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SUSTAINABLE URBAN STREET DESIGN AND ASSESSMENT

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ABSTRACT

A tremendous opportunity is emerging to greatly enhance the sustainability of urban areas by changing approaches to street design. In the United States there are four million miles of streets and highways. Street construction is expensive and consumes substantial material and energy resources during construction. In the U.S., 80 percent of the population lives in cities and much of this urban land is devoted to street right-of-way. Most of the current roadway infrastructure was developed based on guidelines that emphasize vehicle mobility and safety and minimizing short-term upfront costs, with less consideration given to social and environmental aspects.

This paper identifies an approach for applying sustainable design guidelines for urban streets. By defining sustainability in a broader context a case will be made for enhancing the sustainability of urban streets. Relevant sustainable solutions and their application to urban streets will be described and visual examples of numerous options are provided. Guidelines for assessing sustainable urban street options will be discussed along with key challenges facing the widespread adoption of these principles.

Considering and assessing sustainable options will enable urban streets to function in a manner that is more beneficial to people, communities, the economy and the environment.

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INTRODUCTION

This paper identifies an approach for applying sustainable design guidelines for urban streets. By defining sustainability in a broader context a case will be made for enhancing the sustainability of urban streets. Relevant sustainable solutions and their application to urban streets will be described and visual examples of numerous options are provided. Guidelines for assessing sustainable urban street options will be discussed along with key challenges facing the adoption of widespread sustainable urban street implementation.

This paper primarily addresses the design, construction and maintenance of streets inside existing urban cities. As such, it presumes that streets are needed and appropriate in most cases. In other words, that an analysis of the broader transportation problem has been made, and transportation alternatives including no action have been evaluated, and a street has been identified as the appropriate solution. The question of where urban development should be allowed through land use planning is not addressed in this paper. It should be noted that destroying sensitive environmental resource areas or otherwise eliminating natural landscapes to build new roads may not be a sustainable practice regardless of the design. This paper also does not address the more ambitious approaches such as closing existing streets to motorized traffic or for exclusive transit operations such as in some European cities.

Considering and assessing sustainable options will enable urban streets to function in a manner that is more beneficial to people, communities, the economy and the environment. With 80 percent of the U.S.'s population living in urban areas, urban streets should serve the public across all modes of travel and provide key mobility links within urban communities. Public right-of-way is one of the primary categories of public land in communities and affects livability. However, most of the current roadway infrastructure in the U.S. is based on guidelines that emphasize vehicle mobility and safety and minimizing short-term upfront costs, with less consideration given to social and environmental aspects.

There is an increasing need to invest and revitalize the aging infrastructure in the United States, which is also a prime opportunity to implement new design practices that focus more on sustainability. A comprehensive list of Sustainable Urban Street Options (see Appendix) is proposed to enable street designers to consider potential features to enhance and incorporate urban sustainability in the street right-of-way. A total of 161 options have been identified, which cumulatively align to five broad goals:

- Reduce Energy Consumption
- Reduce Consumption of Material Resources
- Reduce Impacts to Environmental Resources
- Support Healthy Urban Communities
- Support Sustainability During Implementation

Throughout the paper representative examples of sustainable options are provided, and the general category that each option aligns with.

Support Energy Efficient Movement of People: Transit Lanes, Curitiba, Brazil

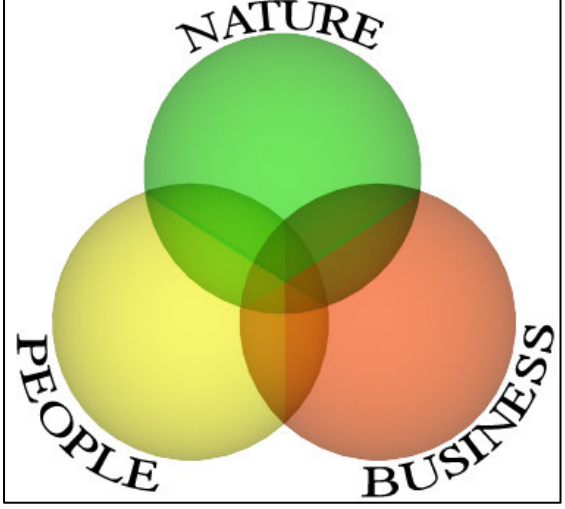
Support Energy Efficient Movement of People: Enhanced Bus Zone and Shelter, Richmond, Canada

DEFINITION OF SUSTAINABILITY

What is sustainability? There are a variety of definitions, but all share similar tenets. The oft-quoted definition by Norwegian prime minister Gro Harlem Brundtland states that sustainable development is one that "meets the needs of the present without compromising the ability of future generations to meet their own needs." The Wikipedia definition says, sustainability is "a means of configuring civilization and human activity so that society and its members are able to meet their needs and express their greatest potential in the present, while preserving biodiversity and natural ecosystems, and planning and acting for the ability to maintain these ideals in a very long term."

Central to these definitions is sustainability's applicability to three elements of life: nature, people and business, as represented in Figure 1. The interlocking circles show that all three of these categories are highly interdependent. For example, at a global level, business flourishes when water is abundant and raw materials are plentiful. People (and the environment) are healthy when they have clean air and water. People prosper when their businesses and institutions prosper. The idea of this interaction continuing on indefinitely is central to sustainability.

FIGURE 1
THREE ELEMENTS OF SUSTAINABILITY



The importance of sustainability has become a recognized driving force in determining society's course of development. Increased pressure on natural ecosystems, rapid industrialization in emerging countries, the continued and increasing demand for raw materials,

water shortages, and an aging civil infrastructure all serve as examples of strain to the planet. In regard to climate change the Intergovernmental Panel on Climate Change writes “Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting snow and ice, and rising global average sea level.” (*1*). Unsustainable practices have led to many of these issues.

Require Less Infrastructure in Solution:
Catenary Lighting System, Stockholm, Sweden

Minimize Impact on Natural Environment:
Bioretention Swales, Seattle, Washington, U.S.A.

CASE FOR SUSTAINABLE STREETS

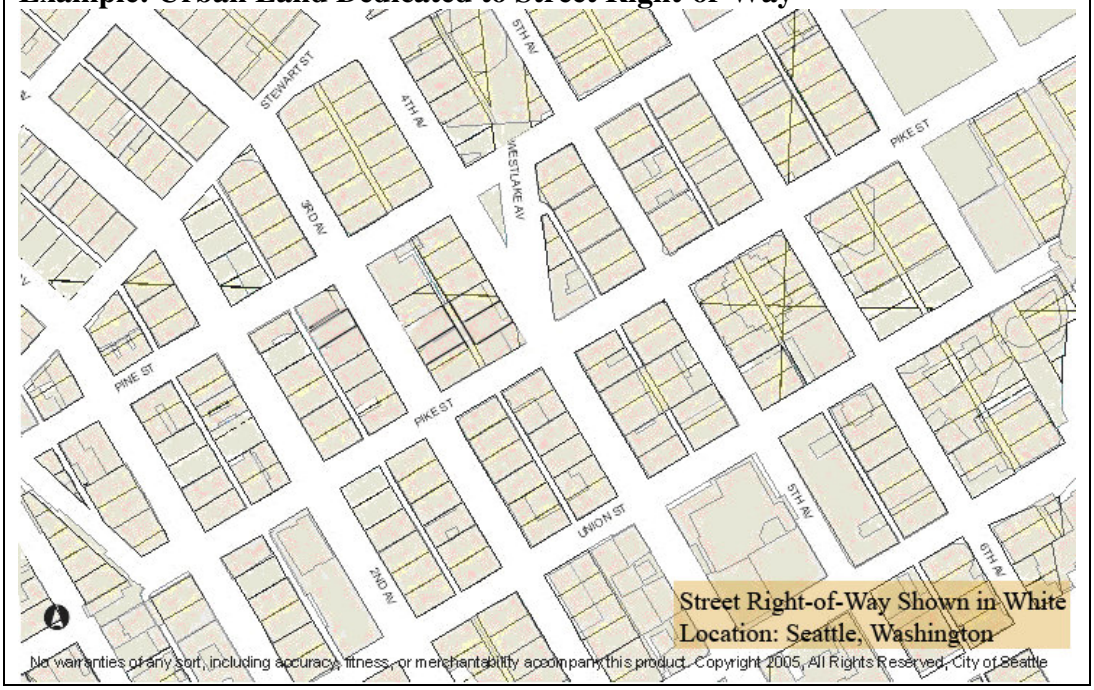
In 2006, the transportation sector accounted for two-thirds of the U.S.’s oil consumption, and 28 percent of the total energy (*2*). New traffic lane construction in urban areas costs an average of 1-to-8 million dollars, per mile (*3*). The amount of material used and energy consumed in street construction and improvements is staggering. Although interest in sustainable design has increased within select sectors of the construction industry (mainly buildings), little has been done in terms of developing options and guidelines for sustainable street design.

Several key points illustrate the scale of opportunities where positive impacts can be made, in the U.S. alone:

- There are four million miles of streets, highways and bridges in the U.S.
- 80 percent of the population lives within cities (*4*)
- 25-40 percent of land within urban areas is in the public streets right of way; land owned, used, maintained and utilized by the public

Figure 2 represents GIS data for a portion of Seattle, Washington. Urban streets are delineated in white and represent approximately 40 percent of this area, while private property is lightly colored and comprises the other 60 percent. This situation is typical for U.S. cities. Because urban street rights-of-way comprise large percentages of urban land, they are an ideal infrastructure for focused sustainable design practices.

FIGURE 2
Example: Urban Land Dedicated to Street Right-of-Way



Urban streets play a strong role in how cities are built and function. Cities with poorly designed urban streets, inadequate transit and unfocused development result in urban sprawl. As a result more vehicle trips are generated, congestion on roads increases, and communities become more isolated and less livable as a result. Time spent by individuals commuting negatively impacts their health from prolonged sitting, stress from driving in heavy traffic and less time for exercise. More fuel used by vehicles consumes mainly non-renewable resources and increases air pollution.

Implementing sustainable urban streets can create more livable communities. With amenities and attractions closely located, individuals are more likely to utilize alternative mode choices such as walking, biking or transit, which leads to improved health of individuals and the environment. Total vehicle miles traveled are reduced and less land needs to be developed because of a greater population density. Streets busy with pedestrian and bicycle traffic are safer and strengthen a sense of community.

The possible growth for sustainable urban street design has the potential to follow or exceed the dramatic growth seen in the area of green building. Energy used by buildings represents close to half of the U.S.'s total energy use. Seeking a way to standardize the certification of green buildings, The United States Green Building Council (USGBC) created the Leadership in Energy and Environmental Design (LEED) certification system, now the international baseline for green building. Since its inception in the year 2000, USGBC membership has seen a 10-fold increase and as of May 2007, 824 projects have become LEED certified (*5*).

Redeveloping baseline guidelines for street design and incorporating sustainability as a key aspect in new development and redevelopment will entail positive change for nature, people and business.

DEFINING SUSTAINABILITY FOR URBAN STREETS

A compilation of 161 potential Sustainable Urban Street Options that can support sustainability has been assembled by CH2M HILL in the Appendix, Sustainable Urban Street Options. The intent is to consider and evaluate all options and seek to integrate as many as are practical, depending upon the context and function of the specific project.

Features that Support Community and Livability: Art in Walls, Portland, Oregon, U.S.A.

Features that Support Community and Livability: Sidewalk Art, Seattle, Washington, U.S.A.

On a broader scale, many of the options within the Appendix table draw from already established sustainability oriented practices. Examples are Low Impact Development (LID) for storm water management practices, support of alternative transportation modes (biking, walking, and transit) and the use of recycled materials. A comprehensive approach is achieved by providing a rich set of readily available options that can be used for projects that aspire to accomplish higher levels of environmental and sustainable standards.

The broad categories that CH2M HILL's Sustainable Urban Street Options address are (listed in no particular order):

Reduce Energy Consumption

This category includes options and project solutions that reduce energy consumption, such as solutions that support non-motorized travel, solutions that support energy efficient movement of people and goods, and solutions that use resources with lower operations and maintenance requirements.

Reduce Consumption of Material Resources

This category includes design solutions that reduce consumption of material resources. Design options that use recycled materials in construction, require less infrastructure in the solution, or increase durability and life of the design solution are addressed here.

Reduce Impacts to Environmental Resources
Solutions that reduce impacts to environmental resources are addressed here. This category includes solutions that minimize impacts on the natural environment, encourage and support biodiversity, and reflect historical and cultural context.

Support Non-Motorized Travel:
Separate Bike Lanes, Amsterdam, Netherlands

Features that Support Community and Livability:
Trash + Recycling Receptacles, Melbourne, Australia

Support Healthy Urban Communities
Sustainability options that support healthy urban communities are listed here. This category includes solutions that incorporate features that support community livability, public services and adjacent land uses, and enhance public health, safety and security.

Support Sustainability During Implementation
The final category of the Sustainable Street Design Options Table is for sustainability options that can be considered during the implementation of street projects, such as solutions that support local economic, social, and resource management needs, or that reduce impacts during construction.

Minimize Impact on Natural Environment:
Permeable Pavers, Seattle, Washington, U.S.A.

Features that Support Community Livability:
Public Toilet, Sydney, Australia

Certain elements within one category have overlapping benefits with another category. As an example, the use of porous pavements in sidewalks or parking areas increases the amount of

stormwater retained on site and reduces runoff impacts to environmental resources; as a result less detention vault capacity needs to be constructed which in turn reduces the consumption of resources. Likewise, not all of the options can be implemented and some of them conflict with each other. As an example, there is some inherent conflict between using narrow streets and providing adequate emergency vehicle access or simultaneously providing truck access and pedestrian access within a confined right-of-way.

Although sustainable street design is still in its infancy, a number of new projects are emerging. In the U.S. cities such as Seattle, Portland, San Francisco and Chicago are leading the way with adopting sustainable practices and implementing pilot projects. Many European nations have a longer-standing commitment, especially in Western Europe and Scandinavia. Future projects can draw on the experience and research already in place.

A few examples of options from CH2M HILL's Sustainable Urban Street Options Table are provided in Table 1 below, with the full table provided in the Appendix.

TABLE 1

SUSTAINABLE ASPECT	A FEW EXAMPLES OF OPTIONS
Reduced Energy Consumption	• Traffic Signal Coordination/Optimization • Low Energy Lighting • Transit Lanes • Bike Lanes • Transit Signal Priority
Reduce Consumption of Material Resources	• Recycled Aggregates • Narrow Traffic Lanes • Fewer Luminaire Poles/Catenary Lighting System • Higher Strength Concrete Pavements • Precast or Modular Construction Elements
Reduce Impacts to Environmental Resources	• Rain Gardens for Storm Water Infiltration • Diverse Plant/Tree Selections • Interconnected Bioretention Swales • Storm Water Infiltration Basins in Planter Strips • Porous Pavement for Traffic Lanes
Support Healthy Urban Communities	• Trash and Recycling Receptacles • Noise Reducing Pavement Materials • Public Art • Pedestrian Refuges in Medians • Emergency Vehicle Access
Support Sustainability During Implementation	• Reclamation of Demolition Materials • Use of Renewable Fuels for Construction Equipment • Use of Locally Obtained Materials • Driveways for Access to Affected Businesses • Minimize Construction "Footprint"

ASSESSING SUSTAINABLE URBAN STREET OPTIONS

Positive impacts made to community, quality of life, livability and the environment all contribute to the overall value for a project. Value extends beyond a strict, bottom-line financial measure. Selecting the least expensive options up-front for projects does not necessarily equate the best value, thus assessing the overall benefit of sustainable solutions requires a multitude of approaches.

Considerations for developing sustainable streets include:

- Sustainability must be addressed from the onset of the project
- Community must have significant input and interest in the project
- Design and sustainability solutions must be tailored to specific project conditions
- The full lifecycle of the project must be addressed in evaluating costs
- Measures of success, financial and otherwise, must be defined at the start

Use of Recycled Materials in Construction, Minimize Impact on Natural Environment: Recycled Materials for Bollards, Rain Gardens for Storm Water Infiltration Melbourne, Australia

Use of Recycled Materials in Construction: Recycled Material in Walls, Portland, Oregon

Development and re-development of urban streets is heavily influenced by a full range of stakeholders. Developers, architects, planners, landscape architects, engineers, utility companies, city officials, local jurisdictions, community members, neighborhood associations, and financing agencies, among others, all share a vested interest in the outcome of the project.

Holding a formal workshop to address sustainability can serve as an effective means of reaching consensus on how to incorporate sustainability principles. Utilizing project evaluation criteria with all potential sustainable urban street options, attendees evaluate each sustainability option. Attendees can be asked to assess each option for potential applicability on a project using evaluation criteria. Options can then receive one of three participant votes: 1) Accept for Inclusion in Design 2) Evaluate for Inclusion in Design 3) Reject/Not Applicable for Design.

Options can be assessed on certain criteria, including:

- Compliance with design guidelines
- Compatibility with budget
- Affect on schedule
- Lifecycle costs
- Benefit to sustainability
- Aesthetic appeal

Minimize Impact on Natural Environment:
Storm Infiltration Basin in Planter
Portland, Oregon, U.S.A.

Minimize Impact on Natural Environment:
Porous Pavement
Portland, Oregon, U.S.A.

Important to note in the design of urban streets is the uniqueness of each project in function and its location, which dictates the need for a context sensitive approach. Street projects in a heavily urban area will serve a different function from more suburban projects. The geography and climate of a project site will also bear significant impacts on the design; a hot arid climate will call for different sustainable solutions as opposed to a wet, marine climate. CH2M HILL's matrix of 161 sustainable options provides possible paths and solutions to attaining a sustainable outcome. Further developments within in the field, research, data from pilot projects and peer review of methods could serve to provide a weight measure for each element.

Support Sustainability During Construction:
Public Information Sign About Sustainability,
Portland, Oregon, U.S.A.

Support Healthy Urban Communities:
Emergency Vehicle Access
Santa Monica, California, U.S.A.

CHALLENGES TO ADOPTING SUSTAINABLE STREET SOLUTIONS

Given the clear benefits of sustainable urban street design, it is important to address challenges and barriers that may prevent this from becoming more commonly adopted. Frequent challenges to adopting sustainable approaches and relevant counter arguments are provided below.

(1) Common Misconception that Sustainable Strategies are too Expensive

When considered on a strict financial level, sustainable design guidelines are competitive with conventional solutions. Drawing parallels to LEED certification for buildings, a LEED Certified building adds a mere 0-2 percent to the upfront cost compared to an up-to-code building. Over the lifecycle of the building, the net financial, environmental and social benefits are well worth the initial capital. Many elements from the table of Sustainable Urban Street Options are also competitive in cost with traditional street design elements. The underlying point is that when sustainable options do add a small percentage more to the projects costs upfront, the net benefit over the life of the project will likely be worth the extra initial investment.

(2) Widespread Public Concern over Sustainability and Environmental Conservation has Only Recently Gained Attention

Increased attention to sustainability issues is a relatively new concept. Though interest continues to grow, full support is not in place yet, and widespread change takes time. Support for sustainability can follow one of two paths. Stricter laws and regulations can mandate requirements or personal initiative by cities, communities and individuals can. Many businesses are adopting sustainability policies, and consumers are increasingly voting with their dollars.

(3) Reluctance of Agencies, Consultants, Contractors and the Public to Adopt New Strategies

Much of our current infrastructure was designed and constructed 20 to 40 years ago. Environmental consequences from rapid development were not as well understood as they are now. Though many experts agree that change needs to take place, modifying well established practices is a challenge. Professionals should strive for constant improvement and innovation in their work in order to continuously enhance public welfare.

Cities that are adopting new strategies are realizing the benefit. It is no coincidence that out of the eight U.S. cities that made the 2007 Mercer Resource Consulting Worldwide Quality of Living Survey top 50 list (*6*), almost all of them have aggressive, sustainable and forward thinking planning and design guidelines for development.


New York, New York


Tucson, Arizona


London, England


Paris, France

Support Non-Motorized Travel: Pedestrian Refuges

SUMMARY

Sustainability includes principles, ideas and methods that should be adopted across all businesses to increase quality of life and to provide for a positive, long term outlook for the planet. Readily available, cost-competitive options with conventional solutions exist that can be utilized to create more sustainable streets. Cities focused on sustainability are benefiting locally by creating more livable communities, and positively affecting the planet. Given the extent of urban street right-of-way, their ownership and use by the public, an opportunity is presented to greatly enhance sustainability of urban areas through application of sustainable street options for urban street projects.

APPENDIX
SUSTAINABLE URBAN STREET OPTIONS

APPENDIX

Sustainable Urban Street Options

CH2MHILL

Reduce Energy Consumption			Reduce Consumption of Material Resources			Reduce Impacts to Environmental Resources			Supports Healthy Urban Communities			Support Sustainability During Implementation	
Support non-motorized travel	**Support energy efficient movement of people and goods**	**Use resources with lower operations and maintenance requirements**	**Use recycled materials in construction**	**Require less infrastructure in solution**	**Increase durability and life of design solution**	**Minimize impact on natural environment**	**Encourage and support biodiversity**	**Reflect historical and cultural context**	**Incorporate features that support community and livability**	**Incorporate features that support public services and adjacent land uses**	**Incorporate features that enhance public health, safety and security**	**Support local economic, social and resource management needs during construction**	**Reduce environmental and community impacts during construction**
Pedestrian sidewalks	Enhanced bus zones and shelters	Water-appropriate plantings	Recycled base course	Reversible lanes	Higher strength concrete pavements	Storm water infiltration basins in planters	Plantings that support animal species diversity	Preservation and incorporation historic buildings and structures into project	Public drinking fountains	Wireless access	Signalized pedestrian crossings	Reclamation of demolition materials	Minimization of traffic interruptions, including detours
Pedestrian shelters	Transit lanes	Low maintenance pavements	Recycled asphalt	Narrow lanes less than standard width	Portland Cement Concrete pavements	Rain gardens for storm water infiltration	Plantings that attract and support desirable insects	Displays providing information about site history and prehistory	Public art	Fire protection access	Pedestrian refuges in medians	Reuse of top soil	Driveways for access to affected businesses
Pedestrian supportive signals (count down heads & audible signals)	Transit signal priority	Low maintenance plantings	Recycled aggregates	Remove on-street parking	Increased capacity of street/number of lanes	Porous pavement for traffic lanes	Minimal tree removal	Reuse of historical materials in construction	Phone booths	Comfortable interfaces for public spaces	Sidewalk bollards to separate or illuminate potential conflict locations	Reclamation and salvage of poles, grates, and other metal objects	Noise reduction (quieter equipment, reduced working hours)
Bike lanes	ITS/Advanced Transit Information Systems	Low energy lighting	Recycled pavers	Fewer luminare poles/higher mast	Ability to expand capacity to move people/goods	Porous pavement in parking areas	Diverse plant/tree selections	Design of public views to historically and culturally significant sites	ADA access for physically or visually challenged people	Emergency vehicle access	Open visibility to sites and public spaces	Use renewable fuels for construction equipment	Erosion and sedimentation control
Bike racks	High Occupancy Vehicle Lanes	Solar power photovoltaic energy sources	Recycled material in sign posts	Self guided/fewer signs using physical design to augment way finding	Utility corridors/utilidors	Porous sidewalk pavements	Plantings that emphasize native species/species diversity	Reflection of ethnic and cultural history in architectural design	Trash and recycling receptacles	Refuse collection access	Curbed medians at high traffic conflict locations	use of locally obtained materials	Maintenance of utility services
Bike storage lockers	Truck lanes	Reuse of stormwater for irrigation	Recycled material for sign panels	Surface conveyance for stormwater	Precast or modular construction elements	Storm water treatment vaults	Enable ecological connectivity with habitat crossings	Incorporation of distinctive motifs from historical structures in new construction	Comfortable separation of pedestrians from vehicular traffic	Utility maintenance access	Continuous curbed medians to control or focus left turning traffic	Employment and training of labor from local community	Safe pedestrian access during construction
Pedestrian refuges in medians	Truck turn accommodations	Mulch planting areas	Recycled material for luminare poles	Catenary lighting systems	Flexibility of design to adapt to changing conditions in the future	Reuse of storm water for irrigation	Designs that enhance and create "edge effect"	Urban design that respects historic content	Benches	Delivery vehicle access	Reduction or consolidation of driveways to minimize traffic/bicycle/pedestrian safety conflicts	Promotional information regarding sustainable elements in the project	Reduce air emissions through restrictions on idling, use of low sulfur fuels, etc.
Signalized pedestrian crossings	Traffic signal interconnection and coordination	Digital Sign Inventory with Geographic Positioning Systems (GPS)	Recycled material for street furniture	Reduced stormwater vaults through natural drainage systems	Backup power for sustaining operations during emergencies	Planted/pervious strips	Designs to minimize impoundment or drainage of wetlands		Postal service mail boxes	Customer access	Directional left-turn pockets		Encourage carpooling & transit use by construction workers
Bicycle detection at signals	ITS/Advanced Transportation Management Systems	Digital Tree Inventory with GPS (to track maintenance, health, etc.)	Recycled material for bollards	Use of existing infrastructure with available capacity	Long-lasting exterior finishes and coating systems	Planted/pervious medians	Plantings that provide shade in riparian corridors		Noise reducing pavement materials	Provide connections and signage to nearby neighborhoods	Signal protected turns		Clean up of existing hazardous materials
Bicycle priority at signals		Low energy traffic signals using Light Emitting Diode (LED) signal heads	Recycled material for utility trench backfill	Efficient use of adjacent street in the roadway network	Installation of ultimate utility systems to avoid pavement removal	Tree retention	Daylighting stream crossings where feasible		Linkages and connections that integrate land uses	Use streetscaping as a buffer for sensitive land uses	Illumination of traffic/bicycle/pedestrian conflict areas		Minimize construction "footprint"
Bicycle route signage			Recycled utility covers	Combine signs, lights, signals, etc. on same pole	Vandal-resistant designs and materials	Tree pit enhancement	Create pocket green spaces and connectivity		Retention or introduction of tree cover to reduce heat gain on paved areas	Collaborate with property owners for mutual benefit (e.g. frontage inputs)	Surveillance cameras for increased security and/or emergency response		Off-site construction worker parking
Way finding and signage to local/regional trail system			Incorporation of recycled vegetative material	Access Management treatments to enable more efficient traffic flow	Use of structural planting medium	Natural drainage systems			Pedestrian lighting		Traffic calming features including speed humps or tables, traffic circles, chicanes, and chokers to manage traffic speeds		
Shorten street crossings			Recycled material in sound attenuation walls	Road Diet features including conversion of lanes or reducing lane widths for other uses of right-of-way		Bioengineered planting strips			Information kiosks				
			Recycled rubber for sidewalks			Interconnected bioretention swales			Shelters for protecting pedestrians from weather				
			Recycled material for retaining walls			Soil amendments to reduce use of fertilizer			Public toilets				

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