should the roads be?"

Starting in the 1970s a series of management paradigms were implemented. Transportation system management, then travel demand management, and more recently, transportation control measures (TCM) were used to control demand-side pressure on transportation systems. These methods proved to be too sophisticated for the traditional travel demand models because they

targeted specific travel segments and policies that the models could not accurately represent (*31*).

The simplicity of the models that were developed 50 years ago are no longer able to keep up with the increasingly complex ways that people move about and the remedies being considered to address the travel problems that we face. Specifically, the current models are deficient in the following areas (*31*):

- Internal inconsistencies (trip productions and attractions do not match).
- Data inefficiency (household characteristics are lumped into zonal averages).
- Lack of behavioral foundation (trip generation does not consider employment status).
- Not policy sensitive.
- Issues of accessibility and land use are not integrated into the models (i.e., impact of new transportation infrastructure on land use and impact of congestion on trip generation and attraction).
- Time of day is ignored; thus, shifts in travel time, as suggested by TCM, are not captured by the current process.
- Congestion pricing is difficult to model because of this lack of ability to model specific time periods.
- Induced travel, namely the tendency of new capacity to generate new trips, is not considered.
- Bicycling and walking trips are not considered.

These deficiencies in traditional transportation models act as a barrier to the use of models to promote sustainable outcomes in transportation planning.

Travel Model Improvement Program

A joint program of the USDOT and the Environmental Protection Agency (EPA), with input from state DOTs and metropolitan planning organizations (MPOs) as well as from private-sector entities, is underway to remedy many of the problems with the current modeling process. Started in 1992, the Travel Model Improvement Program project is designed to develop a new model structure that will be sensitive to policy scenarios, including environmental concerns and growth management issues. Links to land use will be direct, and increased accuracy for air quality impacts will be included.

The project has four tracks:

1. *Outreach*—This tract helps practitioners improve their existing planning procedures, which include training, technical assistance, research coordination, and a clearinghouse for new findings.
2. *Near-term improvements*—Similar to outreach efforts, this track in particular aims to assist state DOTs and MPOs in implementing model improvements that have already been developed but have not been widely disseminated.
3. *Long-term improvements*—This track is a complete redevelopment of travel and land use forecasting models.
4. *Data collection*—Because the new models will be so data intensive, this track was developed to improve data-collection procedures and evaluate data needs (*32*).

Of particular note, the new model TRANSIMS (Transportation Analysis and Simulation System) is being designed to more accurately model congestion and air quality. The model will predict trips for individual households, residents, and vehicles instead of for zonal aggregates of households, as do the current models. TRANSIMS is now being tested in Dallas, Texas, and Portland, Oregon.

LUTRAQ

Begun in 1988, the project headed by 1,000 Friends of Oregon called Making the Land-Use–Transportation–Air-Quality (LUTRAQ) Connection has been analyzed in depth (*33*). Started as an effort to oppose a proposed western bypass around Portland, the project grew into a model program that sought alternative outcomes to automobile-dependent land use patterns. This secondary objective demonstrated that development could be accommodated while minimizing land consumption, thus reducing vehicle trips per capita and improving air quality.

The LUTRAQ project used many of the transportation planning tools that support sustainable development. Of primary note, transit-oriented development, market strategies (parking charges and free transit passes), and a balanced transportation system were included in the model. The success that was demonstrated by the LUTRAQ project was made possible, in part, because changes were made to the standard travel demand forecasting process. This was done by developing the PEF variable that models how the natural and built environment makes walking easier or harder, thus influencing how a person decides to make a trip. The four components are ease of street crossing, sidewalk continuity, local street connections, and topography (*33*).

Models also need to be capable of scenario-based planning. This means that transportation models need to be linked to land use and economic models. For example, a sprawl scenario needs to be compared to a transit-oriented development scenario in deciding what land use pattern the design of the transportation system should support.

Planning Research for Transportation Models

- State-of-the-art or best practices in the use of policy-sensitive models to promote sustainable transportation planning.
- Use of PEFs in transportation models. Perhaps a similar methodology can be used for bicycling to measure the relative bicycle-friendliness of land uses for predicting bicycle usage under various land use scenarios.
- Modeling for nonplanners—how to inform transportation decision makers of the consequences of their land use and transportation decisions.
- Integration of models (subdivision, neighborhood, community, region) to promote sustainable outcomes.

Institutions

One of the most overlooked aspects of ISTEA and TEA-21 is how thoroughly these two laws "reshuffled the deck" on institutional roles and responsibilities for transportation planning. A great deal of attention has been focused on the increased role, and power, of MPOs in project programming and financing under the new laws and the discipline imposed on both MPOs and state DOTs through the requirement that transportation improvement programs be financially constrained. Opportunities for citizen participation also have been increased at all levels of transportation planning, not just at the traditional project location stage. All these new institutional roles and relationships, by expanding the number of participants in project development and selection beyond the traditional transportation community, provide opportunities to integrate notions of sustainability into transportation planning.[12]

However, an institutional change that has not received much attention is the role reversal in program objectives between the federal, state, and local participants in the federal aid program. Specifically, the federal interest in "getting us out of the mud" through capital construction has been transformed into a priority on "taking care of what we've got" through efficient system management, operations, and preservation. Conversely, the state and local roles, which were at first limited to system maintenance, have been increased to assume more of the burden of system expansion as the benefits of such expansion are perceived as being captured locally, not nationally.

Transit, in many places, is also perceived as making a significantly higher contribution to national objections of choice, efficiency and social equity than previously recognized. TEA-21 includes more than 100 "new starts" for transit, a clear endorsement of the perceived national benefits of this travel mode. Intermodalism is strongly supported in the new statutory scheme, which will require changes in program administration to allow people, data, and funds to flow more easily between modal agencies as well. Bicycling and walking, another traditionally local priority, have been given a strong federal endorsement in the Transportation Enhancements Program, as their contribution to a broad array of sustainability objectives is increasingly recognized.

Even the area of transportation research has experienced this role reversal. During the early stages of our national highway construction program, research, especially policy research, was not a priority. USDOT had fewer policy positions than any other federal agency. Building infrastructure was a technical job, devoid of policy choices. Thus, research was highly decentralized and focused almost exclusively on ways to improve pavement performance or bridge loads. As the need to incorporate multiple objectives into transportation decision making became more important, so did research to accomplish this objective. This meant more centralized research, more technology transfer, and more policy research.

Finally, the role of the customer—the transportation user and the host community—has gained in importance as objectives and concerns about community impacts have expanded. As sustainability becomes a higher priority for transportation planning, the role of communities and citizens will become even more important, perhaps even sharing the role of problem identification with transportation professionals. Fitting transportation within the "visioning process," by which many communities conduct their comprehensive planning, instead of fitting community goals within a long-range transportation grid developed by computer models, represents a huge change in institutional relationships between the professional and nonprofessional in transportation planning.

This bottom line of transportation planning for sustainability is that a lot more people, representing a lot more interests, are going to be involved in the transportation planning process. These interests are not just vertical but cut across agency and jurisdictional lines as well. That means more cross-jurisdictional planning at the regional level and more cross-agency planning at all levels. An EPA task force on TEA-21 has been established with one overriding goal: early involvement in the planning process. Communities are demanding "place-based decision making" to ensure that community goals are respected throughout the planning process. The days when the district highway engineer wrote up an annual work program and had it rubber-stamped by the regional planning organization are over.

ISTEA and TEA-21 require that the transportation planning process be much more participatory and much

more inclusive in terms of desired outcomes. This requirement is good for sustainability. However, stalemate is not good for anyone. How can the planning process be participatory and effective in promoting sustainability? That is the big institutional issue.

Institutional Roles and Relationships for Sustainability: Research Agenda

- Role of comprehensive plans in integrating transportation and land use planning at the community level,
- Federal role in promoting sustainable development in the transportation planning process,
- State role in promoting sustainable development in the transportation planning process,
- Role of MPOs in promoting sustainable development in the transportation planning process,
- Role of nongovernmental organizations in promoting sustainable development in the transportation planning process,
- Role of the citizen in planning for sustainable development in the transportation planning process,
- Strategies for effectively involving environmental agencies in transportation planning for sustainability, and
- Best practices for becoming a "green state DOT."

Conclusion

This discussion does not cover many strategies for promotion of sustainability through improved transportation system development and management. That subject is enormous and includes a complete analysis of material sources and flows for transportation, policy options (especially pricing for sustainability, life-cycle costing, and measurement and pricing of externalities), and a whole host of technological strategies that have nothing to do with transportation planning. If we are to achieve the radical change in transportation service delivery that is called for at the beginning of this paper, all these strategies will be needed.

This paper has outlined a few research ideas for the transportation planning community to help integrate concepts of sustainable development, smart growth, and livability into the transportation planning process. Certainly, if interest in such issues continues to grow, and if new strategies are sought to meet the targeted reductions in greenhouse gases that was called for by the Kyoto Protocol, there is much fruitful work to be conducted in this area. Instead of being a barrier to meeting rising public demand for action to promote sustainability, transportation could become the catalyst for such action.

Notes

1. The quote is by John Prescott, the Secretary of State for the Environment, Transport and the Regions (*1*). His duties combine those of EPA and USDOT.

2. This is not entirely a problem of poor implementation. The explicit predicate of both Title 23 (highways) and Title 49 (transit) of the U.S. Code is that transportation is a federal, state, and local partnership, with the federal government largely funding capital costs and state and local governments assuming costs of maintenance and system preservation. This partnership reflected a perception that the benefits of new construction were primarily national (promoting interstate commerce), thus, justifying the federal lead in capital funding. This relationship has now flipped, with federal priorities focusing on system preservation to meet national financial, environmental, and social goals, while new capacity is increasingly perceived as providing mostly localized benefits that should be financed locally. The structures of Titles 23 and 49 do not yet reflect this role reversal.

3. An intergenerational approach to sustainability focuses on "keeping within the environmental fences" (i.e., avoiding system collapse or impacts that are not reversible within a generation). Impacts that are controllable within a generation are not included on the assumption that we are not compromising the ability of future generations to meet their own needs (Bruntland definition of sustainability), as long as we pass on natural, social, and economic systems that, however depleted, can still feasibly be restored to health. This is a minimalist definition of sustainability. Most statements of sustainability aspire to pass on to future generations social, environmental, and economic systems that show continuous improvement in their performance indicators.

4. For example, the Center for Sustainable Transportation in Toronto, Canada, estimates that about one-third of the reduction in transportation-related greenhouse gases needed to meet Kyoto targets can be achieved through technology. The other two-thirds will have to come from changes in our patterns of travel consumption and behavior (*10*).

5. Defenders of the status quo in transportation often point to the fact that air emissions or other environmental impacts are declining per VMT as a demonstration that transportation is getting more sustainable. This makes no sense in the context of sustainability because it is the total load of transportation-related impacts on larger natural systems that count. Any metric of efficiency relative to a measure of consumption (VMT) is irrelevant in a sustainability context.

6. PL 105-178 (June 9, 1998) at Section 5107 requires the secretary of transportation to undertake a transportation-environment cooperative research program, which includes a project "to study the relationship between highway density and ecosystem integrity, including the impacts of highway density on habitat integrity and overall system health, and develop a rapid assessment methodology for use of transportation and regulatory agencies in determining the relationship between highway density and ecosystem integrity."

7. ISTEA and TEA-21 specifically identify historic transportation facilities and railroad corridor preservation (including conversion to trail use) as historically important, and set aside significant funds for their preservation and development under the Transportation Enhancements Program. Also, corridor preservation is one of the seven planning factors required to be considered in the metropolitan and state planning processes [23 U.S.C. Sections 134(f)(1)(G), 135(c)(1)(G)]. The preservation of historic transportation facilities, such as deports and corridors, can promote in-fill development around these facilities and help preserve historic downtown areas. These facilities may also qualify for funding under EPA's Brownfield Redevelopment Program.

8. Three of the management systems address asset management and three systems address performance management. The Surface Transportation Policy Project's report entitled *ISTEA Planner's Workshop* provides a good discussion on the different requirements of these two management systems and how the performance management systems, especially congestion management, can advance sustainability goals (*18*).

9. The failure of land use controls to regulate timing and sequencing of new land development in the United States has been identified as a prime contributor to sprawl.

10. 23 U.S.C. Section 109(a)(2) directs the secretary of transportation to ensure that highway design, in addition to meeting minimum safety and other requirements, will "conform to the particular needs of each locality." Additional information is presented in the FHWA report *Flexibility in Highway Design* (*25*).

11. The Surface Transportation Policy Project has used technology in this manner to analyze transportation system performance from a new sustainability paradigm. The resulting studies, effectively publicized through the media, have significantly influenced the public policy debate on transportation. A summary of some of these studies can be found at www.transact.org.

12. Under orders from the governor, the Pennsylvania Department of Transportation has developed a plan for becoming a "green agency." This is a new role for a state DOT.

References

1. *A New Deal for Transport: The Government's White Paper on the Future of Transport (U.K.)*, Oct. 1998, p. 2.
2. Lindquist, E. Moving Toward Sustainability: Transforming a Comprehensive Land Use and Transportation Plan. In *Transportation Research Record 1617*. TRB, National Research Council, Washington, D.C., p. 1.
3. Critical Issues in Transportation. *TR News*, No. 193, TRB, National Research Council, Washington, D.C., 1995, pp. 10-20.
4. *Special Report 251: Toward a Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology*. TRB, National Research Council, Washington, D.C., 1997.
5. *Sustainable Transport, Priorities for Policy Reform*, World Bank, Washington, D.C., 1996; *Urban Travel and Sustainable Development*, Organization for Economic Cooperation and Development, 1995.
6. Burchell, R. W., N. A. Shad, D. Listokin, H. Phillips, A. Downs, S. Seskin, J. S. Davis, T. Moore, D. Helton, and M. Gall. *TCRP Report 39: The Costs of Sprawl—Revisited*. TRB, National Research Council, Washington, D.C., 1998.
7. Quality of Life Campaign of the Surface Transportation Policy Project, www.transact.org.
8. *Sustainable Transport, Priorities for Policy Reform*. World Bank, Washington, D.C., 1996, p. 28.
9. *Special Report 231: Transportation, Urban Form, and the Environment*. TRB, National Research Council, Washington, D.C., 1991.
10. *Sustainable Transportation Monitor*, Vol. 1, March 1998, p. 11.
11. Forman, R. T. *Land Mosaics: The Ecology of Landscapes and Regions*. Cambridge University Press, United Kingdom, 1995.
12. Forman, R. T., et al. Road Ecology and Road Density in Different Landscapes, with International Planning and Mitigation Solutions. In *Trends in Addressing Transportation Related Wildlife Mortality*, Florida Department of Transportation, 1996, pp. 1–22.
13. Livability Initiative. American Institute of Architects, Washington, D.C., Jan. 11, 1998.
14. Moe, R., and C. Wilkie. *Changing Places: Rebuilding Community in the Age of Sprawl*. Henry Holt and Company, 1997.
15. Deakin, E. *Combating Global Warming Through Sustainable Surface Transportation Policy*. Transit Cooperative Research Program Task Force on Global Warming and Sustainable Transportation, Oct. 1998.
16. Apogee Research, Inc. *Transportation and Global Climate Change: A Review and Analysis of the Literature*. Federal Highway Administration Report. U.S. Department of Transportation, June 1998.

17. Dittmar, H. A Broader Context for Transportation Planning. *Journal of the American Planning Association*, Vol. 61, 1995, p. 7.
18. *ISTEA Planner's Workbook*. Surface Transportation Policy Project, 1994.
19. *Transportation Infrastructure: States' Implemen-tation of Transportation Management Systems*. GAO/RCED-97-32. U.S. General Accounting Office, 1997.
20. Lindquist, E. Unintended Consequences of Policy Decisions: What Happened with the Intermodal Surface Transportation Efficiency Act Management Systems? In *Transportation Research Record 1617*, TRB, National Research Council, Washington, D.C., Jan. 1998, p. 112.
21. *NCHRP Synthesis of Highway Practice 270: Transportation Management Center Functions*. TRB, National Research Council, Washington, D.C., 1998.
22. Dittmar, H. Outline for a Model Transportation Improvement Model. In *ISTEA Planner's Workbook*, Surface Transportation Policy Project, Oct. 1994, p. 105.
23. *The Road to a Cleaner Environment: How to Use Highway Funds to Enhance Water Quality, Wetlands, and Habitat Connections*. Final Draft. Claremont Graduate University Research Institute and Rails-to-Trails Conservancy. Nov. 23, 1998 (unpublished).
24. Thinking Beyond the Pavement. Presented at AASHTO Workshop on Integrating Highway Development with Communities and the Environment While Maintaining Safety and Performance, May 1998.
25. *Flexibility in Highway Design*. FHWA-PD-97-062. Federal Highway Administration, U.S. Department of Transportation, 1997.
26. Carson, R. *Paying for Our Growth in Oregon*. POGO Report. 1,000 Friends of Oregon, Oct. 1998.
27. *Indicators of Sustainable Community*. Sustainable Seattle, 1998.
28. *Sustainable Communities*. Task Force Report. The President's Council on Sustainable Development, 1997.
29. Wells, K., and T. Horan. Toward a Consumer Demand-Driven Intelligent Transportation System Policy: Findings from Southern California. In *Transportation Research Record 1679*, TRB, National Research Council, Washington, D.C., Jan. 1999.
30. Horan, T. *Wired to Go: The Information Age Hits the Streets*, Aug. 1998, p. 17.
31. *Activity-Based Modeling System for Travel Demand Forecasting*. DOT-T-96-02. U.S. Department of Transportation, Sept. 1995.
32. *Travel Model Improvement Program Newsletter*, July 1998.
33. *Making the Connections: A Summary of the LUTRAQ Project*, 1,000 Friends of Oregon.