Commission Briefing Paper 4J-05

Efficacy of Revisions to Infrastructure Design Standards to Mitigate Environmental Impacts

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Introduction

This paper is part of a series of briefing papers to be prepared for the National Surface Transportation Policy and Revenue Study Commission authorized in Section 109 of SAFETEA-LU. The papers are intended to synthesize the state-of-the-practice consensus on the issues that are relevant to the Commission's charge outlined in Section 1909, and will serve as background material in developing analyses to be presented in the final report of the Commission.

This paper presents information on the potential for changes in design standards to mitigate the environmental impacts of surface transportation. Surface transportation contributes to many of the environmental problems faced by the United States: air and water pollution, heavy energy use, fragmented farmlands and habitat, wildlife and biodiversity losses, and community disruption. These problems adversely affect human and ecosystem health, and the nation's overall quality of life. As the U.S. population grows, the economy expands, and passenger-miles traveled increase, transportation professionals face the significant challenge of providing socially and environmentally responsible transportation facilities and services (TRB 2002).

Design standards are the physical dimensions of design elements (i.e., lanes, shoulders, vertical clearances, etc.) incorporated into the facility. The purpose of standards is to achieve consistency or uniformity of design to promote efficiency, economy, safety, and capacity. Increasingly, designers and engineers are encouraged to apply a Context Sensitive Solutions (CSS) approach in transportation planning and design and use the flexibility within design standards to mitigate environmental impacts and preserve and enhance environmental quality.

Background and Key Findings

This white paper draws upon available published research and personal interviews. Telephone interviews were conducted with engineering design and environmental professionals at FHWA, FTA, TRB, AASHTO and several state departments of transportation. Key findings are:

- Data on the environmental impacts specific design standards is scarce. Little published research exists on the ability of potential revisions to infrastructure design standards to mitigate environmental impacts. Further research on this topic would be beneficial.
- There are no widely accepted design standards for transit projects. Rather, the standards appropriate to the vehicle and propulsion form the basis for further design. Each transit system authority or owner develops context sensitive solutions, individual design standards and specifications based on experience, and subject to state and local regulations and policies. American Railway Engineering and Maintenance of Way

Association (AREMA) design standards address the design and operations of rail systems of all kinds, considering safety and capacity requirements.
- According to both AASHTO and FHWA, highway design standards primarily focus on measures that provide occupant safety and vehicle capacity. Historically, revisions to design standards for the purpose of mitigating the roadway's environmental impacts have been considered only after safety and capacity requirements have been met. Other than noise, the environmental impacts from vehicles operated on roadway are not incorporated into the design standards.
- Few opportunities appear to exist to mitigate environmental impacts through changes in design standards, although environmental objectives can be accommodated through flexibility in the application of standards. The CSS approach stresses the flexible application of design standards to better fit the surrounding natural, social, and cultural environment, and can result in the mitigation of environmental impacts on a project-by-project basis.
- Technological advances must occur before substantial changes to design standards become possible. However, changes to the clear zone, median width, number of lanes, grades (vertical alignment) and level-of-service criteria could result in moderate reductions in environmental impacts
- The use of a CSS approach, where collaboration between agencies and communities is early, open, and continuous, along with sustainable design efforts, would appear to hold greater promise for mitigating environmental impacts than changes to design standards.
- Over a longer time horizon, as vehicles become smarter and intelligent transportation systems (ITS) develop further, design standards could be modified to realize the greater environmental mitigation enabled by these technologies, allowing a decrease in environmental impacts without sacrificing safety and capacity.
- When considering changes to design standards to mitigate one environmental impact, the overall effect of the change should be evaluated at a systems level to ensure that other impacts are not worsened, including the potential effect on safety and capacity.

Results

Standards are conservative by nature. Standards promote consistency of design, and tend to accommodate and reflect current practices, rather than lead to or define new ones.

1. Highway/Roadway

Green Book. AASHTO's Policy on Geometric Design of Highways and Streets (2004), known as the Green Book, is based on established practices supplemented by recent research. It accepts and relies upon current vehicle technology and observed driver behavior. The AASHTO Subcommittee on Design, Geometric Design Technical Committee, is reluctant to change established design standards or adopt new practices without well-documented supporting research. Future planning for design standards at AASHTO focuses on a five- to ten-year horizon, concurrent with the expected publication of a revised Green Book in 2010.

The Committee focuses primarily on improving safety and reducing traffic congestion within fiscal constraints. Improving safety and capacity usually requires more space – wider lanes and shoulders, longer weave lengths, flatter curves – to provide greater separation between vehicles and the roadside (allowing drivers a greater margin of error). The general Committee consensus is that reducing or relaxing design standards to mitigate environmental impacts may compromise safety and/or roadway capacity. In reviewing individual design standards, the following were identified as having the greatest potential to minimize the highway footprint and thereby mitigate environmental impacts:

- Clear zone
- Median width
- Number of lanes
- Grades (vertical alignment)

With future improvements to vehicle control technologies, the frequency of errant vehicles leaving the roadway is expected to decrease. This would allow the standard clear zone and median widths to be decreased. Improved control technologies would allow vehicles to be platooned with a decreased spacing between vehicles, potentially reducing the number of lanes needed on a facility. Stronger and more efficient vehicle engines would allow steeper grades to be traversed without affecting operating speed.

Manual on Uniform Traffic Control Devices (MUTCD). FHWA's MUTCD (2003) contains design standards and guidance for traffic control devices (e.g., signs, signals, and pavement markings). Requiring traffic control devices to be smarter, more efficient, and more responsive to traffic demand reduces congestion, air pollution, and energy consumption. Future planning for MUTCD should include a greater emphasis on innovative technologies to further improve traffic flow. Future editions of the MUTCD should also address the impact of Bus Rapid Transit (BRT) operations on the highway system. The rapidly increasing number of BRT systems that are being deployed throughout the U.S. involve highway geometric and pavement design changes, enhance transit operations, and minimize pollution caused by buses stalled in traffic.

Highway Capacity Manual (HCM). The 2000 HCM is used to determine the capacity of a wide range of surface transportation facilities from signalized intersections and two-lane highways to sidewalks and urban streets. Baseline level of service requirements control the number of lanes. By lowering the acceptable level-of-service, the number of lanes can be reduced. Much of the criteria on this standard are based on decades-old research and driver expectations. Revisions to level-of-service criteria have the potential to reduce the footprint of facilities and mitigate environmental impacts.

State of the Practice: Traffic Control Strategies for Toll Plazas. Toll plaza design strategies are not currently found in either the AASHTO Green Book or MUTCD. The development of Electronic Toll Collection (ETC) technology offers potential benefits for environmental mitigation as it requires significantly less space and energy to achieve the same traffic throughput, and eliminates the need for motorists to stop to pay tolls. ETC technology reduces the noise, air pollution, and space requirements associated with traditional plazas. ETC provides toll agencies the opportunity to implement congestion pricing strategies, a powerful economics-based tool for congestion management, and mitigate potential environmental impacts.

A Policy on Design Standards —Interstate System. This document reinforces the need to design the interstates "to ensure safety, permanence, utility, and flexibility to provide for predicted growth in traffic." The document does not advocate relaxing or otherwise changing design standards to mitigate environmental impacts.

Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400). This 2001 AASHTO document supplements the Green Book by focusing exclusively on the unique design requirements of very low-volume local roads. This document encourages a more flexible approach to the interpretation of design standards. A flexible approach affords an opportunity to mitigate environmental impacts (e.g., maintaining a one-lane bridge design to reduce stream impacts rather than conclude that two lanes are required in all locations).

FHWA Flexibility in Highway Design. This 1997 FHWA publication highlights the need to consider the setting and character of the surrounding area during the highway design process. It emphasizes a CSS approach, and encourages engineers to consider environmental impacts when applying the Green Book criteria. The guidance advocates using the flexibility within design standards to mitigate environmental impacts. To further integrate this approach into the design process, merging of this publication into the Green Book should be considered.

2. Rail

American Railway Engineering and Maintenance-of-Way Association's Manual of Railway Engineering (AREMA). AREMA provides criteria for track design and design of railroad and transit tracks, signals and structures (primarily bridges), as well as general design standards for a variety of railroad infrastructure and passenger facilities. The facilities design standards include site-related issues, such as selection of an appropriate site; functional layout and space requirements; and structural, mechanical, electrical and life safety needs. While the track and structures criteria are very specific and parallel AASHTO, the facilities criteria for railroad bridges serves only as general guidance. The AREMA criteria contain no information on potential environmental issues or related design requirements.

AREMA Committee 13 Environmental is initiating an effort to prepare a new chapter for the Manual of Railway Engineering. Currently all committees except Committee 13 are represented in the Manual. The focus of the new environmental chapter will be to provide guidance on environmental issues common to railroad projects (e.g., wetlands mitigation and stormwater permitting). The chapter will reference local and state policies and standards for specific sites.

This approach to addressing environmental issues is typical for both railroad and transit projects. Requirements for environmental compliance are controlled at the state and local level; policies acceptable in one region could meet opposition in another region. In the AREMA Manual, specific design standards are provided to address safety and operations. Railroads and rail transit agencies weigh alternatives based on safety and operations, then address environmental mitigation and permitting with state and local authorities as required.

3. Transit

There are no widely accepted design standards for transit projects. The American Public Transportation Association (APTA) has published design standards and specifications, prepared by organizations including the American National Standards Institute (ANSI), American Society of Civil Engineers (ASCE), AREMA, and FTA. However, these standards serve only as guidelines and are heavily dependent on the mode and vehicle technology selected. The Transit Capacity and Quality of Service Manual, a companion document to the Highway Capacity Manual, also does not set policy on quality of service or capacity, but does provide a consistent set of evaluation techniques for bus, rail and ferry operations.

Typically, each transit system develops its own design standards based on existing systems and vehicles and local experience, subject to local regulations and policies. Design standards typically address clearances, applicable codes and regulations, and owner preferences, and respond to safety, durability and operations. Requirements for, or consideration of, environmental compliance are not typically represented in this criteria, with the exception of noise and vibration. Noise and vibration are addressed from the standpoint of minimizing impact to riders, as opposed to the surrounding community.

While transit is intrinsically more environmentally friendly than highway traffic, transit agencies are increasingly promoting environmental stewardship. The International Association of Public Transport Charter on Sustainable Development is a worldwide network of transit professionals that promote sustainable design. Their sustainable design standards are being implemented by the New York City Transit Authority (NYCT), with similar policies in force in other states. Sustainable design, along with the NEPA process, offers greater opportunities for mitigating environmental issues than revisions to transit design standards.

4. Ports

No standards for channel deepening appear to exist. Deepwater ports generally require 50-foot channel depths. Channel deepening and port expansion require significant alteration of the environment through dredging and filling, and port operations have the potential to impact the quality of air and water resources. The common challenge faced by ports is the need to conduct operations in an environmentally sound yet economically productive and competitive manner.

Dredging is needed to improve navigation of an existing channel (i.e., maintenance) and to improve navigation channels to provide access to increasingly larger vessels. The key elements of dredging are: excavation, transport of dredged material, and disposal or reuse of dredged material.

Every year, U.S. ports dredge approximately 400 million cubic yards of material. Dredged material is used to create land for land reclamation, to create or restore wetlands, and for beach replenishment to help prevent erosion and flooding. The beneficial reuse of dredged material, if free from contamination, should be promoted.

Distribution of cargo from ports using highway or rail networks can have effects on air quality, noise levels, water quality, and impact adjacent communities. Improved and expanded port volumes will intensify these impacts unless mitigated.

Future Direction

1. Technological Innovations/Intelligent Transportation Systems

Over the next 50 years, the nation's transportation strategies will be characterized by policies that manage congestion rather than simply add capacity. These policies will be enabled by ITS, which is the multimodaly integrated application of modern technologies and management strategies in surface transportation systems.

ITS will allow smarter vehicles to interface directly with smarter infrastructure—often referred to as vehicle infrastructure integration. Current design standards are limited by human factors (e.g., stopping sight distance, decision sight distance, weaving lengths, etc.). The greatest potential for improvement in transportation system efficiency is through automation and development of more sophisticated vehicle and infrastructure technology and in providing real-time information to the traveling public to allow mode and route changes before and during a trip. ITS technology would enable more efficient use of existing multimodal transportation facilities by allowing vehicles to travel at higher speeds with shorter headways with the opportunity for better mode choice decisions.

Under this scenario, many driver actions (e.g., navigation, accelerating, braking, weaving, etc.) would be performed more efficiently by the vehicle itself, assisted by roadside sensors. The roadway would be designed to communicate pavement and traffic conditions to the vehicle's on-board sensors. The driver's current duties would be largely taken over by this on-board guidance and control system. Vehicles would be able to stay on course while traveling at higher speeds.

Dramatic changes to current design standards may be possible as ITS applications advance over the next 50 years. Increased navigational and mode choice reliability would benefit the environment by reducing the need for shoulders, wide medians, roadside clear zones and minimizing single occupant vehicles. Shifting control to the on-board guidance and control system would eliminate the need for long sight distances required to safely negotiate horizontal and vertical curves.

The vehicles operated on the roadway are assumed to be rubber-tired, driver-operated vehicles powered by an onboard motor (fossil fuel or electric) with an onboard energy storage system (fuel tank or battery). The only exception is electric buses operated on public roads by drawing power from an overhead catenary.

2. Context Sensitive Solutions

An approach using, or based on, CSS is among the most significant concepts to emerge in highway project planning, design, and construction in recent years (TRB 2002, Page 2). CSS allows for the flexible application of design standards so that transportation facilities can better fit within the context of the surrounding land use, community and environment. The FHWA defines CSS as:

> *"a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic and environmental resources, while maintaining safety and mobility. CSS is an approach that considers the total context within which a transportation improvement project will exist. CSS principles include the employment of early, continuous and meaningful*

involvement of the public and all stakeholders throughout the project development process."

In CSS, one of the most important decisions made is the selection of the design controls at the beginning of a project. Design controls are physical and operational characteristics that guide the selection of design standards. Some design controls are fixed (e.g., terrain, climate and some driver performance characteristics), but many controls can be influenced through design. Design speed selection has a significant influence on design standards. NCHRP presents an example of the importance of selecting a reasonable design speed:

Selection of the initial design speed produced significantly greater requirements for longer vertical curves, and hence greater earthwork and right-of-way impacts. The resulting design was viewed as being overly impacting on the surrounding terrain. Moreover, the existing safety performance of the roadway did not indicate a problem related to the vertical alignment or sight distance. As a result, CTDOT revised the design, selecting a lower design speed, which produced an alignment considered to be substantively safe, with fewer environmental impacts and lesser cost (TRB 2002).

An FHWA/AASHTO International Scanning Tour to view European Context Sensitive Design demonstrated the community, environmental and safety benefits of careful consideration of design speed. In towns and developing areas, traffic calming, which includes treatments such as speed humps, diverters, chicanes, and road narrowing, can reduce the social impact of a transportation facility (TRB 2002).

Due to the static, safety-based nature of AASHTO and other design standards, the flexibility of the CSS approach appears to have potential to reduce environmental impacts. A CSS approach can substantially minimize environmental impacts on a project-by-project basis. Because CSS is a nascent and subjective strategy, few quantitative analyses on its efficacy exist. Case studies attest to the success of the approach *(FHWA Flexibility in Design, Part III: Case Studies and CSS website, www.contextsensitivesolutions.org).*

3. Project Delivery

Infrastructure project delivery has traditionally been led by public entities. By integrating privatization into project delivery, market economics would dictate the design standards and facilities would be optimized. This could result in environmental mitigation if such mitigation is incorporated into the concession agreement for the project.

Technological advances in materials and construction practices continue to evolve. Further research, with an emphasis on sustainable materials and construction practices to extend facility life and minimize maintenance, should be performed. Programs such as Highways for Life should be further investigated as a means to mitigate environmental impacts.

4. Systems-level Perspective

Environmental science literature increasingly advocates a systems-level perspective on environmental impact assessment. Ecosystem health, watershed effects, regional air quality, environmental justice, habitat preservation, and public health effects are best evaluated at a system level. A recent TRB survey of state and MPO officials asked which environmental factors would most likely be more important 10 years from now in connection to transportation planning. Both DOT and MPO officials identified factors best handled at a scale of analysis much greater than the project level (e.g., energy, water quality, farmland conversion). Therefore, when considering changes to design standards to mitigate one environmental impact, the overall effect of the change should be evaluated at a systems level (TRB 2005).

Isolated analyses can also miss tradeoffs often inherent in environmental mitigation strategies (e.g., a new bypass reduces air pollution associated with traffic congestion, but creates wetland and habitat loss). Changes to design standards must consider potential tradeoffs between a mitigated impact and other environmental resources. Cost-benefit analysis is one method for weighing environmental tradeoffs; one drawback is the absence of widely-accepted monetary values for many environmental resources.

Stormwater and design standards are regulated at state and local levels; national design standards for stormwater management do not exist. The development of national or regional minimum design standards for transportation projects has the potential to mitigate environmental impacts for those states and local areas that do not have standards.

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CONSOLIDATED COMMENTS FROM MEMBERS OF THE BLUE RIBBON PANEL OF TRANSPORTATION EXPERTS - PAPER 4J-05

One reviewer commented as follows:

Sustainable infrastructure design and planning has recently received much attention by both practitioners and researchers. Past research has concluded that ITS applications, context sensitive design solutions and advanced transportation materials can be promising practices to mitigate environmental impacts. The efficacy of privatization into project delivery for environmental mitigation is yet to be tested. Environmental justice requirements are also to be considered to ensure that low-income and minority populations are not subject to disproportionately high and adverse environmental impacts. There are opportunities to incorporate sustainability aspects in infrastructure design standards. Many of the existing standards were adopted several decades ago, long before sustainable and environmental concerns were well understood.