AUTHOR: **Ms. Ellen Greenberg**

Co-author: **Dr. Susan Handy**

Presenter: **Susan Handy**

Title of Paper **Sustainable Street Design**

Sustainable Transportation Center
University of California Davis
1 Shields Avenue
Davis, CA 95616
(530) 752-5878
slhandy@ucdavis.edu

Concerns over sustainability and climate change have spurred local governments to create new practices that promote sustainability in street design. This paper reports on the results of the Sustainable Streets Project, which set out to document and assess the emerging practice of sustainable street design in the U.S. We define sustainable streets as encompassing three themes: movement, ecology, and community. A search for sustainable street examples in the U.S. yielded 50 examples, for which available documentation was collected and compiled. Our analysis of this database shows that few of these examples comprehensively address all three sustainable street themes, though they illustrate many different ways that local agencies are incorporating multiple objectives into street design. We identify four categories of projects: *Neighborhood Plus,* involving new and redesigned neighborhoods that seek to foster community values, reduce transportation impacts, and preserve natural resources; *Downtown Revitalization Plus,* for projects in older communities that are using street design as a tool to spur economic activity and support compact and infill development downtown; *Stormwater Plus***,** including projects designed with implementation of stormwater management features as a primary design objective; and *Movement Plus,* for projects in which arterial streets are re-designed to meet sustainability goals ranging from improving bike parking to supporting high-density residential infill. Advancement of the practice of sustainable street design in the U.S. depends on an improved knowledge base, design innovation, and new planning tools. A comprehensive approach to sustainable streets can create harmony among the goals of community, the demand for mobility, and the mandate for environmental stewardship.

Introduction

For decades, the practice of street design in the United States has been in a state of transition, as professionals and community leaders have struggled to achieve harmony between societal demands for ever-increasing mobility on the one hand, and the goals of community on the other. The practice of Context Sensitive Solutions emerged in the late 1990s as a framework for meaningful integration of community concerns into roadway design. It is now the dominant framework for innovative design, though critics say it is too narrowly focused on protecting historic and scenic resources as required by state and federal environmental laws (Greenberg and Dock, 2003).

Now, the practice of street design in the United States is under further pressure as sustainability and climate change surge to the top of public policy agendas. This pressure has already spurred local governments to create new initiatives to promote sustainability in street design. Efforts have been documented in publications such as Portland Metropolitan Council's *Green Streets* (2003), New York City's *High Performance Infrastructure Guidelines* (2005), and the City of Chicago's *Green Alleys Handbook* (2007). In the Sustainable Streets Project, sponsored by the Sustainable Transportation Center at the University of California Davis, we set out to document and assess the emerging practice of sustainable street design in the U.S. This paper reports on our results.

Definitions and Concepts

We propose the following definition for sustainable streets:

> Sustainable Streets are multimodal rights of way designed and operated to create benefits relating to *mobility*, *ecology*, and *community* that together support a broad sustainability agenda embracing the three E's of environment, ecology, and economy.

This definition establishes a straightforward framework for design professionals, decision makers, and members of the public that can be used as a basis for selecting objectives and design features as well as for policy making, priority setting, and evaluation (see examples in Table 1). Each of the three themes can be broadly defined and may be tailored to reflect local priorities. For example, the Washington D.C. (2008) "Great Streets" program, rooted in economic development goals for distressed arterial corridors, addresses all three sustainable streets themes with the following five principles (notes in italics added):

- Care: Work together to build inclusive communities (*community*)
- Energize: Strengthen businesses and other local service (*community*)
- Refresh: Work with natural systems (*ecology*)
- Move: Choice in how to travel (*movement)*
- Distinguish: safe, vibrant places that reflect local character (*community*)

Table 1: Sustainability Objectives and Features from Sustainable Streets Survey Results

Movement	
Objectives	**Features**
Increased pedestrian activity	Highly connected multimodal network
Reduced VMT through increased transit and non-motorized mode share and shorter average trip length	Supporting land use pattern with diverse activity in close proximity and connected by multimodal system
Increased transit use	Vehicle speeds compatible with context, community objectives, and energy efficient operations
High level of overall accessibility	Facilities for transit services, safe and convenient bicycling and walking
Increased bicycle use	Mid-block pedestrian paths

Ecology	
Objectives	**Features**
Improved Air Quality	Tree Preservation; newly planted trees
Water conservation; Improved Water Quality; compliance with NPDES permitting requirements	Biofiltration (variety of features)
Enhanced ecological health and productivity	Permeable paving
Mitigated urban heat island effect	Use of energy-efficient traffic signals and lighting
Efficient use of energy and resources overall	Preserved natural features and processes
Reduced greenhouse gas emissions	Use of dark-sky lighting

Community	
Objectives	**Features**
Placemaking: identity, distinction and beauty through natural and built features	Public gathering places, parks, outdoor dining
Support for compact and infill development	Narrowed carriageway width; "road diets" reducing number of travel lanes
Local priorities, traditions and resources reflected in design	"Shared streets" and "festival streets" designed for community events
Achieve positive public health outcomes: physical activity, safety, noise exposure	Custom lighting, furnishings reflecting local design traditions
Promote sociability and community life	Access to adjoining properties
Create value for adjoining properties	Landscaping with native plants
Reduced travel-related injuries and fatalities	Improved aesthetic environment

All three themes operate at several levels. As illustrated in the above example, the community theme encompasses equity, economic development, safety, and vibrancy. The ecology theme encompasses the resource value of landscape and natural elements within the right of way but also the impacts on the ecological processes of the movement system, including the air, water and climate impacts of motor vehicle emissions. The final theme addresses the movement of people and goods by all on-street modes and for all trip purposes in the context of a circulation network. If directed toward shifting movement from automobiles to lower impact modes like transit, walking, and biking, street design can support both movement and ecological objectives.

Planning and design professionals have many opportunities to pursue sustainability objectives, as do those responsible for the management and operation of the transportation system. In new developments, professionals can influence network configuration and roadway alignment, while those working in older cities and towns may instead focus on operating an established system. These varied opportunities can be thought of as phases in the street's life cycle, from the earliest planning stages through design, construction, operations, maintenance, repair, and restoration. Each phase offers opportunities for strategies designed to contribute to sustainability goals.

The mechanisms by which streets can contribute to sustainability objectives are straightforward in some cases and highly complex in others. For example, installation of pervious paving offers direct and reliable ecological benefits by increasing on-site percolation, thereby reducing urban runoff. This predictability contrasts with the more complex and less reliable chain of events required to shift movement from automobiles to lower impact modes and produce benefits relating to carbon emissions, energy savings, and air and water quality. In this case, benefits are contingent on a specific behavioral response. For this reason and others, sustainable street design should be implemented as one component of an integrated and comprehensive sustainability program.

Survey of Sustainable Street Practice

During the second half of 2007 and the first quarter of 2008, the Sustainable Streets Project solicited examples of sustainable streets from engineering and design professionals in the public and private sectors across the U.S. The objectives were to document specific projects and to gain an understanding of how local agencies are applying the concepts of sustainability to street design, including the allocation of right-of-way to different functions, specific design features, and network considerations. The responses yielded approximately 50 examples, for which available documentation was collected and compiled. We analyzed this database to identify overall patterns and important examples of sustainable street practice.

The state of the practice is clearly in transition, though in the early stages. Many localities are in planning and design phases of sustainable streets, a small number has pilot projects underway, and an even smaller number is actively working to change their standards so that sustainable streets will become standard practice in their agencies.

Nationally, a small number of "early adopters" are incorporating very innovative work in numerous projects. Chicago, Seattle, and Portland stand out. In addition to projects, early-adopting agencies are incorporating sustainable street elements into design guidance, codes, and regulations.

Few projects identified in our search incorporated all three themes – community, ecology, and movement – and most reflected just one or two. Most common were stormwater management projects, usually including landscaping for bioretention/biofiltration and pervious paving. These and associated techniques appear to be the most clearly understood by practitioners as contributing to sustainability goals. Some projects had no identifiable movement objectives, with no changes to design features supporting movement, and projects emphasizing bicycle, pedestrian, and transit facilities appear to be under-represented. Overall, the projects challenge the traditional assumption that vehicle movement should determine street design.

Given the lack of projects incorporating all three themes, we organized projects according to their principle objectives into four categories: Neighborhood Plus, Revitalization Plus, Stormwater Plus, and Movement Plus. We present selected examples here to illustrate the state of sustainable street practice in the U.S.

Neighborhood Plus

Two projects at the neighborhood scale illustrate the use of different features to achieve a variety of objectives. Each was designed and implemented to emphasize multiple objectives, from a tripling of density on an infill site at Garrison Woods in Calgary, Alberta, to a comprehensive approach to sustainability at New Columbia in Portland, Oregon. In each of these neighborhood scale projects, the street plan is one part of a broader approach to achieving the development program.

In Garrison Woods, Calgary Alberta, a 165-acre former army base is reused for compact residential and mixed-use development. The development has an urban character and is within the inner ring suburbs around Calgary's downtown. Key aspects of the plan are increased residential density and street connectivity, and customized design of all streets. The more highly-connected network supports an increase in the total dwelling unit count onsite from 600 to 1,800 units.

With perhaps the most diversified set of sustainability features of any project in the sample, New Columbia integrates street network connectivity, stormwater management best practices, and tree preservation into a mixed-use, mixed-income redevelopment project. The project, initiated by the Housing Authority of Portland, Oregon (HAP), transformed an 82-acre public housing site into a mixed-use, mixed-income community. The street plan was intended to help facilitate the social and economic integration of the site into the greater community as well as to maximize connectivity, encourage sociability and community by creating a "safe" place for pedestrians and cyclists, and effectively managing stormwater on-site. Inclusion of space for small scale retail businesses as well as a school and other public services, a central park with community

garden and basketball courts, with bus routes through the neighborhood all support conditions for short trips and a high level of non SOV use, which is supported by the project's location close to downtown Portland's job, shopping and cultural destinations.

Downtown Revitalization Plus

The revitalization projects focused on Smart Growth principles, in particular, facilitating successful infill development. Each treats street design as a key element of intensification and creation of walkable urbanism. Movement and community objectives are thus central to these projects, while the inclusion of ecological function in the right of way is a secondary consideration – or not a consideration at all. However, if the projects are successful in their aims to reduce vehicle miles traveled on a per capita basis, they will have indirect ecological benefits.

Supporting compact development and re-use of land while revitalizing the downtown was the overarching objective of a major civic effort in Chattanooga, Tennessee. In Chattanooga's Riverfront Parkway and Downtown Streets project, a five-lane limited access highway was narrowed to a two-lane surface street with an adjoining riverfront esplanade and realigned to create sites for new housing. On-street parking and crosswalks were added, travel lanes narrowed and posted speed lowered for a new emphasis on livability rather than accommodating through travel movement. These improvements are among those included in an ambitious strategy to attract investment to downtown Chattanooga.

Across the U.S., many economic revitalization programs, particularly in smaller cities and towns, focus on the redesign of traditional Main Streets to create improved settings for commerce and public gathering. East of San Francisco Bay, the Livermore, California example includes a dramatic "Main Street" design along First Street, the downtown spine. The street was redesigned as a community centerpiece intended to stimulate investment, business activity, and the community life. The project includes reducing four vehicle through-lanes to two, creating "flexible zones" that can accommodate either angled parking or outdoor dining as needed by revitalizing businesses, and using pedestrian paving and locating new street trees and architectural trellises in the "flexible zones" to shrink the perceived car territory.

Stormwater Plus

The largest category of projects involved best management practices (BMPs) for stormwater. The National Pollution Discharge Elimination System Municipal Separate Storm Sewer System (NPDES MS4) permitting program is a key driver of municipal stormwater management activity in the U.S. Most of these projects are on facilities where travel volumes are low and space in the public way could be allocated to ecological functions without changing the movement features of the street. A number of projects are modest in scope but useful for testing new designs and for community education. More ambitious projects, such as New Columbia in Portland, illustrate use of an extensive palette of stormwater management techniques at the neighborhood scale.

A dramatic example of an integrated approach to Sustainable Streets is being undertaken as part of a redevelopment project in the Denny Triangle neighborhood of Seattle. Taylor 28 is an urban infill project in which green building is integrated with re-design of the street with stormwater features and public gathering space. Stormwater management features are designed to result in zero-discharge during a 25-year storm event within the plaza street zone.

Movement Plus: Projects on Arterial Streets

Arterial streets pose a particular challenge to reconciling the three themes of sustainable streets. Essential movement functions are served with long-distance capacity and connectivity. However, high volumes often make re-allocating space to either community or ecological functions a difficult proposition. The adjoining roadside typically is the place most strongly affected by the negative impacts of vehicle noise and emissions, which can discourage pedestrians and make adjoining properties difficult to design and develop. In the worst cases, arterials lack even continuous sidewalks that provide basic pedestrian safety.

Sustainable Street projects on arterials can be classified into two types. The first are arterial designs that are essentially remedial. These focus on safety and access for pedestrians and bicyclists, access management, and aesthetics. In the case of Aurora Boulevard in Shoreline, Washington, stormwater management was also integrated into the design. These projects result in a facility that safely accommodates multiple modes, including walking and bicycling, along a high volume route. They are not directly associated with changes to land use or development policy, however, and their near-term impact on walking and bicycling is likely to be limited by dominant land use patterns that are characterized by low densities, long distances between trip origins and destinations, and auto-oriented design. Examples include Sandy Boulevard in Portland Oregon, Aurora Avenue, and East Market Street in Greensboro North Carolina.

The second category comprises more comprehensive arterial projects that use street design as one element in efforts to both improve the corridor right of way and support revitalization of adjoining properties or districts. Chattanooga's Riverfront Parkway, discussed above, is one such example. In this project, street changes are seen as setting the stage for desired land use changes. In contrast, the re-design of Pacific Boulevard in the False Creek neighborhood of Vancouver, British Columbia, follows the creation of a very high-density residential district. This project, underway in 2008, is intended to activate and "green" the street while improving conditions for transit, bicyclists, and walkers. Numerous sustainability features are explicitly identified by the project's designers: supports pedestrian activity, bicycling, and transit; supports compact residential development; reduces heat island effect and contributes to the city's urban forest; and promotes stormwater infiltration through the creation of a completely permeable center median.

Discussion

The concept and practice of sustainable streets are both evolving. To support development, implementation, and ultimate success in advancing sustainability objectives, progress is needed in three areas: (1) An expanded knowledge base, (2) An improved palette of design techniques, and (3) New planning tools that support sustainable streets in practice.

Knowledge Base

The most significant need is for data on the effectiveness of specific techniques in all areas of sustainable street design and operations. A robust knowledge base will be multidisciplinary, addressing topics as diverse as the long-term performance of pervious pavement materials and the impact on real estate values of streetscape improvements. Understandably, public agency personnel are particularly interested in having available data on implementation cost, maintenance requirements, and performance over time with respect to the full range of sustainability outcomes as well as near term roadway operations and safety concern.

A subject of particular importance, as well as complexity, is the role of the street in transportation performance as measured through the lens of sustainability. Metrics of particular interest include modal split, vehicle miles traveled, vehicle trips, and vehicle delay. Ample research shows that, on a per capita basis, compact communities produce lower levels of vehicle miles traveled and vehicle trips. Less well understood are the contributions of street design to these positive travel performance characteristics, particularly with respect to increasing the use of modes other than single-occupant vehicles. With public agencies promoting street design aimed toward a wide range of objectives, evidence of the effectiveness of these strategies as well as their impact on traffic operations and safety is needed.

Design Innovation

New objectives for streets are stimulating design innovation. These innovations, in turn, will require testing over time for their performance and cost characteristics. Where designs change existing roadway characteristics, safety and operational impacts will be of particular importance.

Innovation in street design is particularly challenging because of reliance in U.S. practice on design guidance published by a small number organizations (notably the Federal Highway Administration, the American Association of State Highway and Transportation Officials (AASHTO), and the Institute of Transportation Engineers) that have wide influence on standards adopted by state departments of transportation and local governments. All three entities are encouraging creativity by supporting flexibility in the application of design guidance and expanded application of the context sensitive solutions approach, and practitioners are beginning to take advantage of this flexibility.

The sustainable streets projects reviewed illustrate a number of innovative design elements. Some, such as the use of a single 10-14 foot wide traffic lane on local streets, are relatively well established (NAHB, et al. 2001). Others, such as the use in Vancouver of a multi-way boulevard cross section, have only limited recognition in professional design guidance (see, for example, Institute of Transportation Engineers 2006). The techniques in use are based on the experience, judgment, and creativity of the sponsoring agencies and designers. The utility of these designs for meeting objectives relating to movement, community, and safety needs to be investigated, and safety and performance characteristics documented.

New Planning Tools

Using street design to advance a wide range of sustainability goals represents a sea change. Mainstreaming this concept into the practice of street design and management will require a shift from the ad hoc practices seen in the Sustainable Streets Project to more consistent and systematic efforts. Basic planning tools such as the traditional street classification system must evolve in order to support this change. Because of its use as a guide to funding, design, operations, and communication of policy intent, functional classification is a particularly rich area for innovation. In the context of comprehensive planning activities, localities such as Denver and Seattle have expanded a standard classification framework to consider facility speed and access to adjoining parcels. These new systems use land use or community character type as a basis for classifying streets.

A functional classification system for sustainable streets should identify the role of the individual facility within the circulation network as well as the functional emphasis for facilities with particular characteristics and/or in particular contexts. For example, community features are likely to be a top priority for busy downtown streets; high-volume, highly connected streets would have a through movement focus; local residential streets might provide opportunity for equal attention to (slow) movement, ecological functionality, and establishing a positive setting for social activity. A new classification system should also establish baseline standards for each of the three sustainability functions. For example, ecology standards might be set for on-site filtration, use of recycled materials, and energy efficient lighting. This system should used as a tool for funding, design, implementation and management of the street.

Conclusion

Sustainable street practice must go further than basic principles of sustainable design by responding to the unique role of public streets in networks that shape human settlement and movement patterns. A comprehensive approach to sustainable streets offers an opportunity to transform the public rights of way in our cities and towns so as to create harmony among the goals of community, the demand for mobility, and the mandate for environmental stewardship. Pioneering public agencies are already pointing the way to a new practice that embraces these aims.

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