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Report #3 in the Series:
Moving Communities Forward

Enhancing Environment and Health in Transportation Project Design

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Good transportation design that enhances communities results in positive impacts on the natural environment—the air, water, soil, and biodiversity that are the life support systems for human society on earth. Design of outdoor and indoor environments can also positively influence human health. The issues related to environment and health fall under the concept of sustainability.

This research includes a review of environmental assessment methods, rating systems and guidelines that are currently being used to transform sustainable building practices in the United States. In addition, there is an examination of case studies of exemplary transportation projects demonstrating the benefits of sustainable design approaches. The research includes case studies at three scales—large-scale development, buildings, and infrastructure—and identifies the lessons learned from these projects.

While environmental sustainability issues are not new in transportation projects, there is a new and growing recognition that problems are more extensive and more urgent than previously recognized and that there must be a deeper understanding of the connection between planning, design, and construction decisions, as well as their resulting impacts. Transportation design can and should address regional and community scale ecological issues. Effective practices include applying an integrated design approach, making environmental outcomes explicit in the design process, and measuring performance outcomes during the life of the project. An emerging set of sustainable guidelines and standards can be effective tools for setting goals and organizing the design process for well-designed transportation projects.

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Enhancing Environment and Health in Transportation Project Design

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Final Report

Prepared by:

John Carmody
Virajita Singh

Department of Landscape Architecture
University of Minnesota

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University of Minnesota
200 Transportation and Safety Building
511 Washington Ave. SE
Minneapolis, MN 55455

Preface

Well-designed transportation projects demonstrate the potential to shape a community in ways that go far beyond the project's original purposes. Anecdotal evidence and advocacy exist on behalf of the benefits of well-designed transportation projects on communities, yet there is little organized quantifiable or qualitative data, nor is there a comprehensive guide for communities to maximize or integrate the diverse benefits that well-designed transportation projects can bring.

Recognizing this lack of data about the role of design in transportation, Congress authorized a study in Section 1925 of the 2005 Safe, Accountable, Flexible, Efficient, Transportation Equity Act: A Legacy for Users (SAFETEA-LU) to achieve two goals: (1) begin to measure how well-designed transportation projects can bring multiple enhancements to communities in terms of economic development, health and the environment, visual identity and design, public participation, and public safety; and (2) provide communities, designers, transportation officials, and policymakers a set of principles and practices to adapt to their unique situations and needs.

The *Moving Communities Forward* research team employed a case study-based approach, analyzing nearly 30 transportation projects that represent a broad spectrum of regions, demographics, and project types. The research team identified key principles and practices that designers and others can use—in the context of their unique situation and environment—to realize multiple enhancements to their communities.

Funding for the study was derived from a grant to the American Institute of Architects (AIA) from the Federal Highway Administration (FHWA), authorized by Congress in SAFETEA-LU. In 2006, the AIA selected the Center for Transportation Studies (CTS) at the University of Minnesota to conduct the pioneering research study.

To address the interdisciplinary issues raised by the study, CTS assembled a research team drawn from multiple fields. Research was allocated to five research projects; a sixth project synthesized the study's key findings into a single document highlighting major themes and recommendations:

1. Promoting Economic Development
2. Improving Health and the Environment
3. Designing Great Places
4. Fostering Civic Participation
5. Making Communities Safer
6. Study Synthesis

Results of this research are available in a series of reports on the *Moving Communities Forward* Web site: www.movingcommunitiesforward.org. The site also includes a summary report submitted by the FHWA to Congress in September 2007. The Web site is part of a coordinated outreach effort designed to share the research findings and recommended practices with transportation and design professionals, policymakers, and the public.

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Report Design
PAM DEL CANTO
GRETCHEN MAXWELL

CENTER FOR TRANSPORTATION STUDIES UNIVERSITY OF MINNESOTA

ROBERT JOHNS
Director, Center for Transportation Studies

LANCE M. NECKAR
Professor, Landscape Architecture, CTS Faculty Scholar/Fellow, University Institute on the Environment

Research Team

Economic
JOHN S. ADAMS (Principal Investigator)
Professor, Geography/CTS Faculty Scholar/Co-Director, University Metropolitan Consortium

BARBARA J. VANDRASEK (Co-Investigator), Research Associate, University Metropolitan Consortium/CTS Scholar

Health and the Environment
JOHN CARMODY (Principal Investigator)
Director, Center For Sustainable Building Research

VIRAJITA SINGH, Senior Research Fellow, Center For Sustainable Building Research

CHRIS PETIT, Research Assistant, Center for Sustainable Building Research

Visual Design
ANN FORSYTH (Principal Investigator)
Professor, Architecture/Director, Metropolitan Design Center/CTS Faculty Scholar

JUSTIN JACOBSON, Research Assistant
KATIE THERING, Research Fellow, Metropolitan Design Center

Public Participation
CARISSA SCHIVELY (Principal Investigator)
Assistant Professor, Urban And Regional Planning, Humphrey Institute Of Public Affairs/CTS Faculty Scholar

MEAGAN BEEKMAN, Research Assistant

CYNTHIA CARLSON, Research Assistant

JENN REED, Research Assistant

Public Safety
GARY A. DAVIS (Principal Investigator)
Professor, Civil Engineering/CTS Faculty Scholar

Staff
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The American Institute of Architects (www.aia.org) is the voice of the architectural profession and the resource for its members in service to society. As AIA members, more than 80,000 licensed architects in over 300 state and local chapters express their commitment to excellence in design and livability in our nation's buildings and communities. Members adhere to a code of ethics and professional conduct that assures the client, the public, and colleagues of an AIA-member architect's dedication to the highest standards in professional practice.

ABOUT THE CENTER FOR TRANSPORTATION STUDIES

The Center for Transportation Studies' (www.cts.umn.edu) mission is to serve as a catalyst for transportation innovation through research, education, and outreach. CTS works with University of Minnesota faculty in over 25 disciplines to advance knowledge in a variety of transportation-related research areas. In 1997, CTS first became involved with transportation and urban design issues in its leadership of a major interdisciplinary effort, the Transportation and Regional Growth Study, which produced new understandings of the relationship between transportation and growth in the Twin Cities area. CTS has also worked closely with the Minnesota Department of Transportation and local governments in advancing Context Sensitive Design/Solutions practices through the development of training courses and web resources, which have helped Minnesota to be recognized by FHWA and AASHTO as a leading state in applying Context Sensitive Design/Solutions.

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Michelle Holland, Woodrow Wilson Bridge Project
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Mickey Thomason, DEP Office of Greenways & Trails
Marriano Berrios, Florida Dept. of Transportation
Carol Sheppard, DEP Office of Greenways & Trails

Enhancing Environment and Health in Transportation Project Design

Table of Contents

Executive Summary

Good transportation design that enhances communities includes positive impacts on the environment—the air, water, soil, and biodiversity that are the life-support systems for human society—and on the health of people affected by physical and psychological aspects of both outdoor and indoor environments.

Recent years have seen a dramatic increase in interest in the concept of sustainable development, defined by the 1987 United Nations' Brundtland report as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Today there is recognition that sustainability is not just about the environment and natural resources, but instead represents a balance between environment, economics and equity.

Because two of the largest emitters of carbon into the atmosphere are the built environment (approximately 48% in the U.S.) and the transportation sector (27%), the design of transportation systems not only results in environmental impacts from the projects themselves but from the transportation patterns that are established by development (Architecture2030, 2007). Much of the focus of sustainable design activity in the recent past has been on individual buildings. But the design community is paying increasing attention to sustainability at the infrastructure, development and community scales.

Environmental issues are not new in transportation projects. Transit-oriented development, smart growth, and context sensitive design embody many of the principles of sustainable development. What is new, however, is the growing recognition that problems are more extensive and more urgent than previously recognized. Design professionals and the scientific community believe that there must be a deeper understanding of the connection between planning, design and construction decisions and the resulting impacts. Well-designed transportation projects in the future must include a major change in design practices in response to these issues.

Conducting research on the environmental benefits of transportation projects on their communities presents several challenges, not the least of which is the fact that the field of sustainable development is constantly evolving. The key questions are:

- What are the critical outcomes to be measured?
- What are appropriate strategies to achieve those outcomes?
- What is an effective process to ensure and measure success?

Three categories of transportation projects addressed in this study are development (community) scale, building (facility) scale, and infrastructure scale. The report reviews state-of-the-art environmental assessment methods, rating systems and guidelines as well as case studies at each of the three scales.

Development Scale

By changing transportation use and patterns at the city or development scale, there are impacts on vehicle miles driven and associated energy use and emissions from cars including greenhouse gasses. For example, according to a recent Caltrans study, transit-oriented development can reduce rates of greenhouse gas emissions by 2.5 to 3.7 tons per year for each household (CALTRANS, 2002). Community scale design can facilitate greater densities and mixed use development patterns which support more effficient mass transit systems. In addition, regional and community scale ecology (soil, stormwater, biodiversity) are affected at the development scale. There are also potential reductions in congestion and time spent commuting, and safety can be enhanced by reducing the number of vehicles on the road. Green development guidelines are emerging nationally as well as regionally.

Building Scale

At the scale of individual buildings or facilities, sustainable design principles can have impacts on site ecology (soil, stormwater, biodiversity, heat island and light pollution); water consumption, treatment and management; operating energy and embodied material impacts (energy, global warming, air quality, water quality, resource depletion, and waste); and health within facilities. In individual transportation facilities, owners and designers are beginning to consciously address sustainable design issues by applying national and regional rating systems to transit facilities.

A separate set of voluntary environmental assessment and rating systems have been developed for the housing sector. National green residential building guidelines and standards are emerging. In addition, there are numerous well-established local and regional green building programs. Separate guidelines have been developed in the affordable housing sector.

Infrastructure Scale

Infrastructure projects such as roads and bridges include impacts on site ecology (soil, stormwater, biodiversity, heat island effects and light pollution). Some infrastructure projects include energy and water use impacts. In addition, life cycle assessment can be applied to embodied material impacts (energy, global warming, air quality, water quality, resource depletion, and waste). Guidelines on sustainable infrastructure are emerging in local areas. Infrastructure projects such as roads incorporate context sensitive design but do not consistently address overall life cycle impacts of the construction. Newly emerging road ecology design principles are changing practice by focusing on the impact of transportation infrastructure on biodiversity. Road ecology experts say the approximately 3.9 million miles of public roads that criss-cross the United States impact animals in at least three ways: road kill, habitat loss, and habitat fragmentation.

Case Studies

Three areas have been identified for the case studies in this report: sustainable development, sustainable buildings and sustainable infrastructure. Sustainable development is illustrated by two case studies of transit-oriented development: Prairie Crossing and Highlands' Garden Village. Sustainable building is illustrated by two case studies: The Rapid Surface Transportation Center and the Pentagon Metro Transit Entrance Facility. Sustainable infrastructure is illustrated by the Woodrow Wilson Bridge Project and the Marjorie Harris Carr Cross Florida Greenway Land Bridge. The case studies are intended to demonstrate a range of work in the transportation area addressing a diversity of scales and types as well as approaches to application of sustainable design principles.

The Future

While there is significant progress, emerging guidelines and standards, and good examples of design process and finished projects, the urgency and magnitude of current environmental issues requires more action.

Environmental assessment methods, rating systems and guidelines have played an important role in advancing sustainable development and building design in the United States. Generally, these methods and tools include prescriptive best practices, performance standards, and processes that enhance or ensure compliance and improved outcomes. The drawback of rating systems is that they combine these different types of measures into a point-based rating as a surrogate for actual performance. Wherever possible, actual outcomes should be determined, but this information is not tracked consistently.

There is a knowledge gap between what designers want to know and what current tools can tell them about performance outcomes. While all of the case studies include some performance outcome calculation

and monitoring, they are not complete. Effective life cycle cost (LCC) and life cycle assessment (LCA) tools are needed as well as more comprehensive tools such as an "environmental balance sheet." As better tools are being developed, a better understanding of critical outcomes and the appropriate metrics will continue to come into focus.

Following guidelines and standards does not necessarily result in the predicted performance. An important element in transforming the built environment to be more sustainable is the creation of feedback loops that occur through monitoring project performance and conducting post occupancy evaluations. The resulting information needs to be collected and maintained in common publicly accessible knowledge bases that can inform not only the specific building owners, operators and occupants, but that also inform the design professions and the public.

Principles and Practices

The guideline review and case studies revealed key principles and practices to enhance environmental and health outcomes that can be applied to transportation projects at all scales.

1. ***Address sustainability throughout project design***
   Transportation projects at all scales have substantial impacts on environmental problems such as global warming, destruction of ecosystems, and loss of biodiversity that need to be urgently addressed. There is a need for more comprehensive assessment of the impacts of transportation projects on natural systems. Projects should not only be designed to minimize environmental damage but be seen as opportunities for ecological restoration.

2. ***Apply elements of an effective design process to the project***
   Integrated design is an emerging practice critical to achieving sustainable design goals in transportation projects. Integrated design identifies a broader range of issues early in the process and addresses them with an interdisciplinary team approach. Critical elements of a successful process include establishing guiding principles, involving key stakeholders in a participatory planning process, and holding design charrettes.

3. ***Focus on performance outcomes during project design***
   To achieve sustainable goals, performance outcomes must be made explicit during design of transportation projects. Outcomes vary depending on the project scale, site and function. Existing tools and methods must be utilized and new ones developed to assist in the design process.

4. ***Measure performance outcomes during the life of the project***
   There is a critical need to measure outcomes during the operating life of a transportation project. This will also provide a feedback loop for continuous improvement within the project and collective information to the design professions.

5. ***Apply appropriate sustainable guidelines, rating systems, and standards to the project***
   Emerging practices such as the use of voluntary or required guidelines and standards are effective in helping identify goals, educating stakeholders, and establishing an integrated design process on transportation projects.

6. ***Use education to overcome barriers to sustainable design***
   Education through public engagement in the process as well as designs that make environmental features visible are helpful strategies to increase awareness of environmental impacts. Providing information about costs and actual benefits can also overcome resistance to accepting new ideas and technologies.

Overview

Good transportation design that enhances communities includes positive impacts on the environment. *Environment* in this context refers to the natural environment—air, water, soil, and biodiversity that are the life support systems for human society on Earth. An important related impact area is the health of human beings affected by physical and psychological aspects of both outdoor and indoor environments. Issues related to environment and health fall under the concept of sustainability. The definition of sustainable development as it is known today began in 1987 with the Brundtland report from the United Nations that stated, "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987).

Sustainable design today draws from many roots that date back to the energy and environmental concerns of the 1970s but is based on a more holistic and comprehensive vision. There is now recognition that sustainability is not just about the environment and natural resources, it represents a balance between environment, economics and equity. During the 1990s, the impact of the built environment on people and the natural environment became more evident and widely discussed in the design professions. The movement toward more ecological design principles is based on the growing understanding that conventional development practices are not sustainable. According to the Millennium Ecosystem Assessment, "Over the last 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber,

Figure 1. Station Square and Burnham Building at Prairie Crossing. Photo by Hedrich Blessing, courtesy of Prairie Holdings Corporation.

Figure 2. Canopy of The Rapid, Surface Transportation Center. Photo by Chuck Heiney, courtesy of Progressive AE.

and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth" (MEA, 2005). The worldwide impacts of climate change in particular have recently been documented in reports by the United Nations Intergovernmental Panel on Climate Change (IPCC). According to the IPCC Synthesis report, "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC, 2007).

According to the *Architecture 2030* initiative, the built environment is responsible for 48% of carbon (CO_2) emissions in the United States. The transportation sector is responsible for another 27% of carbon emissions. Recently, the American Institute of Architects endorsed the goals of *Architecture 2030*, which sets a target of zero carbon emissions from buildings by 2030 and requires emissions to be reduced by 60% by 2010 (*Architecture 2030*, 2007). It is well documented that the building sector uses large shares of the world's wood, minerals, water, and energy and generates a large portion of the waste going to landfills (Worldwatch, 1995).

Planning and design of the built environment not only results in environmental impacts from buildings themselves, but also impacts from the transportation patterns that are established by development. For example, according to a recent Caltrans study, transit-oriented development can reduce rates of greenhouse gas emissions by 2.5 to 3.7 tons per year for each household (CALTRANS, 2002).

Much of the focus of sustainable design activity in the recent past has been on individual buildings, however the same issues and impacts apply to infrastructure, developments and cities. Transportation projects occur at all of these scales. Of course, environmental issues are not new in transportation projects. Transit-oriented development and context sensitive design embody many of the principles of sustainable development. What is new, however, is the growing recognition that problems are more extensive and more urgent than previously recognized. There must be a deeper understanding of the connection between planning, design and construction decisions and the resulting impacts. Immediate action must be taken so that all transportation projects in the future must include a major change in design practices in response to these issues.

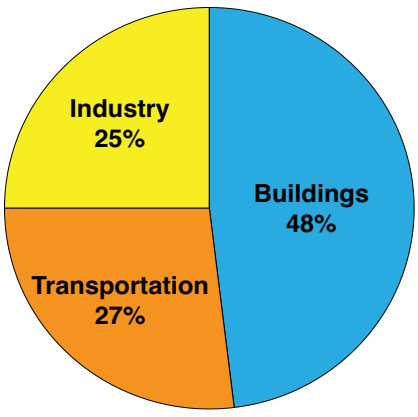


Figure 3. U.S. energy consumption by sector. Source: Architecture2030.

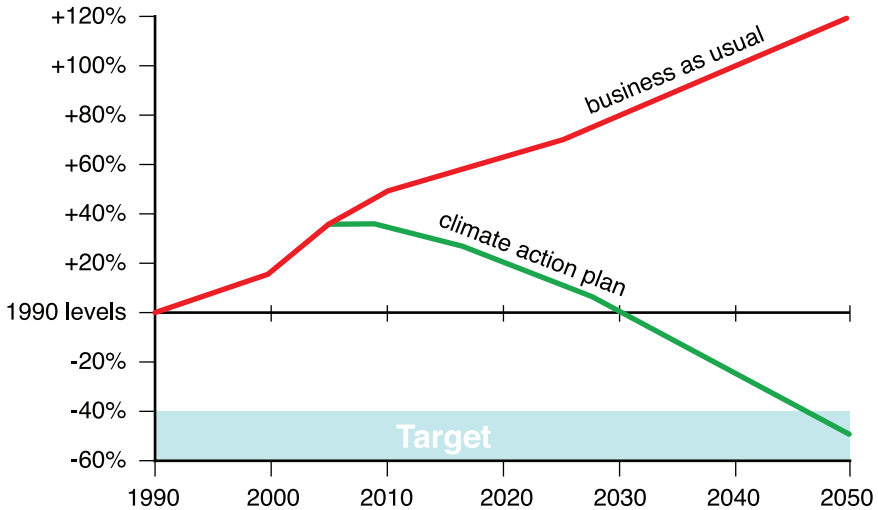


Figure 4. Building Sector CO_2 Emissions (assumes a 15% embodied energy reduction in the construction of new buildings). Source: Mazria Inc., 2005.

Research Approach

The overall purpose of this study is to identify the benefits of good design and best practices to achieve it. Conducting research related to designing for environmental issues in transportation projects presents several challenges. A vast range of issues must be addressed at varying scales in a rapidly emerging field. Three categories of transportation projects are addressed in the study: development (community) scale, building (facility) scale, and infrastructure scale. The key questions are:

- What are the critical outcomes to be measured?
- What are appropriate practices and strategies to achieve those outcomes?
- What is an effective process to ensure and measure success?

At this early stage in the evolution of sustainable design practice, it is important to identify emerging best practices and processes even if they are not thoroughly reflected in available case studies of transportation projects. The first part of the research consists of a review of state-of-the-art environmental assessment methods, rating systems and guidelines at each of the three scales. The second part of the research consists of selection and analysis of case studies in each of the three categories that illustrate a range of project types and approaches. At all three scales, sustainable design has been assessed through an inventory of best practices in areas that are not easily measured, through documentation of the process of sustainable design, and collection of outcome information where it exists.

The case studies provide an opportunity to evaluate the effectiveness of current sustainable design practices. Information on current practices was gathered from literature searches and discussions with experts in the field. Case study information was from literature, analysis of project documents, and interviews with project team members.

Figure 5. Praire Crossing, a sustainable, transit-oriented residential development. Photo by Vaughn Wascovich, courtesy of Prairie Holdings Corporation.

Figure 6. The Rapid, a sustainable transit facility. Photo by Chuck Heiney, courtesy of Progressive AE.

Figure 7. Marjorie Harris Carr Cross Florida Greenway, a model for infrastructure development. Photo by Sky Storms, courtesy of the Florida Department of Environmental Protection's Office of Greenways & Trails.

Environmental Assessment Methods, Rating Systems and Guidelines

Several approaches can be applied to accelerate the transformation into a more sustainable built environment. Stronger building codes and other required standards play a role along with tax and other incentives to building developers and owners. Beyond these formal mechanisms, building owners and design teams are motivated by the actual life cycle cost savings, recognition in the community, and the desire to do the right thing.

Environmental assessment systems, ratings systems, and guidelines have played an important role in raising public awareness and transforming the market for more sustainable building practices in the United States. These systems define criteria for sustainable building and may be used as the basis for establishing requirements or incentives. Voluntary, market-based guidelines may be viewed as a precursor to more formal changes to standards and codes.

A history of sustainable guidelines and rating systems is shown in Figure 8. This list includes the major national systems in the United States, Canada and the United Kingdom along with some of the more prominent regional and local examples. Most guidelines developed so far address the building scale and can be categorized into new commercial, existing commercial, and new residential buildings. Some emerging remodeling guidelines address the existing residential sector. Figure 8 also identifies four ANSI green building standards under development—three for new commercial buildings and one for new residential buildings.

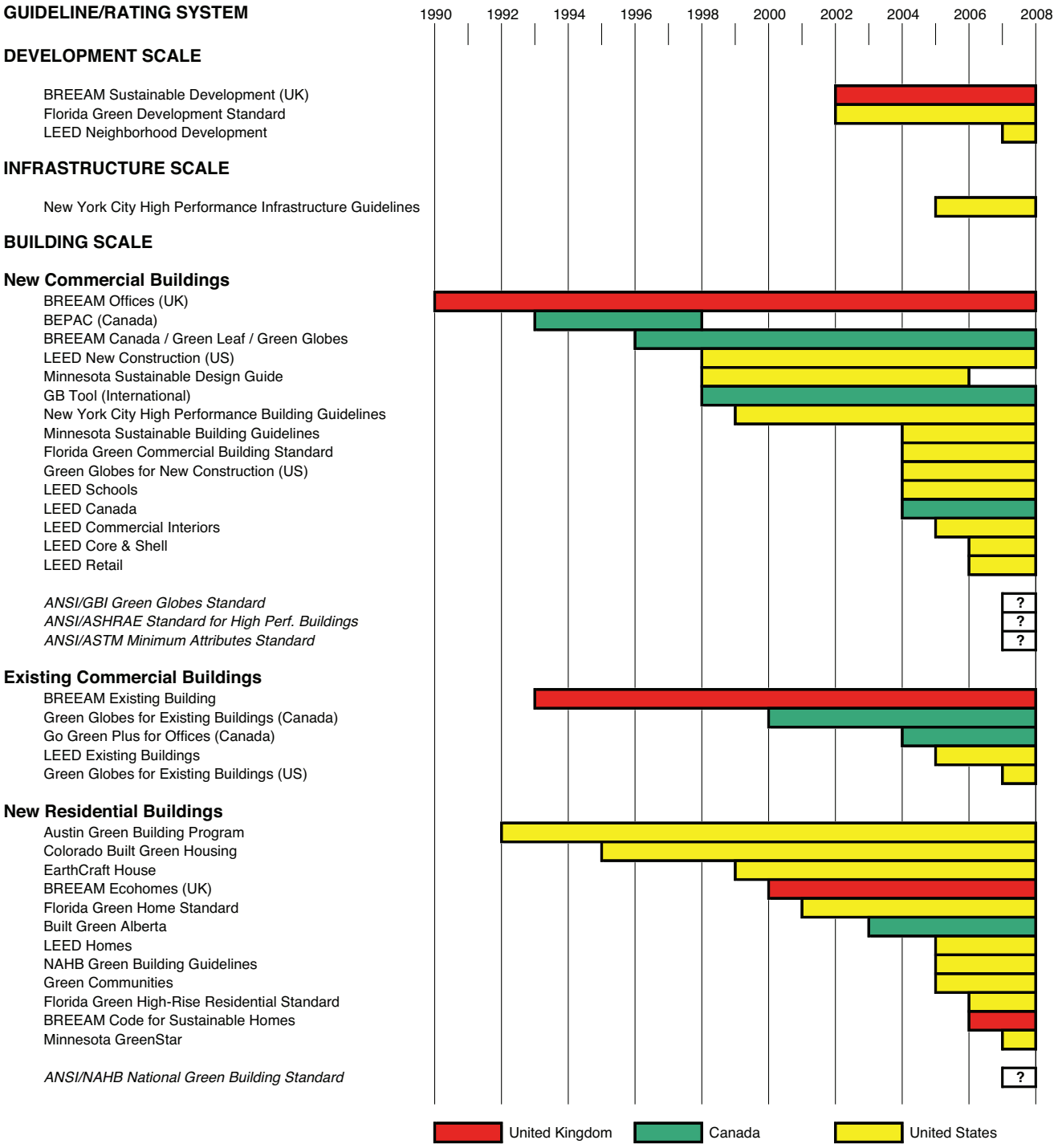
The introduction of new assessment and rating systems and the continuous updating of existing ones represent an evolution driven by several factors. These include the expansion of guidelines into new scales of development, additional phases of the process, and customized versions for specific building types. The evolution of guidelines is also driven by the desire for regional variation as well as accommodating new knowledge developed about best methods and practices. A key question in the development and use of these systems is whether they lead to the desired environmental outcomes when applied to real projects. This is a difficult issue because of the varying definition of the scope and outcomes in sustainable design and the fact that some things are more easily measurable than others. Most guidelines consist of a mixture of recommended processes, best practices, and some performance outcomes. Processes and practices are not always measurable and cannot be translated into quantifiable environmental outcomes.

One of the most common ways of combining information is the use of point-based ratings systems. Relatively easy to understand and use, the points serve as surrogate indicators of real performance. This does not lead to a rigorous assessment or results that can be compared across projects (Cole, 2006). The drawback is that point-based systems can simply become like a set of specified requirements without fundamentally influencing the approach to achieving a high performance design. In addition, point-based systems reflect a weighting of the various environmental practices and impacts introducing subjectivity into the process. There is often no tracking of actual performance after a project is built. For sustainable design to evolve toward better practices and outcomes, this feedback loop must be more strongly established. To better understand the current state-of-the-art of these assessment methods and rating systems, the basic characteristics of several approaches are described in the section that follows.

DEVELOPMENT SCALE

By changing transportation use and patterns at the city or development scale, there are impacts on vehicle miles driven and associated energy use and emissions from cars including greenhouse gasses. Community scale

Figure 8. History of Sustainable Guidelines and Rating Systems.



design can facilitate greater densities and mixed use development patterns which support more effficient mass transit systems. In addition, regional and community scale ecology (soil, stormwater, biodiversity) are affected at the development scale. There are also potential reductions in congestion and time spent commuting, and safety can be enhanced by reducing the number of vehicles on the road.

Green development guidelines are emerging nationally (e.g. LEED ND) and regionally or locally (e.g. Florida Green Development Guidelines). Many older transit-oriented development projects do not explicitly follow pre-existing guidelines or measure environmental impacts, but they include many of the strategies associated with sustainable development. Some newer developments do follow guidelines that include sustainable principles, although the issues addressed can vary widely and actual performance metrics often are not always available or tracked very often.

LEED® for Neighborhood Development™ (ND)

One of a family of rating systems from the US Green Building Council (USGBC), LEED for Neighborhood Development (LEED ND) is a national point-based rating system with credits in the following areas:

Figure 9. LEED for Neighborhood Development Rating System.

SMART LOCATION & LINKAGE

Prereq 1	Smart Location
Prereq 2	Proximity to Water and Wastewater Infrastructure
Prereq 3	Imperiled Species and Ecological Communities
Prereq 4	Wetland and Water Body Conservation
Prereq 5	Agricultural Land Conservation
Prereq 6	Floodplain Avoidance
Credit 1	Brownfield Redevelopment
Credit 2	High Priority Brownfields Redevelopment
Credit 3	Preferred Locations
Credit 4	Reduced Automobile Dependence
Credit 5	Bicycle Network
Credit 6	Housing and Jobs Proximity
Credit 7	School Proximity
Credit 8	Steep Slope Protection
Credit 9	Site Design for Habitat or Wetlands Conservation
Credit 10	Restoration of Habitat or Wetlands
Credit 11	Conservation Management of Habitat or Wetlands

NEIGHBORHOOD PATTERN & DESIGN

Prereq 1	Open Community
Prereq 2	Compact Development
Credit 1	Compact Development
Credit 2	Diversity of Uses
Credit 3	Diversity of Housing Types
Credit 4	Affordable Rental Housing
Credit 5	Affordable For-Sale Housing
Credit 6	Reduced Parking Footprint
Credit 7	Walkable Streets
Credit 8	Street Network
Credit 9	Transit Facilities
Credit 10	Transportation Demand Management
Credit 11	Access to Surrounding Vicinity
Credit 12	Access to Public Spaces
Credit 13	Access to Active Public Spaces
Credit 14	Universal Accessibility
Credit 15	Community Outreach and Involvement
Credit 16	Local Food Production

GREEN CONSTRUCTION & TECHNOLOGY

Prereq 1	Construction Activity Pollution Prevention
Credit 1	Certified Green Buildings
Credit 2	Energy Efficiency in Buildings
Credit 3	Reduced Water Use
Credit 4	Building Reuse and Adaptive Reuse
Credit 5	Reuse of Historic Buildings
Credit 6	Minimize Site Disturbance through Site Design
Credit 7	Minimize Site Disturbance during Construction
Credit 8	Contaminant Reduction in Brownfields Remediation
Credit 9	Stormwater Management
Credit 10	Heat Island Reduction
Credit 11	Solar Orientation
Credit 12	On-Site Energy Generation
Credit 13	On-Site Renewable Energy Sources
Credit 14	District Heating and Cooling
Credit 15	Infrastructure Energy Efficiency
Credit 16	Wastewater Management
Credit 17	Recycled Content in Infrastructure
Credit 18	Construction Waste Management
Credit 19	Comprehensive Waste Management
Credit 20	Light Pollution Reduction

INNOVATION & DESIGN PROCESS

Credit 1	Innovation in Design
Credit 2	LEED Accredited Professional

- Smart Location and Linkage
- Neighborhood Pattern and Design
- Green Construction and Technology
- Innovation and Design Process

LEED ND is currently in the pilot phase. Depending on the number of points, a project can achieve a certified, silver, gold, or platinum level. The system includes a small number of prerequisites and mostly optional credits listed in Figure 9. There is third party certification through the USGBC. Compared to rating systems for individual buildings, the neighborhood or communities scale practices address larger planning issues such as protection and restoration of natural habitats and wetlands as well as avoidance of flood plains and steep slopes. Other practices such as compact development, walkable communities, and proximity to schools and jobs have environmental benefits of preserving land while reducing automobile travel, but they also build community. The LEED ND guidelines also include practices such as local food production that build the local economy as well as reduce the embodied energy in transporting food long distances.

Measurable outcomes include energy and water use at the district scale as well as the building scale. Water quality and biodiversity in addition to preservation and restoration of land are other outcome measures appropriate at this scale. Processes included in the guidelines range from transportation demand management to comprehensive waste management. Applying the guidelines requires an integrated design process for the team. Neighborhood scale development guidelines such as these can address transportation issues such as automobile dependence, bicycle networks, and access to transit.

Florida Green Development Guidelines

The Florida Green Development Guidelines are an example of a regional approach to sustainable neighborhood development. Developed and administered by the Florida Green Building Coalition, the point-based guidelines are organized into the following categories:

- Protect Ecosystems and Conserve Natural Resources
- Circulation
- Green Utility Practices
- Amenities
- Covenants and Deed Restrictions
- Provide Educational Information to Help Achieve and Promote Green Living Practices

There are no mandatory requirements in the Florida Green Development Guidelines, but achieving a certain number of points results in the green development designation. In addition to recognition and marketing advantage, the designation may be linked to local incentives such as a quicker review process for the developer. As shown in Figure 10, the Florida guidelines include practices related to environmental protection as well as creation of a walkable, high-quality environment. Regional guidelines provide the opportunity to address local environmental issues and standards. Providing amenities such as parks and community pools are one priority in Florida. The guidelines have a particular emphasis on education and training programs. Monitoring outcomes such as energy and water use, water quality, and wildlife provide a feedback loop to the community. The Florida guidelines focus on roads and parking issues but have less emphasis on access to public transportation.

BUILDING SCALE

At the scale of individual buildings or facilities, sustainable design principles can have impacts on site ecology (soil, stormwater, biodiversity, heat island and light pollution); water consumption, treatment and management; operating energy and embodied material impacts (energy, global warming, air quality, water quality, resource depletion, and waste); and health within facilities. In individual transportation facilities, owners and designers are beginning to consciously

Figure 10. Florida Green Development Guidelines.

CATEGORY 1: PROTECT ECOSYSTEMS AND CONSERVE NATURAL RESOURCES

P-1 Redevelop an Already Developed Site
P-2 Develop Management Plan for Preserved, Created or Restored Wetlands/Uplands
P-3 Conduct of Vegetation and Tree, Topographical, Soil and Wildlife Survey prior to Design
P-4 Conservation Areas and Nature Parks
P-5 Preserve the Most Valuable Spaces for Biodiversity
P-6 On-Site Conservation Plan for Specific Wildlife Species
P-7 Maintain or Provide Wildlife Corridors
P-8 Preserve Upland the Buffers to Enhance Preserved Wetlands
P-9 Preserve or Provide Ground Water Recharge Areas
P-10 Restore Native Wildlife Habitat
P-11 Reuse or Recycle Materials on Site
P-12 Treating Stormwater from Neighboring Sites or in Pre-existing Developments
P-13 Conserve Land via Dry Stormwater Areas that Serve as Other Amenities
P-14 Community Flowed Plots, Garden Parks

CATEGORY 2: CIRCULATION

C-1 Pedestrian Structure
C-2 Road Design
C-3 Street Trees
C-4 Street Lights
C-5 Parking
C-6 Connection
C-7 Orientation
C-8 Road/Trail/Parking Construction Materials
C-9 Access

CATEGORY 3: GREEN UTILITY PRACTICES

U-1 Minimize Disturbance Due to Utilities
U-2 Deliver Green Power
U-3 Supply Irrigation System that Uses Stormwater or Reuses Water
U-4 Irrigation Meter System
U-5 Water Irrigation Budget
U-6 Submeter Parcels by End User

CATEGORY 4: AMENITIES

A-1 Neighborhood Parks
A-2 Community or Regional Park
A-3 Community Pool
A-4 Compost/Mulch Facility
A-5 Golf Course Minimally Treated or Excluded
A-6 Landscape Criteria and Management Plan for Common Areas and Amenities

CATEGORY 5: COVENANTS AND DEED RESTRICTIONS

CDR-1 Green Construction Standards
CDR-2 No Language that Prohibits Green Practices

CATEGORY 6: PROVIDE EDUCATIONAL INFORMATION TO HELP ACHIEVE AND PROMOTE GREEN LIVING PRACTICES

E-1 Staff Training
E-2 Dedicated On-Site Green Specialists for Parcel Owners
E-3 On-Site to Green Buyer Training Buyer Incentives for Off-Site Training
E-4 Environmental Education in Marketing Material
E-5 In-House Green Practices
E-6 Demonstration Green Buildings
E-7 Outdoor Environmental Educations Signs
E-8 Green Web Site
E-9 Monitoring Program

address sustainable design issues by applying national rating systems to transit facilities. LEED for New Construction (NC) and the Green Globes rating systems are discussed in more detail below. Sustainable guidelines reflecting regional and local issues and innovative approaches are also applied (e.g. New York City High Performance Building Guidelines, Minnesota Sustainable Building Guidelines, and the Florida Commercial Building Guidelines).

LEED® for New Construction™ (NC)

The most widely known and used national rating system is LEED from the US Green Building Council (USGBC). LEED is a point-based system with credits in the following categories:

- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Interior Environmental Quality
- Innovation and Design Process

Based on the number of points, a project can attain a certified, silver, gold, or platinum level. These levels make LEED an effective vehicle to reward achievement and receive recognition. There are a small number of required prerequisites while the majority of the credits are optional. This means that a building can be certified without necessarily advancing exemplary performance in one or more of the categories. Compliance with the credits is based on third-party certification. There is one set of credits that apply nationwide. Regional variations such as LEED Canada must be approved by the USGBC. A complete listing of prerequisites and credits for LEED NC-Version 2.2 appears in Figure 11.

Some LEED credits are for following processes such as commissioning while most are for following best practices such as the use of recycled materials or provision of daylight. The actual performance outcomes represented by LEED credits include energy consumption, water consumption, and construction waste disposal. At the individual building scale, transportation issues are addressed in a prescriptive way through credits for public transportation access, bicycle storage, low-emitting and fuel efficient vehicles, and reduced parking capacity.

The USGBC has introduced a family of rating systems to address separate phases of construction and building types. These include: commercial interiors projects, core and shell development projects as well as application guides for schools and retail buildings. The LEED Existing Buildings and Operations rating system addresses the occupancy phase of the building where actual outcomes can be tracked. The USGBC is participating in the development of *ASHRAE 189P, Standard for High Performance Buildings*.

Green Globes™

The Green Globes ratings system originated in Canada based on the BREEAM™ system from England and was introduced to the U.S. market by the Green Building Initiative. It is a point-based system with four levels of achievement from one to four globes. Some of the points can be designated as not applicable to a particular project and the ratings calculated based on the remaining points. This means that a particular site or building type is not penalized if points are not achievable, and the development of multiple ratings systems for special purposes is not as necessary. An existing building rating system called BOMA GoGreen in Canada is being introduced in the United States as the Green Globes Existing Building guidelines.

The current version of Green Globes gives points in the following categories:

- Project management—Policies and Practices
- Site
- Energy
- Water
- Resources, Building Materials, and Solid Waste
- Emissions and Other Impacts
- Indoor Environment

Similar to other rating systems, points are given for processes, practices, and performance outcomes. A key feature of Green Globes is that it is entirely Web-based. The user answers a series of questions appropriate for the phase of design. It serves as an educational guide during this process. The Green Globes rating system is going through the ANSI standards process and major revisions are being incorporated by the Technical Committee. Anticipated changes include the incorporation of a life cycle assessment tool based on the Athena EcoCalculator that determines environmental impacts of building assemblies and materials (Athena 2007).

Minnesota Sustainable Building Guidelines

The Minnesota Sustainable Building Guidelines (MSBG) are an example of a regional system. The guidelines were mandated by state legislation for all

Figure 11. LEED for New Construction Version 2.2.

SUSTAINABLE SITES

Prereq 1 Construction Activity Pollution Prevention Required
Credit 1 Site Selection
Credit 2 Development Density & Community Connectivity
Credit 3 Brownfield Redevelopment
Credit 4.1 Alternative Transportation, Public Transportation Access
Credit 4.2 Alternative Transportation, Bicycle Storage & Changing Rooms
Credit 4.3 Alternative Transportation, Low Emitting & Fuel Efficient Vehicles
Credit 4.4 Alternative Transportation, Parking Capacity
Credit 5.1 Site Development, Protect or Restore Habitat
Credit 5.2 Site Development, Maximize Open Space
Credit 6.1 Stormwater Design, Quantity Control
Credit 6.2 Stormwater Design, Quality Control
Credit 7.1 Heat Island Effect, Non-Roof
Credit 7.2 Heat Island Effect, Roof
Credit 8 Light Pollution Reduction

WATER EFFICIENCY

Credit 1.1 Water Efficient Landscaping, Reduce by 50%
Credit 1.2 Water Efficient Landscaping, No Potable Use or No Irrigation
Credit 2 Innovative Wastewater Technologies
Credit 3.1 Water Use Reduction, 20% Reduction
Credit 3.2 Water Use Reduction, 30% Reduction

ENERGY & ATMOSPHERE

Prereq 1 Fundamental Commissioning of the Building Energy Systems Required
Prereq 2 Minimum Energy Performance Required
Prereq 3 Fundamental Refrigerant Management Required
Credit 1 Optimize Energy Performance
Credit 2 On-Site Renewable Energy
Credit 3 Enhanced Commissioning
Credit 4 Enhanced Refrigerant Management
Credit 5 Measurement & Verification
Credit 6 Green Power

MATERIALS & RESOURCES

Prereq 1 Storage & Collection of Recyclables Required
Credit 1.1 Building Reuse, Maintain 75% of Existing Walls, Floors & Roof
Credit 1.2 Building Reuse, Maintain 95% of Existing Walls, Floors & Roof
Credit 1.3 Building Reuse, Maintain 50% of Interior Non-Structural Elements
Credit 2.1 Construction Waste Management, Divert 50% from Disposal
Credit 2.2 Construction Waste Management, Divert 75% from Disposal
Credit 3.1 Materials Reuse, 5%
Credit 3.2 Materials Reuse, 10%
Credit 4.1 Recycled Content, 10% (post-consumer + 1/2 pre-consumer)
Credit 4.2 Recycled Content, 20% (post-consumer + 1/2 pre-consumer)
Credit 5.1 Regional Materials, 10% Extracted, Processed & Manufactured Regionally
Credit 5.2 Regional Materials, 20% Extracted, Processed & Manufactured Regionally
Credit 6 Rapidly Renewable Materials
Credit 7 Certified Wood

INDOOR ENVIRONMENTAL QUALITY

Prereq 1 Minimum IAQ Performance Required
Prereq 2 Environmental Tobacco Smoke (ETS) Control Required
Credit 1 Outdoor Air Delivery Monitoring
Credit 2 Increased Ventilation
Credit 3.1 Construction IAQ Management Plan, During Construction
Credit 3.2 Construction IAQ Management Plan, Before Occupancy
Credit 4.1 Low-Emitting Materials, Adhesives & Sealants
Credit 4.2 Low-Emitting Materials, Paints & Coatings
Credit 4.3 Low-Emitting Materials, Carpet Systems
Credit 4.4 Low-Emitting Materials, Composite Wood & Agrifiber Products
Credit 5 Indoor Chemical & Pollutant Source Control
Credit 6.1 Controllability of Systems, Lighting
Credit 6.2 Controllability of Systems, Thermal Comfort
Credit 7.1 Thermal Comfort, Design
Credit 7.2 Thermal Comfort, Verification
Credit 8.1 Daylight & Views, Daylight 75% of Spaces
Credit 8.2 Daylight & Views, Views for 90% of Spaces

INNOVATION & DESIGN PROCESS

Credit 1.1 Innovation in Design
Credit 1.2 Innovation in Design
Credit 1.3 Innovation in Design
Credit 1.4 Innovation in Design
Credit 2 LEED Accredited Professional

projects with state funding. Consequently, they apply mainly to public buildings for state agencies. The need for regional systems is driven by the desire to integrate state programs and standards into the guidelines, the need to establish which guidelines are mandatory, and the need to set performance levels and add guidelines not covered by national guideline models. The Minnesota Sustainable Building Guidelines are not a point-based system and simply consist of the required or recommended guidelines in the following areas:

- Performance Management
- Site and Water
- Energy and Atmosphere
- Indoor Environmental Quality
- Materials and Waste

The benefit of having a mostly required set of guidelines is that all agencies and design teams know they must comply and application of a specific set of guidelines is ensured. Since there are no higher levels of achievement designated, this type of system does not result in the same level of recognition associated with LEED or Green Globes. The Minnesota Sustainable Building Guidelines are designed to emphasize actual performance outcomes as the basis for comparing buildings. As the user completes documentation, a scorecard or environmental balance sheet of key outcomes such as energy use and carbon emissions are determined. This lends itself to integration with performance-based initiatives such as *Architecture2030*. The Minnesota guidelines also incorporate a regional version of the Athena EcoCalculator to determine actual environmental impacts of building assembly and material choices.

Housing Sector Assessment Methods and Rating Systems

A separate set of voluntary environmental assessment and rating systems have been developed for the housing sector. At a national level, LEED for Homes has been developed by the USGBC as one of a family of rating systems that covers the following topic areas:

- Innovation and Design Process
- Location and Linkages
- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environmental Quality
- Awareness and Education

The National Association of Home Builders (NAHB) has developed the NAHB Green Building Guidelines promoted through the Green Building Initiative. Guidelines are organized under the following categories:

- Lot Design, Preparation, and Development
- Resource Efficiency
- Energy Efficiency
- Water Efficiency
- Indoor Environmental Quality
- Operation, Maintenance & Homeowner Education
- Global Impact
- Site Planning and Land Development

Both LEED for Homes and the NAHB Guidelines are point-based systems with multiple levels of achievement. The NAHB Guidelines are currently going through the ANSI standards process. There are numerous well-established local and regional green building programs such as the Austin Green Building Program, BuiltGreen Colorado, BuiltGreen Washington, and EarthCraft Homes in Atlanta.

In the affordable housing sector, the Green Communities Initiative was developed by Enterprise. Launched in the fall of 2004, the initiative is a five-year, $550 million commitment to build more than 8,500 environmentally friendly affordable homes across the United States. As shown in Figure 12, about half of the guidelines are mandatory and the remaining ones are optional. Meeting the mandatory requirements and achieving points for meeting optional criteria are

linked to obtaining grants and other project funding opportunities from Enterprise. Compliance with the guidelines is not certified by a third party. Priorities emphasized in the Green Communities guidelines are the creation of walkable communities, energy efficiency, and occupant health. The ENERGY STAR® Homes program is a basis for meeting energy requirements. The guidelines also include processes such as developing a durability plan as well as homeowner manuals and training. The guidelines apply to new construction as well as rehabilitation projects where performance criteria are set lower.

Figure 12. Green Communities Criteria.

INTEGRATED DESIGN PROCESS
- 1.1* Green Development Plan

LOCATION AND NEIGHBORHOOD FABRIC
- 2.1a* Smart Site Location: Proximity to Existing Development
- 2.1b* Smart Site Location: Protecting Environmental Resources
- 2.1c* Smart Site Location: Proximity to Services, New Construction
- 2.2* Compact Development
- 2.3* Walkable Neighborhoods: Sidewalks and Pathways
- 2.4 Smart Site Location: Make Use of Passive Solar Heating/Cooling
- 2.4b Smart Site Location: Grayfield, Brownfield or Adaptive Reuse Site
- 2.5 Compact Development
- 2.6 Walkable Neighborhoods: Connections to Surrounding Neighborhoods
- 2.7 Transportation Choices

SITE IMPROVEMENTS
- 3.1* Environmental Remediation
- 3.2* Erosion and Sedimentation Control
- 3.3* Landscaping
- 3.4 Surface Water Management
- 3.5 Storm Drain Labels

WATER CONSERVATION
- 4.1a* Water Conserving Fixtures: New Construction
- 4.1b* Water Conserving Fixtures: Moderate Rehab
- 4.2* Efficient Irrigation

ENERGY EFFICIENCY
- 5.1a* Efficient Energy Use: New Construction
- 5.1b* Efficient Energy Use: Moderate Rehab
- 5.2* ENERGY STAR Appliances
- 5.3a* Efficient Light: Interior
- 5.3b* Efficient Light: Exterior
- 5.4* Electricity Meter
- 5.5a Additional Reductions in Energy Use: New Construction
- 5.5b Additional Reductions in Energy Use: Moderate Rehab
- 5.6a Photovoltaic (PV) Panels
- 5.6b Photovoltaic (PV) Ready

MATERIALS BENEFICIAL TO THE ENVIRONMENT
- 6.1 Construction Waste Management
- 6.2 Recycled Content Material
- 6.3 Certified, Salvaged and Engineered Wood
- 6.4a Water-Permeable Walkways
- 6.4b Water-Permeable Parking Areas
- 6.5a Reduce Heat-Island Effect: Roofing
- 6.5b Reduce-Heat Island Effect: Paving

HEALTHY LIVING ENVIRONMENT
- 7.1* Low/No Volatile Organic Compounds (VOC) Paints and Primers
- 7.2* Low/No VOC Adhesives and Sealants
- 7.3* Formaldehyde-free composite Wood
- 7.4* Green Label Certified Floor Covering
- 7.5a* Exhaust Fans-Bathroom: New Construction
- 7.5b* Exhaust Fans-Kitchen: New Construction
- 7.6* Ventilation: New Construction
- 7.7* HVAC Sizing
- 7.8a* Water Heaters: Mold Prevention
- 7.8b Water Heaters: Minimizing CO
- 7.9* Cold Water Pipe Insulation
- 7.10a* Ventilation: New Construction
- 7.10b* Materials in Wet Areas: Tub and Shower Enclosure
- 7.11a* Basements and Concrete Slabs; Vapor Barrier
- 7.11b* Basements and Concrete Slabs-Radon: New Construction
- 7.12* Water Drainage
- 7.13* Garage Isolation
- 7.14* Clothes-Dryer Exhaust
- 7.15* Integrated Pest Management
- 7.16* Lead-Safe Work Practices
- 7.17a Healthy Flooring Materials: Alternative Sources
- 7.17b Healthy Flooring Materials: Reducing Dust

OPERATION AND MAINTENANCE
- 8.1* Building Maintenance Manual for Owner
- 8.2* Occupant's Manual
- 8.3* Homeowner and New Resident Orientation

*Mandatory Guidelines

INFRASTRUCTURE SCALE

Infrastructure projects such as roads and bridges include impacts on site ecology (soil, stormwater, biodiversity, heat island effects and light pollution). Some infrastructure projects include energy and water use impacts. In addition, life cycle assessment can be applied to embodied material impacts (energy, global warming, air quality, water quality, resource depletion, and waste). Guidelines on sustainable infrastructure are emerging in local areas (e.g. New York City High Performance Infrastructure Guidelines). Infrastructure projects such as roads, incorporate context sensitive design but do not consistently address overall life cycle impacts of the construction. Newly emerging road ecology design principles are changing practice by focusing on the impact of transportation infrastructure on biodiversity. Road Ecology experts say the approximately 3.9 million miles of public roads that criss-cross the United States impact animals in at least three ways: road kill, habitat loss, and habitat fragmentation.

New York City High Performance Infrastructure Guidelines

The New York City High Performance Infrastructure Guidelines were developed for projects located in the public right-of-way. The guidelines do not have a point system with levels of achievement. They are intended to improve the environmental performance of infrastructure projects while leading to better long-term capital investments. The topics covered by the guidelines fall into the following categories:

- Site assessment
- Streetscape
- Pavement
- Utilities
- Stormwater management
- Landscape
- Construction practices

The complete list of guidelines appears in Figure 13. Many of the guidelines represent prescriptive best practices related to elements such as pavement materials, landscaping, and stormwater management. Some of the streetscape guidelines contribute to more attractive, walkable, and safe urban environments as well. The guidelines include a number of processes such as various site assessments, stormwater planning, and implementing waste management plans during construction. Since enclosed structures are usually not part of the infrastructure in the public right-of-way, there is less emphasis on outcomes such as energy use and carbon emissions. Measurable outcomes include water quality, water use for irrigation, stormwater runoff, and preservation or restoration of biodiversity in the city.

Road Ecology Principles

Road Ecology focuses on the adverse impact of roads on nature. It addresses how ecosystem processes at the landscape scale are interrupted by roads and the vehicles on them, how populations of plants and animals are fragmented by road systems, and the demographic and evolutionary consequences of that fragmentation. It also explores how vehicles and their pollution (including noise) cause mortality and suppress reproduction in both plants and animals. Transportation planners responding to increasing demand for mobility, recognize the need to minimize the adverse impact of roads and vehicles. Practitioners in this developing field have come to see that human communities and natural ecosystems have much the same needs for sustainable transportation systems. This movement toward a fully integrated, multidisciplinary effort culminated in the recent book entitled *Road Ecology: Science and Solutions* (Forman and Sperling, 2003).

Figure 13. New York City High Performance Infrastructure Guidelines.

SITE ASSESSMENT

SA.1 Assess Site and High Performance Opportunities
SA.2 Conduct Soil Analysis
SA.3 Conduct Hydrologic and Hydraulic Analysis
SA.4 Survey Existing Vegetation

STREETSCAPE

SS.1 Work with Community Groups to Enhance and Maintain Streetscape
SS.2 Improve Streetscape for Pedestrians
SS.3 Improve Streetscape for Bicyclists
SS.4 Improve Streetscape for Surface Mass Transit
SS.5 Increase and Improve Right-of-Way Public Space and Green Areas
SS.6 Optimize Security Enhancements
SS.7 Optimize Streetlighting and Signaling

PAVEMENT

PA.1 Maximize Pavement Lifecycle Citywide
PA.2 Minimize Impervious Pavement Area
PA.3 Maximize Pavement Albedo
PA.4 Use Pervious Pavements
PA.5 Use Reduced-Emission Materials
PA.6 Use Recycled and Reclaimed Materials

UTILITIES

UI.1 Minimize Impact of Utility Work
UI.2 Improve Restoration of Utility Cut Trenches
UI.3 Coordinate Utility Infrastructure for Easy Access and Maintenance
UI.4 Use Trenchless Technologies

STORMWATER MANAGEMENT

SM.1 Conduct Integrated Stormwater Management Planning
SM.2 Prevent Water Pollution and Practice Source Control
SM.3 Minimize Runoff from New Building Construction and Major Renovations
SM.4 Optimize Right-of-Way Drainage
SM.5 Use Vegetated Filters and Buffer Strips
SM.6 Use Catch Basin Inserts
SM.7 Use Water Quality Inlets
SM.8 Use Detention Structures
SM.9 Use Infiltration Structures
SM.10 Use Bioretention
SM.11 Use Constructed Wetlands

LANDSCAPE

LA.1 Optimize Citywide Landscape Planning
LA.2 Encourage Ecological Connectivity and Habitat
LA.3 Create Absorbent Landscapes
LA.4 Use Structural Soils Where Appropriate
LA.5 Amend Existing Soils
LA.6 Perform Soil Berming
LA.7 Increase the Quantity, Density and Diversity of Trees
LA.8 Plant Trees to Maximize Shading of Pavement
LA.9 Plant Trees in Trenches or Continuous Soil Zones
LA.10 Use Healthy Plant Selection and Planting Practices
LA.11 Reduce Use of Turfgrass
LA.12 Use Low-Maintenance, Salt-Tolerant, Native or Naturalized Species
LA.13 Use Water-Efficient Landscape Design
LA.14 Use Biointensive Integrated Pest Management
LA.15 Use Biotope-Based Plant Arrangement Along the Shade-Light Continuum

CONSTRUCTION PRACTICES

CP.1 Develop and Enforce a Site Protection Plan
CP.2 Protect Existing and Future Planted Areas
CP.3 Protect Water Sources During Construction
CP.4 Implement a Waste Management and Recycling Plan
CP.5 Minimize Disruption and Impact of Right-of-Way Construction
CP.6 Use Cleaner Construction Equipment

Case Studies

Three areas have been identified for the case studies—sustainable development, sustainable buildings and sustainable infrastructure. Sustainable development is illustrated by two case studies of transit-oriented development: Prairie Crossing and Highlands' Garden Village. Sustainable building is illustrated by two case studies: The Rapid Surface Transportation Center and the Pentagon Metro Transit Entrance Facility. Sustainable infrastructure is illustrated by the Woodrow Wilson Bridge Project and the Marjorie Harris Carr Cross Florida Greenway Land Bridge. The case studies are intended to demonstrate a range of work in the transportation area addressing a diversity of scales and types as well as approaches to application of sustainable design principles.

CASE STUDY 1: Prairie Crossing, Illinois

Prairie Crossing is a 667-acre sustainable, transit-oriented residential development located 40 miles northwest of Chicago in the town of Grayslake, Ill. The development was designed to meet goals of responsible development, preservation of open land and easy commuting by rail. At a total cost of $100 million, Prairie Crossing includes 359 single-family homes and 36 condominiums. The first residents moved into Prairie Crossing in December 1994. The community includes a 12-stall animal barn, farmer's market, community center, tennis courts, fitness center, gardens, a 22-acre lake, 10 miles of interior trails linked to a regional trail system, and a new commuter rail station.

Figure 14. Station Square and Burnham Building at Prairie Crossing. Photo by Hedrich Blessing, courtesy of Prairie Holdings Corporation.

A series of urban homes—with lots as small as 5,000 square feet are located in a new town center called Station Village, based around the Metra train station. The "Main Street" with office and retail space at street level and office and housing above is located between the two stations, serving as the entries to the Station Village.

Prairie Crossing has met critical acclaim as a conservation community that is suburban yet firmly connected to transportation beyond the automobile while also demonstrating a number of sustainable practices. It is a potential model for other such development nationally.

Sustainable Strategies

Land use

The project is a landmark example of sustainable land use and restorative development. Prairie Crossing is part of the Liberty Prairie Reserve, 5,800 acres of publicly and privately held land that includes nature and forest preserves, farms and trails. Only 20% of the permitted density is utilized compared to 70% for typical new residential subdivisions. More than 350 acres on the site have been protected from any future development (by conservation easements held by The Conservation Fund) with 174 acres comprising restored prairie and 150 acres dedicated to wetlands and working farm fields. Thirty acres are restored wetlands and 16 acres are historic hedgerows. The larger goal of the development was to protect the environment, native vegetation and wildlife of the Midwest.

Figure 15. Site plan of Prairie Crossing. Image provided by Prairie Holdings Corporation.

Site

The green site strategies include preservation of a village green and development of trails, a lake, and community-supported gardens consisting of a 10-acre organic farm. The land has been contoured to properly manage stormwater without the use of concrete culverts and other conventional stormwater discharge systems. Instead, vegetated swales and detention basins were used.

Water

Native plants are used in landscaping to reduce water demand. Stormwater is managed sequentially through a series of open lands, including grasslands, prairie, wetlands and lakes.

Energy

Within the development, 317 homes are constructed with energy-efficient and resource-efficient technologies. Prairie Crossing homes are 50% more energy-efficient than comparable homes in Chicago. A 20 kW wind turbine partially funded by the Illinois' Renewable Energy Resources Program provides 30,000 to 40,000 kWh per year to the organic farm, enough to cover the farm's greenhouses, lights, and washing and cooling systems. Excess energy is sold to the electric utility (ComEd) and sent to its power grid.

The amount of wind energy being produced by the turbine can be viewed online in real time on the Prairie Crossing Web site.

Transportation

Ten miles of trails have been provided to encourage transportation by bikes. The trails travel over a landscape of farm fields, pastures, lakes and ponds, native prairies and wetlands. In addition, Prairie Crossing is linked by regional trails to the Liberty Prairie Reserve, over 3,200 acres of legally protected land. In terms of mass transit, two adjacent Metra Metropolitan Rail lines are present with two stations roughly 0.1 miles apart. The Prairie Crossing-Libertyville station serves the North Central Line running between Antioch and Chicago. Another line serves the Milwaukee District North Line. The mass transit strategy provides many benefits:

- The two stations have become a regional mass transit hub since it is a natural transfer point between the lines.
- Almost 300 trains a week stop at the two Prairie Crossing/Libertyville stations, offering virtually unprecedented rail access for a suburban community.
- From one station, passengers can reach Chicago's Union Station in a little over an hour on Metra's North line. From the other station, passengers can get to O'Hare International Airport in 35 minutes as well as to downtown Chicago on Metra's North Central line.

Indoor Environmental Quality

Ventilation fans are controllable by occupants for fresh air exchange. Non-toxic glues were used in the project.

Resources: Building Reuse, Materials, Waste

Nearby historic buildings, saved from demolition, have been moved and restored to form the Market Square. For example, the Byron Colby Barn, a dairy barn built nearby in 1885, was moved to Market Square and is now used as a community center hosting a number of

Figure 16. Train station at Prairie Crossing. Photo by Regional Transportation Agency, courtesy of Prairie Holdings Corporation.

community events including homeowners' meetings, concerts, lectures, school assemblies, workshops and conferences.

Efficient framing techniques, and efficient structural engineering reduce construction waste by 20–30%. Recycled wood products were used on the project. A community-wide recycling and composting program has been established as well.

Effective Process Elements

1. ***Guiding Principles for the development focused on sustainability***

   The ten guiding principles established for the project are:

   - Environmental protection and enhancement
   - Healthy lifestyle
   - Sense of place
   - Sense of community
   - Economic and racial diversity
   - Convenient and efficient transportation
   - Energy conservation
   - Lifelong learning and education
   - Aesthetic design and high-quality construction
   - Economic viability

2. ***Create a homeowner's association committed to sustainability***

   The environmental mission of the Prairie Crossing Homeowners' Association, an organization that maintains, enhances, and protects the common areas of the community, also reflects sustainable values. The Prairie Crossing Homeowners' Association is "committed to stewarding its common areas and natural areas such that the ecological health and functions improve every year until it reaches a 'steady state' of sufficient quality that it enhances the surrounding open space in the Liberty Prairie Reserve."

3. ***Model and survey environmental issues at the start of the project***

   Stormwater and hydrology modeling was done at the start of the project as well as surveying and monitoring of bird and plant species.

4. ***Use sustainable standards and guidelines***

   This project pre-dated LEED, which was still under development at the time. No overall sustainable guidelines or rating systems prevalent today were used in the design of the project. Prairie Crossing was the first community in the nation to implement Building America energy conservation standards. Twenty percent of the landscaping on each lot was required to be native prairie plants as well.

   In addition, the following guidelines were developed by the Prairie Crossing Homeowners' Association for daily operations and maintenance of the communal lands in order to uphold the values portrayed in their mission statement:

   - Aesthetic expectations should be consistent with a healthy, rural environment.
   - All management decisions should recognize the

Figure 17. Aerial view of Prairie Crossing. Photo by Terry Evans, courtesy of Prairie Holdings Corporation.

importance of the interconnections within an ecosystem. The health of the entire ecosystem should be the principle criteria.

- It is usually cheaper to prevent a problem than to fix it. For example, it is far cheaper to prevent the overloading of the lake with nutrients and chemicals than it is to clean it up later.
- Healthy native ecosystems contain low levels of weeds. Weeds are not all equal. Some weeds are transitory in the establishment of new plant communities. Others are pernicious and dramatically reduce the ecological health of the ecosystem. Decisions about weed management should include ecosystem threats as well as aesthetic threats.
- Inputs that are not immediately used entirely by the intended plant community run off and become pollutants in downstream areas and water bodies.
- No pesticides or fertilizers should be applied on common areas without being first reviewed (ingredient list, application procedures, MSD sheets) by the Environmental Consultant.
- All proposed inputs for natural resource management should enhance the ultimate long-term biodiversity, stability and sustainability of the targeted ecosystem and affected ecosystems "downstream".

5. ***Include a sustainability focus in the team planning process***

   Design charrettes were not specifically held around environmental issues: however, ecologists participated in all of the charrettes as well as all ongoing discussions between charrettes.

6. ***Include champions for sustainable design in positions of leadership***

   The original vision for the Prairie Crossing community was formed by conservationists Mr. and Mrs. Gaylord and Dorothy Donneley. The vision came to fruition with an extensive design team under the leadership of George and Vicky Ranney. Approximately 50% of the design team had a specific interest and commitment to sustainability as well.

Communication of Environmental Objectives

According to interviews conducted by Robert Thompson for a study on Prairie Crossing, many inhabitants reported that they were attracted to the open space or the "neo-traditional" aesthetic of the development, yet they did not fully understand the environmental objectives of the community (Thompson, 2004).

1. ***Make new stormwater technologies visible***

   To address the residents' lack of knowledge, the Prairie Crossing design team implemented many creative strategies. Residents typically have little or no idea what happens to water after it drops into a storm drain and disappears into an underground system of pipes. However, at Prairie Crossing, the stormwater system is above the ground and the visibility of the on-site system enables residents to more easily comprehend the connections between the management of their own yard and the larger hydrological system. The constructed lake is also part of the stormwater management system: however, the developer put a sand beach on the lake and created the expectation that it would be boatable, fishable, and swimmable. These goals created expectations for high water quality among the residents.

2. ***Set requirements for residents to follow coupled with information on how to implement them***

   By requiring that 20% of each lot's landscaping consist of native prairie plants, the developer essentially forced the residents to learn how to implement prairie plantings and to discover that it was not difficult. The developer provided detailed practical information, thorough newsletters, workshops, and constructed large common prairie restorations that acted as demonstration projects for the community.

Neighbors also began exchanging prairie seeds and holding residential controlled prairie burns together, which greatly reduced cost and increased environmental knowledge within the community.

3. ***Identify ways to start an enterprise that also reinforces a sustainable lifestyle***
   The Prairie Crossings team addressed the problems of habitat fragmentation by use of a cluster development that preserves more than 60% of the site as open space. The developer of Prairie Crossing bought agricultural land and found an experienced farming couple to lease it. This arrangement offered an inexpensive way to maintain open space as well as provide an organic farm for the development, which eventually was organized around the principles of community-supported agriculture.

Performance Outcomes

1. ***Projected performance of stormwater management system***
   Sediments, heavy metals, fertilizers, de-icing materials, and many other chemical constituents are found in runoff from residential and commercial developments. According to a study done on the Prairie Crossing project, daily and storm event runoff rates are much less than a typical development due to source controls and large-scale restored landscapes designed to serve as the stormwater management system. The landscape stormwater management system is comprised of upland prairie biofiltration, natural swales, wetlands and a lake.

	Percent Leaving Treatment Train Component			
Constituent	Swales	Prairies	Wetlands	Lake
Surface Runoff Volume	80%	35%	35%	35%
Total Suspended Solids	75%	15%	8%	2%
Total Nitrogen	80%	30%	25%	15%
Total Phosphorous	80%	25%	20%	15%
Metals	75%	20%	10%	5%

Figure 18. Percent of Site Runoff Volume and Pollutant Load Leaving Treatment Train Components.

Combined, these measures increase lag time, increase opportunities for pollutants to settle and be filtered out, and reduce the rate and volume of runoff through better infiltration opportunities. Based on published information on the effectiveness of best management practices and hydrologic modeling, the Prairie Crossing development was expected to reduce average annual surface runoff volumes by 65% and reduce solids, nutrients and heavy metals loads by 85% to nearly 100% (see Figure 18). (Apfelbaum).

2. ***Water quality and aquatic wildlife indicators***
   Water quality has been monitored throughout this project's development and construction. According to a study done on the project, the water quality was maintained at a high enough standard that the Illinois Department of Natural Resources stocked the ponds with four species of state listed (threatened/endangered) fish species: blackchin shiner, blacknose shiner, banded killifish, and Iowa darter. Other fish species that were found when sampling the bodies of water in Prairie Crossing are largemouth bass, black crappie, bluegill, and green sunfish.

   The samples for measuring water quality were collected by Integrated Lakes Management, Inc. (ILM) in 2006 based on problems observed at the lake such as heavy plant growth and high salt levels. In 2005 Eurasian water milfoil (EWM) and curly leaf pondweed (CLP) were very dominant in the lake. ILM had recommended for 2006 that spot herbicide treatments and biological control measures (use of EWM weevils) should be performed. Total phosphorus concentrations were similar to previous year's data. The average total phosphorus was measured to be 0.047 mg/l in the lake, which is below the Illinois State Standard of 0.05 mg/l for general use water quality. Although nutrients are fairly low in the lake, they are concentrating due to the long retention time in the lake.

In 2006, the chloride concentration was only slightly lower than in 2005 (341 mg/l vs. 346 mg/l in 2005). Previous data had ranged from 200–300 mg/l from 2001 to 2004. Before 2001, the surrounding roads did not receive road salt, and chloride levels were usually less than 50 mg/l. Since the lake is accumulating salt and is approaching the Illinois state standard of 500 mg/l, the study recommended that road salt be restricted and alternatives to road salt applications be used in Prairie Crossing in order to maintain good water quality in the lake.

3. ***Other wildlife indicators***
   The number of bird species has increased from 15 before the development was constructed to 142 at present.

4. ***Prairie plantings performance***
   In fall 2005, three selected prairie plantings on the Prairie Crossing property were surveyed by Applied Ecological Services, Inc. to assess the vegetative composition and floristic quality. A total of 94 species, 66 species (70%) of which are native, were observed. Control of the exotics, white sweet clover (*Melilotus alba*) and Queen Anne's lace (*Daucus carota*) and the native, Canada goldenrod (*Solidago canadensis*) in the transect areas will help to further increase native species diversity and dominance. Although the three prairie areas have relatively high numbers of native species, these consist mostly of forbs with few grasses. It was recommended that deep-rooted native grasses, such as Indian grass and big blue stem be introduced to increase diversity and water quality benefits. In addition, other management techniques such as burning and mowing were also recommended to increase dominance and diversity of native grasses.

   According to interviews conducted by Robert Thompson, every resident in Prairie Crossing reported maintaining at least the original prairie plantings, and 85% reported expanding their plantings beyond the required 20% (Thompson, 2004). He reported that most had the majority of their yards in prairie. Everyone that was interviewed reported an increase in knowledge about prairie plants and wildlife as well as local hydrology and non-point source pollution. Almost everyone has taken additional steps to manage their own yards in a more ecologically sensitive manner by reducing or eliminating their chemical use and creating pond habitats.

   Residents at Prairie Crossing reported seeing butterflies, birds, and small mammals coming to their yards. These animals serve as tangible signs of success and create community pride. The report pointed out that when the lake experiences an algae bloom or invasive exotic species appear, these negative impacts also provide cues to the residents. The residents can see positive and negative results of their actions, which make it hard to deny problems or to rationalize a lack of action to fix them.

CASE STUDY 2:
Highlands' Garden Village, Denver, Colorado

Highlands' Garden Village is a sustainable, mixed-use development consisting of single-family houses, townhouses, market-rate and affordable senior and multifamily apartments, cohousing, office and retail on a previously developed amusement park site. It is located in northwest Denver—a ten minute commute from downtown. At a total cost of $102 million, the development contains 306 housing units with 52 single family units, 20 carriage homes, 38 town homes/ condos, 63 senior housing units, 74 multifamily units, 33 cohousing units and 26 live/work lofts. Other areas in the development include office, retail, school, theater, carousel, a public charter school and open space.

The restaurants, studios and shops have offices above them and live/work townhouses in close proximity, which creates the opportunity for residents to work and shop within a few minutes walk from their home. The project also provides safe and convenient walking paths and a network of gardens, plazas and public open spaces.

Highlands' Garden Village is a significant example of urban redevelopment of a brownfield site as well as a development that affected the larger city context and public awareness of sustainability. It is a potential model for other such development nationally.

Figure 19. Aerial view of Highlands' Garden Village. Photo by Terry Loome of Aero Arts Aerial Photography, courtesy of Perry-Rose, LLC.

Sustainable Strategies

Site

The project is a 27-acre urban infill and brownfield site, which was occupied by the former Elitch Gardens amusement park as well as zoological and botanical gardens for more than a century. The project also includes community gardens.

Water

The project uses water-conserving native grasses, trees, and plants such as buffalo grass at the Theater Plaza. There is also a rain garden—Sunken Garden by Trocadero Apartments—and 15 detention ponds designed to capture the 2-year and 10-year storm events.

Energy

The units include double-glazed, low-E windows, energy-efficient home appliances, and mechanical systems with programmable thermostats. Advanced sealing techniques through the building envelope—sealing at top and bottom plates, corners and between cavities at penetrations—help reduce air leakage and improve energy efficiency. Blower door testing was conducted on the buildings to confirm proper sealing occurred to minimize air leakage. The project uses alternative energy sources such as wind-generated electricity for parks, civic buildings and apartment buildings. Solar sunscreens and photovoltaic panels will be installed shortly on several commercial buildings within the development.

Transportation

The project has a city bus plaza located on site and provides mass transit by way of bus lines. On-site bus stops have computers that display the arrival time of the next bus that will be going to downtown Denver and nearby shopping areas. The community also offers a car-share program that has one electric and two natural gas-powered vehicles so members can rent a car by the hour when they need a vehicle for occasional errands. Restaurants, studios and shops have offices above them and live/work townhouses within close proximity so residents have the opportunity to work and shop within a short walk from their homes. Traffic control measures such as narrower streets were utilized to make the development more pedestrian-friendly.

Figure 20. Mixed-use and mixed-income housing at Highlands' Garden Village. Photo by Scott Dressel-Martin, courtesy of Perry-Rose, LLC.

Indoor Air Quality

Sealed combustion gas furnaces with outside combustion air are used on the project. Furnace ductwork joints are also sealed with low toxic mastic.

Resources: (Building Reuse, Materials, Waste

The historic theater on site was renovated creating a community performing arts center. The dome housing the old carousel was transformed into a walking labyrinth, the spiritual heart of the community. The entryway to the old amusement park and the greenhouse were restored as well.

All of the buildings' materials exceed Colorado's BuiltGreen and ENERGY STAR programs. The project used recycled and recyclable construction materials and environmentally conscious construction products. The senior and multi-family buildings were constructed using engineered wood I-joists, low VOC paints, concrete with a high flyash content, and decking,

carpeting and flooring made from recycled materials. The single family and townhomes were constructed using concrete with a high flyash content, engineered wood I-joists, reconstituted siding for exterior walls, carpet pads, insulation, and hardboard interior doors made from recycled materials. Avoidance of using large dimension solid lumber and use of engineered lumber products and efficient framing techniques were employed to reduce use of wood. Furnaces are centrally located where possible and all duct runs are reduced as much as possible. These homes also have built-in recycling centers in their kitche.

Thirty tons of concrete were recycled from the demolition and reused for the roadbeds. Job site waste was minimized by using materials wisely and prohibiting the burying of construction debris.

Effective Process Elements

1. ***Establish Guiding Principles for the development focused on sustainability***
   The guiding principles for the Highlands' Garden Village are influenced by New Urbanist Principles with a strong emphasis on sustainability:
   - Resourceful Land Use
   - Diverse Housing Types and Price Points
   - Historic Preservation
   - Green Building & Environmental Sensitivity
   - Creation of Community
   - Attention to the Public Realm & Sense of Place (Neighborhood Revitalization)

2. ***Set specific goals regarding sustainable design for the project***
   The goals set for the project included:
   - Reuse of the land and materials on site
   - Connection with public transit
   - Restoration of existing historic architecture and orchards
   - Income and age diversity
   - Diverse housing types (i.e. cohousing)
   - Energy efficiency

   A lot of thought went into the environmental impacts of the Highlands' Garden Village project and explicit outcome-based goals were set. A topological/hydrological study was conducted on the site. Energy modeling was done for the Sunflower Market.

3. ***Use sustainable guidelines and standards***
   In 1998 during project planning, LEED was still under development. There were no sustainable guidelines available, but the project followed BuiltGreen and ENERGY STAR programs and

Figure 21. Townhomes open onto a community park at Highlands' Garden Village. Photo by Scott Dressel-Martin, courtesy of Perry-Rose, LLC.

Figure 22. Community park at Highlands' Garden Village. Photo by Lance Neckar.

received a five-star rating from the Denver Home Builders Association's BuiltGreen Program and an "e-Star" certification by Energy Rated Homes of Colorado. In 2005, the new Sunflower Market retail building began participating in the LEED Core and Shell Pilot Program and is on track to receive a LEED Silver Certification. Colorado green building standards and EPA standards were also followed.

4. ***Use a participatory planning process and development of unique partnerships to achieve sustainability goals***

   Design workshops engaged citizens and community leaders in the redevelopment. A public survey was used to inform the master plan, and in turn, participants requested features in the plan, such as senior housing, mixed uses, and historic preservation. A Citizen Design Review Board was formed to review and give input into all building designs as well.

   In the Sunflower Grocery Store project on the site of Highlands' Garden Village, charrettes were held at the early phases of the project. The charrettes included the tenants, the building tenants' architect and the developer's and tenants' mechanical engineers. In this project, a unique tenant-landlord partnership emerged where the tenants were included in the design process and have agreed to spend some money toward the green features that would benefit them.

5. ***Select developers with prior commitment to sustainable design***

   The driving force for sustainable design was the developer's commitment to social and sustainability values. The partners of Perry Rose, LLC.—Chuck Perry and Jonathan Rose—have been committed to sustainable issues in their work for a long time.

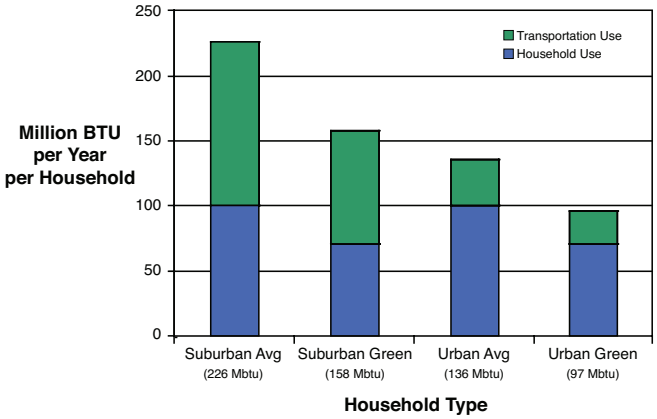


Figure 23. Energy used for Perry-Rose developments. Source: Perry-Rose, LLC.

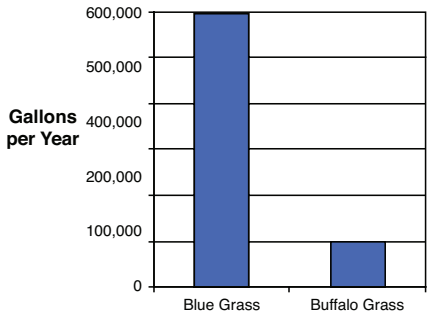


Figure 24. Irrigation water savings in Perry-Rose developments. Source: Perry-Rose, LLC.

Barriers to Sustainable Design

Barriers to sustainable design on this project were due to lack of knowledge in several areas. At the time, the implementation costs for sustainable design were unknown because of few precedents. The unknown costs associated with sustainable design hindered the process. Another issue was lack of knowledge about innovative practices such as stormwater management and pedestrian friendly design by local city officials. For example, the project team wanted to avoid having a curb on every street but had to deal with a lot of resistance from public works on this issue. Detention ponds and rain gardens to improve water quality were other examples of innovative practices where city officials needed education. Two approaches, developing partnerships and leveraging consumer enthusiasm, helped overcome these barriers.

Figure 25. Housing units at Highlands' Garden Village. Photo courtesy of Perry-Rose, LLC.

1. ***Develop partnerships***

   The developers provided support to a not-for-profit organization to renovate the historic theatre. In partnership with the Denver Botanic Gardens, the original garden entry was recreated. Developers worked closely with Denver Urban Renewal Authority (DURA) to structure tax increment financing plans (TIF) to help finance the green infrastructure of Highland Garden Village. To make the development pedestrian friendly, no auto-oriented land uses such as gas stations or restaurants with drive-through windows were placed within the development. Walking and bicycling within the community is encouraged through attractive landscaping, wide sidewalks, narrow streets and carless pathways.

2. ***Leverage consumer enthusiasm for sustainable practices***

   Consumers' enthusiasm for the green features of the development also helped give the developers the support they needed with the city officials. To help with the added upfront cost for some energy saving features for the Sunflower Market, energy savings will be monitored and utility cost savings will be shared between the tenant and the developer on a prorated basis.

Performance Outcomes

1. ***Contribution to sustainable development trends data***

   The Highlands' Garden Village development outcomes confirmed the trends that the developers, Perry Rose, LLC, had been observing related to sustainable development. As shown in Figure 23, the green urban development uses less energy for transportation in comparison to conventional and green suburban developments.

2. ***Comparison of landscape water use by xeriscaping versus conventional practices***

   Stormwater management and xeriscaping help conserve water resources. Figure 24 portrays the water savings through less irrigation of buffalo grass compared to conventional turf grass. The development as a whole consumes one-third less water than a conventional development.

3. ***Economic indicators of success due to sustainable development***

   The development has positive economic as well as environmental outcomes. There is 10% higher occupancy in Highlands' Garden Village in comparison to conventional developments built by the same developers. The rents received are higher and the sale prices tend to escalate quicker in this development as well. Both residential and commercial property values have increased at faster rates in the project area than in the region as a whole. The project has also spurred development on adjacent streets, raising the area's sales tax revenue by 20% during a period of regional sales tax decline.

CASE STUDY 3:
The Rapid, Surface Transportation Center, Grand Rapids, Michigan

The Rapid is a three-story transit facility located in Grand Rapids, Michigan, covering 51,000 square feet with a 500-foot platform that has a tension-membrane canopy for public bus transit. The $19 million facility is shared by Greyhound Bus Lines and Indian Trails for service outside the city.

The project focused on a day in the life experience of transit customers with particular attention paid to the experience of disability groups that rely on public transit. Security was also a very important aspect of the project.

The Rapid is a significant example of a transit facility that embodies sustainable design practices and raises awareness of transit through its innovative design. It is a potential model for other such developments nationally.

Sustainable Strategies

Site

The site is located on a reclaimed brownfield.

Water

The project has an extensive green roof that reduces stormwater runoff and settlement basins where debris separates out before the water is released back into the environment.

Energy

The green roof helps maintain temperature control in the building. The project uses daylighting, huge bands of low-E glass shaded from direct sunlight by deep overhangs, and clerestory windows.

Transportation

The entire facility promotes public transportation. It is a people-friendly inviting place for commuters with natural light, comfortable places to sit, and changing rooms and showers for bicycle commuters.

Figure 26. The Rapid transportation center. Photo by Chuck Heiney, courtesy of Progressive AE.

Figure 27. Natural light enhances the ticketing and waiting area. Photo by Chuck Heiney, courtesy of Progressive AE.

Figure 28. Canopy of The Rapid. Photo by Chuck Heiney, courtesy of Progressive AE.

Resources: Building Reuse, Materials, Waste

The project diverted construction and demolition waste from the landfill—75% of construction waste was diverted. The green roof is expected to significantly increase the life of the roof by shielding it from UV rays. Terrazzo and mezzanine (made of recycled glass) floors that are durable with little or no maintenance were used in the project. Recycled content materials were used during pre- and post-construction, such as recycled steel and concrete in the structure, and 20% of the materials were from local/regional harvesting and manufacturing sources.

Indoor Environmental Quality

Low-emitting materials—adhesives, sealants, paints, and carpet systems—were used on the project.

Effective Process Elements

1. Set explicit goals focusing on sustainable design alongside other project goals

An approach was taken to integrate sustainability goals with other important project goals. For example, the goal to make this project the first LEED certified transit center was also bound by the goals: to have the decisions stay within the maintenance and budget goals; and to have a positive impact on the visitors' experience. As it turned out, the intent to include sustainable design focus had a favorable impact on the budget as well.

2. Hold design meetings to focus on sustainable design issues with interdisciplinary project participants

The meetings included the steering committee from the client's side (leadership from finance, purchasing, facilities and maintenance, and a board representative), the lead architects, engineers and the construction manager.

3. Conduct environmental studies on the site prior to design

Phase 1 and 2 environmental studies were done when the project properties were purchased.

4. Use guidelines and rating systems

The LEED rating system and ASHRAE guidelines were used on the project as were good design practices for public transit facilities. This project was the first LEED-certified transit facility in the country.

5. Include champions for sustainable design on the project team

Two individuals from the architect's office championed the effort to make this project the first LEED certified transit center nationally. The director of the transit agency was an important champion as well. The team and client wanted the project to be a design icon as well as an example of sustainability.

Barriers to Sustainable Design

The separation of first cost and operating cost was a barrier on this project. Often on publicly funded projects, the capital and operating costs are in different budgets making it difficult to justify higher initial costs that result in lower long-term operating costs. Lack of adequate information on paybacks on first cost investments of green technologies was also a barrier to the project.

Performance Outcomes

The performance outcomes documented on the project are utility use for natural gas, electricity and water. The actual energy consumption of the building was less than energy consumption projected during design. The architect attributed this outcome to effective commissioning of controls and systems as well as the high performance design.

Figure 29. Under the canopy of The Rapid. Photo by Chuck Heiney, courtesy of Progressive AE.

CASE STUDY 4:
Pentagon Metro Entrance Facility, Arlington, Virginia

The Pentagon Metro Station is the most highly trafficked Metro stop in northern Virginia. Pentagon Metro Entrance Facility (PMEF), run by the Department of Defense, provides a link for more than 35,000 people arriving every day by public transportation to the Pentagon. The project covers 35,000 square feet and cost $36.5 million.

The project provides two bus lanes with a total of 24 bus bays. The lanes are staggered in elevation, with the outside lane lowered to allow for a pedestrian tunnel under the inside lane. This design enables passengers to safely access buses in the outside lane, simplifies routing of buses and passengers, and provides a better visual aesthetic than having a large paved area. A park-like landscape between the bus terminal, the Metrorail, and the Pentagon entrances also provides a pedestrian-friendly link to the Pentagon and encourages the use of public mass transportation. As a highly visible, well-used transit stop, the Pentagon Metro Entrance Facility is an example of the approach that might be taken when designing other such transit facilities across the nation.

Sustainable Strategies

Land Use

The project was a brownfield redevelopment.

Energy

The project estimates 20% savings in energy consumption and uses skylights for daylighting. The project uses high reflectance ENERGY STAR roofing.

Resources: Building Reuse, Materials, Waste

Over 50% of construction and demolition waste was diverted from the landfill during construction. Recycled concrete was used for the base material of all roadways and sidewalks. Over 50% of the building

Figure 30. Bus loading/unloading area of the Pentagon Metro Entrance Facility. Photo by Sisson Studios, Inc, courtesy of HDR Architects.

materials used were assembled within 500 miles, amd over 50% of the materials used in the project contain recycled content, including recycled-content ceiling panels. FSC-certified products were used for 21% of wood-based materials. The benches at the PMEF are constructed from FSC-certified Ipe' wood, which is naturally weather and insect resistant. Terrazzo flooring was used on the project for durability and low maintenance.

Indoor Environmental Quality

Low-emitting materials were used on the project including adhesives, sealants, paints, carpet systems, and composite wood. Permanent CO_2 monitoring systems were also used.

Transportation

The project provides parking spaces with electric vehicle outlets. It also provides bicycle storage and changing rooms.

Effective Process Elements

1. Establish a Statement of Need and Purpose integrating sustainability

The Pentagon Metro Entrance Facility (PMEF) was a congressionally mandated security project to relocate the Pentagon bus station farther from the building and to create a secure screening facility for visitors entering the Pentagon. A new building housing the tour and badge offices was constructed adjacent to the face of the Pentagon to allow for the screening of visitors prior to entering the main building. The statement of need and purpose reflected the goal of creating a delicate balance between the security needs of the Department of Defense and a welcoming and historically sensitive entrance to the Pentagon that also addressed sustainability.

2. Set sustainable design goals

This project was a precursor to Executive Order 13101 "Greening the Government through Waste Reduction, Recycling, and Federal Acquisition." Even without this executive order, there were goals to minimize environmental impacts as follows:

- Use Resources Efficiently
- Minimize Raw Material Resource Consumption During the Construction Phase as well as Throughout the Life of the Facility
- Reduce Energy Use
- Reduce Water Use
- Minimize Land Use Impacts
- Reduce Environmental Impacts of Materials
- Reuse Resources
- Use Renewable Energy Sources
- Create a Healthy Working Environment
- Build Facilities of Long-Term Value
- Protect and/or Restore the Natural Environment

Figure 31. Aerial image of the Pentagon Metro Entrance Facility. Photo by Sisson Studios, Inc. courtesy of HDR Architects.

3. Use sustainable guidelines and standards

The environmental issues on the Pentagon Metro Entrance Facility project followed the Executive Orders 12843 and 12873 related to greening of federal buildings and operations passed under the Clinton Administration. It is the first project in a series of projects to implement greening issues into the construction and operations of government

Figure 32. Pedestrian entrance of the Pentagon Metro Entrance Facility. Photo by Sisson Studios, Inc, courtesy of HDR Architects.

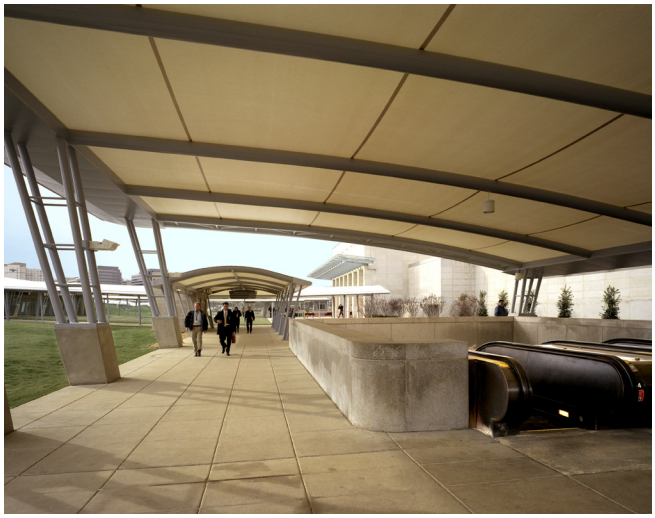


Figure 33. Under the canopy of the pedestrian entrance of the Pentagon Metro Entrance Facility. Photo by Sisson Studios, Inc. courtesy of HDR Architects.

buildings. LEED 2.0 for Existing Buildings was also utilized on this project. The PMEF is the first Department of Defense facility to receive LEED certification from the USGBC. The Secretary of the Interior's and ASHRAE standards as well as Pentagon Renovation Program requirements were followed throughout the design and construction of the project.

4. Include sustainability focus in the team planning process

The Department of Defense coordinated its efforts with the Washington Metropolitan Area Transit Authority, Virginia Department of Transportation, and the Americans with Disabilities Act/Accessibility Focus Group. A charrette that focused on general issues including sustainability was held after the design development phase. Architects, building operators, commissioning engineers, electrical engineers and their subcontractors were included in the charrette. The PMEF project was reviewed by the Virginia State Historic Preservation Officer and other governmental review commissions since the Pentagon is listed as a National Historic Landmark.

5. Include champions for sustainable design on the project team

Michaella Wittman from HDR Architects was one of the driving forces for sustainability on this project. The staff from the Pentagon Renovation program upholding the executive orders also aided in maintaining the sustainability focus of the project. Evey Design-Build also played a role in this regard.

Barriers to Sustainable Design

The first barrier to achieving sustainable design on the project was that the idea of sustainability was still relatively new. The second barrier was that the considerations for sustainability came late in the design process. Lastly, the project's focus on security issues made it difficult to incorporate other issues into the design process.

CASE STUDY 5:
Woodrow Wilson Bridge Project
Maryland and Virginia

The Woodrow Wilson Bridge over the Potomac River connects Maryland and Virginia. Named after Virginia-born President Woodrow Wilson, it is one of seven highway crossings over the Potomac River within the Washington, D.C., metropolitan area. It carries the I-95/I-495 Capital Beltway over the Potomac River at Alexandria, Va. The bridge's west abutment is in Virginia, its east abutment is in Maryland, and about 100 feet of the mid-span portion of the bridge crosses the tip of the southernmost corner of the District of Columbia. After a rigorous local government and community involvement process, the state and federal DOTs (Federal Highway Administration, Virginia Department of Transportation, Maryland Department of Transportation, Maryland State Highway Administration, and District Department of Transportation) proposed to build a new 12-lane, twin-span Potomac River Bridge, with 70 feet of vertical navigational clearance at a cost of $ 2.4 billion.

The Woodrow Wilson Bridge has demonstrated innovative sustainable practices for infrastructure building in environmentally sensitive areas and outstanding participation from both local governments and the community in planning of the project to meet environmental concerns. It is a model for other infrastructure development nationally.

Sustainable Strategies

Site/Habitat

The project required that fish be protected during water pile driving activities that were necessary to support the bridge foundations. Since large piles can produce pressure waves in the water that can injure or kill fish, the project quickly devised and implemented a solution called an "Air Bubble Curtain System," to protect the fish population during pile driving. This system not only allowed pile driving to be completed on schedule, but also provided the project and regulatory agencies with valuable information regarding the protection of fish during construction.

Figure 34. Aerial view looking north at the Woodrow Wilson Bridge. Photo by Top Shots photography, courtesy Potomac Crossing Consultants.

The project also created a permanent 84-acre bald eagle sanctuary north of Rosalie Island in Prince George's County, Md. The project's ongoing efforts to protect the eagles and their habitat are part of the $65 million worth of environmental mitigation programs that are being implemented to compensate for unavoidable impacts to environmental resources in the path of the project.

Other key environmental successes that were executed on the foundations contract include reducing expected impacts to surrounding waters and wetlands through sound minimization techniques and reduced dredging requirements through selective use of equipment.

Water

Hundreds of thousands of gallons of concrete wash water necessary to clean the heavy-duty conveyor systems were effectively managed, thus minimizing impact on the Potomac River.

Resources

Cofferdams, or steel boxes, were installed in the shallows of the river to provide a work area for foundation workers, thus providing protection for the workers and the river. Management techniques were deployed that enabled detailed tracking of environmental permit compliance.

Figure 35. View looking at the Woodrow Wilson Bridge opening. Photo by Potomac Crossing Consultants.

Effective Process Elements

1. Incorporate environmental goals and public participation

An initial negative response from the public and local communities led to environmental responsiveness by agencies and outstanding efforts were made to address these issues. That the bridge would not be used by the neighborhood/communities it traverses ended up being the driving force in making it an environmental project. The initial process to move the bridge project forward was shut down due to public concerns about the project. Two years later, the project was restarted. This time, it included serious environmental goals and public participation that led to a successful interdisciplinary and inter-agency project. Seven to eight work groups were formed and included members from different agencies, government staff, and volunteer groups that examined and worked through about 350 ideas for the bridge project before delivering environmental reports on noise, air and other concerns.

2. Use design charrettes with the participation of diverse stakeholders in the project

Design charrettes were held to develop and examine design alternatives to the bridge idea itself as well as for the bridge designs. Design work groups were comprised of designers and stakeholders who were invited or nominated to participate. Six months of work went into the recommendations of the design work group.

3. Appoint two parallel groups, one monitoring construction quality and the other monitoring environmental compliance

Thirty-plus contractors were involved in implementing the project from plans to construction. To ensure meeting the original environmental goals and standards, government staff monitors were appointed to work with the contractors and

an independent environmental monitor conducted environmental audits of the process. The environmental monitor was empowered to stop the work if necessary.

Other Barriers

While there were no barriers specifically in terms of meeting the environmental goals in general, the history of the Big Dig tunnel project in Massachusetts with its cost overruns and delays influenced how state and federal agencies viewed large infrastructure projects. This view affected the bridge project process and it was audited many times as state and federal teams scrutinized invoices regularly.

Performance Outcomes

Focus areas and outcomes to be addressed were determined during the design phase. A five-year mitigation plan was also established. In relation to planting done along the construction area, many efforts were made to observe and document the progress of the planted areas and reinstate new plantings where the first batch failed. Extensive work was done in terms of removal of construction-related material in the stream to meet project goals. Monitoring of the project is still ongoing.

Outcomes include the following list of environmental mitigation projects initiated as part of the Woodrow Wilson Bridge Project and the current status of each:

- Twenty-two fish passageways and one "fish ladder" created to allow fish to spawn upstream of previous man-made barriers on Rock Creek and Anacostia River tributaries. Status: Completed
- Fifteen million River Herring stocked in Rock Creek and Anacostia River tributaries. Status: Completed
- More than 33 acres of wetlands created, enhanced, and/or restored in Prince George's County. Status: Ongoing

Figure 36. View looking east at sunrise of the Woodrow Wilson Bridge construction. Photo by Joseph Romeo, courtesy of Potomac Crossing Consultants.

- Wilson Bridge Project Area—over 6 acres of wetlands created or enhanced in Fairfax County. Status: Ongoing, 50% complete
- Eighty-four acre bald eagle sanctuary to be established in Prince George's County. Status: Completed
- Four acres of wetlands created or enhanced in Alexandria. Status: Completed
- Three acres of wetlands created in Prince William County. Status: Completed
- Twelve-hundred linear feet of stream bank stabilization and 1,300 segmented feet of breakwaters built to create 5 acres of juvenile fish habitat in Fairfax County. Status: Completed
- More than 100 acres of wetlands created or preserved at two sites in Stafford County. Status: Completed
- Fifty acres of agricultural land restoration, at the Shirley Plantation on the James River, using 500,000 cubic yards of dredge material from the project. Status: Completed
- Twenty-two acres of river grasses planted in the lower Potomac River, serving as fish habitat and cleaning the water. Status: Completed
- Thousands of tons of the old Woodrow Wilson Bridge used to create a fish reef in Chesapeake Bay. Status: Ongoing

Figure 37. View of the Washington Street Urban Deck, Alexandria, Va. Photo by Potomac Crossing Consultants.

Figure 38. View of the reconstruction of U.S. Route 1 interchange. Photo by Trevor Wrayton of VDOT, courtesy of Potomac Crossing Consultants.

- More than 140 acres of woodlands planted or preserved in Prince George's County. Status: Completed

Project Successes

Using innovative solutions and management practices that protected and enhanced the natural environment and neighboring communities, the $125 million foundations contract was completed on-time and on-budget in a manner that met and exceeded stringent permit conditions.

In addition, the Woodrow Wilson Bridge influenced other developments due to the innovative practices implemented during the project. One such example is the recycled material (2,000 tons) used to create a fish reef in the Chesapeake Bay. This effort has spurred an increase of the reuse of old material from infrastructure in Maryland. Another such example is the use of dredge material from the project (500,000 cubic yards) to refill an old quarry in an agricultural area that is now being used as agricultural land again.

CASE STUDY 6:
Marjorie Harris Carr Cross Florida Greenway (Wildlife Crossings Land Bridge)

This 52.5-foot-wide (16-meter-wide) overpass was the first-ever "land bridge" in the United States and was completed in 2000. The bridge lies inside a strip of the Marjorie Harris Carr Cross Florida Greenway that crosses I-75 just north of County Road 484 in Marion County. It rejoined the two halves of the greenway, a 110-mile conservation and recreation corridor split by the interstate years ago. The corridor stretches across the state through rivers, floodplains, lakes, wetlands, ridges, and uplands. Federal transportation enhancements funded the $3.4 million project. The land bridge provides trail users and wildlife safe passage across I-75 where 50,000 drivers pass under it on a daily basis. In addition, hikers, cyclists and horseback riders enjoy an uninterrupted tour of the greenway. Among the bridge's innovative features are a built-in irrigation system, 18-foot (5.5-m) planters on both sides, a 16-foot-wide (5-meter-wide) trail for bicyclists, pedestrians and horseback riders and an oval "passing area" in the center for horse-and-buggy carriages.

This land bridge project, modeled after "ecoducts" from the Netherlands, was the first such project in the United States and was a step forward for the emerging field of road ecology that considers both transportation needs as well as the needs of wildlife and the natural environment. It is a model for other infrastructure development nationally.

Sustainable Strategies

Site/Habitat

Because native plants were used for vegetation on the project, the bridge provides a safe passageway/temporary habitat for deer, fox, coyotes, possums, and other small- to medium-sized mammals that cross the highway through native vegetation on the sandy soil they are used to.

Figure 39. Aerial photo of the Marjorie Harris Carr Cross Florida Greenway. Photo by Sky Storms, courtesy of the Florida Department of Environmental, Protection's Office of Greenways & Trails.

Effective Process Elements

1. ***Use sustainable guidelines and standards***
   Land bridges designed in Europe were an influence on this project. Guidelines from the Netherlands for land bridges were used.

2. ***Attract additional enhancement funds***
   Cost was a perceived barrier on this project—community participants felt money from larger transportation funds was being directed to this land bridge at the expense of other transportation efforts, but in fact this project was able to attract transportation enhancement funds that would otherwise have not been available.

Performance Outcomes

The performance outcomes for this project were determined keeping in mind the three users of the project—wildlife, equestrians and humans. Meetings held with Florida Department of Environmental Protection staff, local community, and local non profit organizations and Florida Department of Transportation staff helped determine the outcomes. The DEP is monitoring wildlife crossings, human and equestrian use.

Figure 40. Aerial photo of the Marjorie Harris Carr Cross Florida Greenway. Photo by Sky Storms, courtesy of the Florida Department of Environmental, Protection's Office of Greenways & Trails.

Figure 41. Marjorie Harris Carr Cross Florida Greenway. Photo by John Moran, courtesy of the Florida Department of Environmental, Protection's Office of Greenways & Trails.

Figure 42. Marjorie Harris Carr Cross Florida Greenway. Photo by John Moran, courtesy of the Florida Department of Environmental, Protection's Office of Greenways & Trails.

E. Conclusion

It is evident that environmental issues are of critical importance and that transportation projects can and should play a significant role in addressing these problems at all scales. The goals of the study have been to determine critical outcomes to be measured, to identify appropriate practices and strategies to achieve those outcomes, and to understand an effective process to ensure and measure success. This study has surveyed current practices, processes and outcomes through an analysis of guidelines as well as selected case studies.

Environmental Assessment Methods, Ratings Systems and Guidelines

In the past few years, there has been a proliferation of environmental assessment methods, ratings systems, and guidelines. Most have been developed at the building scale, but they are emerging at the development and infrastructure scales as well. There is a diverse set of approaches to the topics covered, the accommodation of building type variations, and methods of implementation. The LEED rating systems, developed by the US Green Building Council, represent a highly visible, dominant approach in the market place at this time. However, in such a rapidly evolving field, other alternatives such as Green Globes at a national scale and numerous regional rating systems continue to be developed. This occurs in response to new ideas and implementation approaches as well as simply the need to adjust for local conditions with local stakeholder participation. Emerging guidelines for existing buildings such as LEED and Green Globes begin to address the need for monitoring projects to provide a feedback loop for continuous improvement. When developing or evaluating a system, consider the AIA position on guidelines and rating systems (Figure 43).

It is clear that increased public awareness of the magnitude and urgency of climate change and future energy supply have had two effects. First, sustainable or green building guideline adoption by cities and states is more widespread. By adopting voluntary guidelines as public policy, they are in effect being made mandatory or serve as the basis for financial and other incentives. Guidelines are now being written in the form of standards that can be more easily adopted into building codes. A second effect is that the levels of required performance in the standards are increasing. Until recently, small incremental improvements in energy efficiency were sufficient, but these modest goals are giving way to more aggressive performance levels for energy and carbon emissions such as those stated in *Architecture 2030* effort.

Sustainable development, building and infrastructure guidelines and rating systems really have two distinct aspects—they identify what to do to achieve sustainability and they provide a means of assessing performance. Most guidelines today consist of best practices, processes to ensure success and compliance, and a limited number of actual performance outcome calculations. Assessing performance is often equated with number of points or levels of achievement in point-based rating systems. While simple to understand and implement, this can be misleading by assuming that the highest point rating translates into the best building performance. While performance outcomes are embedded in these systems, the quantifiable environmental footprint of a project is not evident from the rating. Guidelines are tools, not ends in themselves. For this reason, maintaining a focus on outcome-based approaches is critical to meeting long-term sustainable design goals. The desire for measurable outcomes is also represented by the growing use of life cycle assessment tools to assess the environmental impacts of building materials.

Case Studies

The case studies in this report reveal several things about the current state of sustainable design at the development, building and infrastructure scales. At the development scale, Prairie Crossing and Highlands' Garden Village are good examples of transit-oriented development that apply a number of sustainable design practices and principles. Prairie Crossing includes a walkable, mixed use neighborhood development near transit as well as lower density, clustered residential development that leaves significant land area to be restored to a natural state. Highlands' Garden Village is also a walkable, mixed use neighborhood located on an infill site within an existing city. In both cases, access to transportation, land use, density, water use, stormwater management, energy, indoor health and resource use were considered in the designs.

Successful process elements at Prairie Crossing included establishing Guiding Principles and starting a Homeowner's Association committed to sustainability. Stormwater and hydrology modeling was done at the start of the project as well as surveying and monitoring of bird and plant species. At Highlands' Garden Village, establishing Guiding Principles and following available energy guidelines were important. Using a participatory planning process and development of unique partnerships to achieve sustainability goals were also effective. In both developments, important

Figure 43. American Institute of Architects (AIA) position on sustainability rating systems and standards.

The AIA supports the development and use of rating systems and standards that promote the design and construction of communities and buildings that contribute to a sustainable future. The AIA encourages through the efforts of its Board Committees, Knowledge Communities, Task Forces, Working Groups, and related activities the inclusion of the following features in "green building" rating systems, standards, or regulations for the design and construction of the built environment. That it:

1. Is developed and renewed on a regular basis through a consensus-based process, in which all interested parties can participate;
2. Require clearly defined design documentation to demonstrate compliance;
3. Require compliance to be validated by an independent third party;
4. Require the development of sustainable sites avoiding the conversion of prime agricultural lands or wetlands, regenerating brownfield sites, or those that result in regenerative benefits to the natural environment;
5. Require specific goals in the efficient use of water resources that promote application of new wastewater technologies;
6. Require specific goals for significant reductions in energy use, especially non-renewable energy sources, with enhanced performance assured through commissioning of building systems;
7. Promote the use of renewable energy sources;
8. Require reduced use of non-renewable natural resources through the reuse of existing structures and materials, reductions in construction waste, promotion of recycled content materials, and use of materials independently certified as from sustainable sources;
9. Require specific goals for improved indoor environmental quality through enhanced indoor air quality, thermal comfort, acoustics, daylighting, and pollutant source control and use low-emission materials and building system controls;
10. Promote the development and application of innovative designs and collaborative processes intended to improve environmental performance;
11. Recognize the life cycle value of a community or project in addition to construction first costs, including assessment of impact on climate change, acid rain, water pollution, resource depletion, and toxicity factors;
12. Utilize life cycle assessment data as the basis for design and construction decision making;
13. Acknowledge national, regional, and bio-climatic differences;
14. Reduce (and eventually eliminate) on-site and off-site toxic elements in the built environment;
15. Require specific measurable reductions in CO2 production in the built environment; and
16. Require documentation of actual building energy and operational performance.

elements of success were the presence of champions committed to sustainable design in leadership positions on the team. Performance outcomes that have been monitored at Prairie Crossing include stormwater management, water quality, wildlife and prairie plantings. At Highlands' Garden Village, available outcomes include economic indicators, analysis of water use for landscaping, and comparison of energy use for housing and transportation to other development types.

At the building scale, the Rapid Surface Transportation Center and the Pentagon Metro Transit Entrance Facility are excellent examples of sustainable design. Both address site, water, energy, indoor environment and resource issues. Both projects applied the LEED Rating System in addition to other standards and guidelines. The Rapid project was the first LEED-certified transit facility in the country. Successful process elements include setting explicit goals focusing on sustainable design alongside other project goals and holding design meetings to focus on sustainable design issues with interdisciplinary project participants. Similar to the development scale projects, an important element of success in both building case studies was the presence of champions committed to sustainable design on the team. Performance outcomes in these two projects are limited to collecting energy and water use data with no clear plan to feed this information back into a knowledge base for continuous improvement.

At the infrastructure scale, the Woodrow Wilson Bridge Project and the Marjorie Harris Carr Cross Florida Greenway Land Bridge illustrate several innovative strategies. The Wilson bridge is notable for requiring that fish be protected during water pile driving activities that were necessary to support the bridge foundations. Significant effort was also made to minimize the impact of construction on the Potomac River. The Land Bridge is notable because it provides a safe passageway and temporary habitat for small- to medium-sized mammals that cross the highway through native vegetation on sandy soil. The process used in the Wilson bridge project incorporated environmental goals and extensive public participation including the use of design charrettes with diverse stakeholders. During the bridge project construction, two parallel groups were appointed to ensure a successful outcome, one monitoring construction quality and the other monitoring environmental compliance. The Wilson bridge project has an extensive number of environmental improvements that are being monitored including several wetland and habitat restoration projects on adjacent land. On the Land Bridge project, monitoring of wildlife crossings, human and equestrian use is occurring.

The Future

While there is significant progress, emerging guidelines and standards, and good examples of design process and finished projects, the urgency and magnitude of current environmental issues requires more action.

There is a knowledge gap between what designers want to know and what current tools can tell them about performance outcomes. Effective life cycle cost (LCC) and life cycle assessment (LCA) tools are needed as well as more comprehensive tools such as an "environmental balance sheet."

As better tools are being developed, a better understanding of critical outcomes and the appropriate metrics will continue to come into focus. While all of the case studies include some performance outcome calcualtion and monitoring, they are not comprehensive. At the development scale, emerging metrics include total vehicle miles driven and related emissions, overall water and energy consumption, open space and preservation or restoration of ecological systems. Other emerging metrics at the planning scale are discussed in the recenty published book

Sustainable Urbanism (Farr, 2007). At the building scale, measurable outcomes are carbon emissions, energy use, potable water use, wastewater produced, and stormwater runoff. Information on embodied life cycle environmental impacts of materials is emerging with metrics such as energy, global warming potential, water pollution, air pollution, and resource depletion. At the infrastructure scale, outcomes may include the preservation of wildlife species within an ecosystem near a road or bridge project.

Improved tools and metrics will also help to address other barriers to implementing sustainable design. These include lack of awareness of environmental impacts, resistance to accepting new ideas and technologies, and increased cost. Cost can be a greater challenge but effective planning that identifies mutually beneficial partnerships can add resources to a project. Full cost accounting of environmental impacts combined with comprehensive life cycle cost analysis helps justify increased initial costs.

It is well known that following guidelines and standards does not necessarily result in the predicted performance. An important element in transforming the built environment to be more sustainable is the creation of feedback loops that occur through monitoring project performance and conducting post occupancy evaluations. The resulting information needs to be collected and maintained in common publicly accessible knowledge bases that can inform not only the specific building owners, operators and occupants, but that also inform the design professions and the public.

F. Principles and Practices

The guideline review and case studies revealed key principles and practices to enhance environmental and health outcomes that can be applied to transportation projects at all scales.

1. ***Address sustainability throughout project design***
   Transportation projects at all scales have substantial impacts on environmental problems such as global warming, destruction of ecosystems, and loss of biodiversity that need to be urgently addressed. There is need for more comprehensive assessment of the impacts of transportation projects on natural systems. Projects should not only be designed to minimize environmental damage but be seen as opportunities for ecological restoration.

2. ***Apply elements of an effective design process to the project***
   Integrated design is an emerging practice critical to achieving sustainable design goals in transportation projects. Integrated design identifies a broader range of issues early in the process and addresses them with an interdisciplinary team approach. Critical elements of a successful process include establishing guiding principles, involving key stakeholders in a participatory planning process, and holding design charrettes.

3. ***Focus on performance outcomes during project design***
   To achieve sustainable goals, performance outcomes must be made explicit during design of transportation projects. Outcomes vary depending on the project scale, site and function. Existing tools and methods must be utilized and new ones developed to assist in the design process.

4. ***Measure performance outcomes during the life of the project***
   There is a critical need to measure outcomes during the operating life of a transportation project. This will also provide a feedback loop for continuous improvement within the project and collective information to the design professions.

5. ***Apply appropriate sustainable guidelines, rating systems, and standards to the project***
   Emerging practices such as the use of voluntary or required guidelines and standards are effective in helping identify goals, educating stakeholders, and establishing an integrated design process on transportation projects.

6. ***Use education to overcome barriers to sustainable design***
   Education through public engagement in the process as well as designs that make environmental features visible are helpful strategies to increase awareness of environmental impacts. Providing information about costs and actual benefits can also overcome resistance to accepting new ideas and technologies.

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