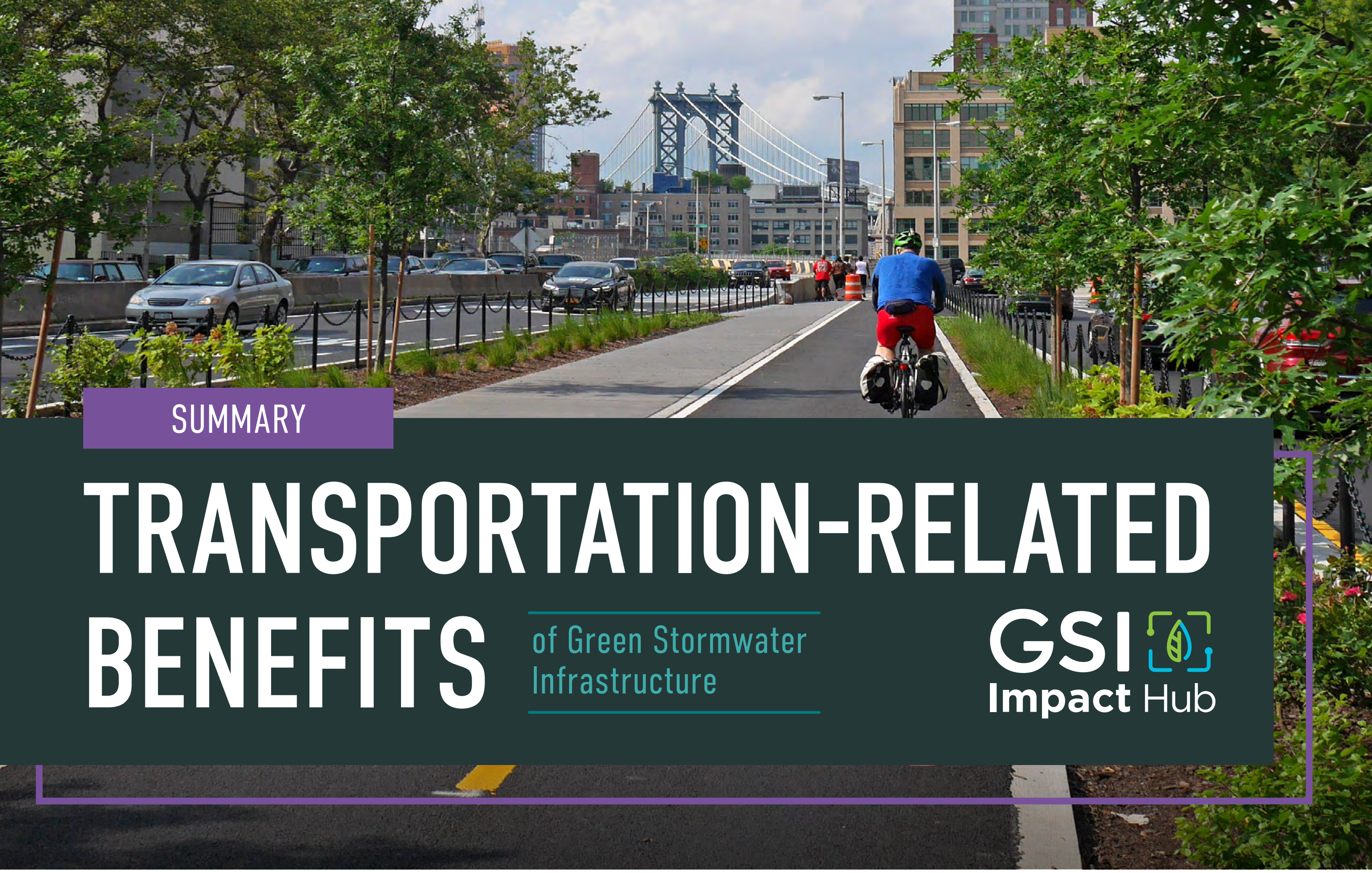


SUMMARY

TRANSPORTATION-RELATED BENEFITS

of Green Stormwater Infrastructure

GSI Impact Hub

WHAT YOU NEED TO KNOW

Integrating green stormwater infrastructure (GSI) and green streets concepts into transportation projects can:

- Improve safety for drivers, pedestrians, and cyclists.
- Increase mobility and encourage non-motorized transit options.
- Reduce noise and air pollution and associated human health impacts.
- Avoid construction of traditional street and stormwater management projects and, in some cases, reduce transportation infrastructure life-cycle costs.
- Revitalize neighborhoods, creating positive economic effects.
- Provide climate resilience benefits – GSI can be added incrementally over time to adapt to changing climate conditions.

This is a summary of a full guide produced as part of the GSI Impact Hub, a larger project that provides resources and support related to specific GSI co-benefits. Please visit the GSI Impact Hub website to explore these resources including:

- Compendium of GSI Co-benefits Valuation Resources
- GSI Impact Calculator, a block-level tool for quantifying and monetizing co-benefits
- Full-length guides related to flood risk reduction, green jobs and economic development, heat risk reduction, habitat and biodiversity, and transportation.

The GSI Impact Hub is a collaboration between The Nature Conservancy, Green Infrastructure Leadership Exchange, One Water Econ, government agencies and technical partners.

[1] Please see the full guide to "Understanding and Quantifying the Transportation-Related Benefits of Green Stormwater Infrastructure" for citations to the sources referenced in this summary.

GSI, including rain gardens, bioretention facilities, trees, and other nature-based practices, can be used to effectively manage stormwater runoff from transportation networks while meeting other community goals. Specifically, well-designed GSI can provide significant environmental and social benefits compared to traditional (i.e., gray infrastructure) approaches for managing stormwater runoff within the public right-of-way.

Pairing GSI with planned road reconstruction or utility upgrade projects can result in overall cost savings for stormwater agencies and transportation departments compared to a siloed approach. However, coordination across departments, program budgets, and competing priorities can be difficult to navigate. Challenges (and in some cases misconceptions) associated with integrating GSI and green street concepts into road projects include concerns about maintenance, impacts to underground utilities, adverse effects on transportation infrastructure, and more. As highlighted in the full guide, many utilities have navigated these challenges through successful partnerships with transportation departments and other stakeholders.

Key Terms

Green Streets: The U.S. EPA defines a green street as a stormwater management approach that incorporates vegetation (perennials, shrubs, trees), soil, and engineered systems (e.g., permeable pavements) to slow, filter, and cleanse stormwater runoff from impervious surfaces (e.g., streets, sidewalks). Green streets are designed to capture rainwater at its source, where rain falls.

Complete Streets: Complete streets incorporate designs that promote neighborhood character, stimulate economic development, and serve the mobility and access needs of all users – motorists, transit riders, bicyclists, and pedestrians. Complete street objectives are primarily achieved by using measures to calm traffic and create well-defined barriers between transportation types.

Sustainable Streets: The term complete streets is often used to refer to street designs that incorporate green street elements/GSI strategies. However, many communities specifically define "sustainable streets" or "vital streets" as those that incorporate both green and complete street principles. For example, San Mateo County (CA) defines sustainable streets as "right-of-way projects that incorporate both complete street elements such as pedestrian, bicycle, and transit improvements as well as green infrastructure components such as stormwater planters and pervious pavement."

APPLICABLE GSI STRATEGIES

A wide range of GSI practices are appropriate for incorporation into transportation projects. Available strategies range from single intersection installations (e.g., curb extensions that incorporate bioretention) to more comprehensive "complete street" or "sustainable street" approaches that can guide transportation planning at the local or regional level (see text box for definitions of these key terms).

GSI practices appropriate for transportation projects generally include adaptations of well-established best management practices (BMPs), such as street trees, bioretention, and permeable pavement. Transportation-specific enhancements reflect designs that fulfill bicycle/pedestrian access objectives, enhance road safety, and/or account for the unique roadway environment (e.g., the linear nature of installations, presence of underground utilities). Road narrowing and removal of curb and gutter, which reduce impervious area and the volume of stormwater runoff entering the sewer system, are also key green street elements.

For any given project, applicable GSI strategies depend on a range of factors, including road typology, mix of users (e.g., transit, pedestrians, vehicles), traffic volumes, adjacent land uses, available space, and other site characteristics. For example, highways and larger arterial roads typically require different treatments than residential streets due to roadway safety requirements, high levels of vehicle traffic, available area, (typically) compacted soils, and existing topography.

IDENTIFYING KEY BENEFITS

Traffic calming and pedestrian safety

Green street features, such as stormwater curb extensions, bump-outs, porous/vegetated islands, and street trees can be incorporated into street designs to help slow traffic, increase safety at crosswalk locations, and create safety buffers for pedestrians and bicyclists (see Table 1). Refer to Section 3.1 of the full Transportation Guide for more detail on these benefits and study references.

Table 1. Findings from select studies documenting the traffic calming and accident reduction benefits of green streets

BMP	Location	Results
Street trees and landscaped medians	Colorado	Streets with 50% vs. 10% tree canopy had 58% fewer crashes, and 64% fewer injuries and fatal crashes. Streets with landscaped medians have 38% to 48% fewer crashes.
Various levels of greening	N/A	Increased doses of greening increased driver attention level and shortened reaction time during emergency incidents.
Street trees & streetside landscaping	Florida	Street treatments with street trees have 40% fewer mid-block crashes and 67% fewer roadside crashes. Wider shoulders increased roadside and mid-block crashes.
Landscape improvements and street trees	Florida	Road segment with landscape improvements had 11% fewer mid-block crashes, 31% fewer injuries, and fewer fatalities (0 versus 6). Fewer pedestrian and bicyclist injuries in the improved road sections.
Street trees	N/A	Trees along suburban roads reduced average vehicle speeds by 3 MPH. People perceived suburban streets with trees as the safest streets and urban streets without trees as the least safe.
Landscape improvements, street trees	Texas	Across urban road sites, landscape improvements and street trees decreased crash rates by 46% over 3 to 5 years. Pedestrian fatalities dropped from 18 to 2.
Multiple GSI strategies, including street trees	Toronto	GSI decreased mid-block accident frequencies on urban roads by 5% to 20%. Savings > $1.4 million within 3 years based on willingness-to-pay to avoid vehicle accidents.

Increasing mobility and encouraging alternative transport

Numerous studies examining the effect of street greenery on active travel have found a significant and positive correlation between well-implemented street greenery and the likelihood, duration, and frequency with which residents engage in walking and cycling. Table 2 highlights findings from select studies that demonstrate these effects. Refer to Section 3.2 of the full Transportation Guide for more detail on these benefits and study references.

Table 2. Findings from select studies documenting the effect of trees and greenery on pedestrian, cyclist, and transit-user behavior

Study Parameters	Location	Key Findings
Factors influencing pedestrian's willingness to walk.	Europe	Overall, attractiveness ranked higher than many safety factors; respondents ranked having a "high landscape or artistic value" as having the greatest influence.
Effects of pedestrian environments on parents' walking behavior, perception of safety, and willingness to let children walk to school.	U.S./National	Parents were more likely to walk, and let their kids walk to school, if the route had sidewalks, landscape buffers, and street trees.
Resident preferences for location of plantings for street trees and bushes and related perceptions of traffic, safety, pollution, and comfort.	Boston	People prefer sidewalks and bike lanes with trees. Study participants preferred the location of trees to be between bike lanes and the street because this reduces the perception of traffic and pollution, and makes participants feel cooler.
Impact of thermal comfort perceptions on transit users' ridership experience and health.	Tucson	Most (82.4%) survey respondents reported feeling hot and over half reported experiencing heat-related illness while at the streetcar stops. More than half (56.1%) of streetcar users identified the addition of more shade and greenery as a potential solution to improve their thermal comfort.
Factors influencing walking and biking to school.	801 schools in DC, FL, TX, and OR	Study showed 25% increase in walking and biking to school over a five-year period because of education and encouragement programs, and additional increase of 18% when paired with infrastructure improvements.

Avoided gray infrastructure and reduced life cycle costs

Many stormwater and transportation agencies report that the costs of GSI can exceed those for gray infrastructure; however, this experience can vary across location, BMP type, and the nature of the urban environment. For example, several studies show that GSI strategies and green street elements can result in cost savings compared to traditional street and/or stormwater management alternatives. This can be because GSI installations have lower overall life cycle costs, and in some cases, because they extend the asset life of streets, pavement, and/or drainage networks. Cost savings can also accrue when GSI strategies are integrated into planned transportation projects, resulting in more cost-effective applications compared to a siloed approach. (i.e., by "digging-once"). Table 3 presents findings from a sample of studies documenting the cost saving benefits associated with green street transportation alternatives.

Table 3. Findings from select studies documenting the benefits of GSI for reducing infrastructure costs and extending the life of infrastructure

BMP	Description	Results
Complete street w/GSI elements	Compared life cycle costs of green street/permeable pavement system in downtown West Union, IA to traditional street treatment.	Permeable pavement would initially be more expensive, but lower maintenance and repair costs would result in cost savings in the long run. City would begin to realize cost savings by year 15 of the project. Estimated cumulative savings over a 57-year period were $2.5 million (2013 USD).
Green street, w/ bioswales and road narrowing	Examined life cycle costs of Seattle's Street Edge Alternatives (SEA) project, which uses bioswales and other GSI to capture and street stormwater runoff.	Bioretention combined with narrowing the roadway, eliminating the traditional curb and gutter, saved 15% to 25% in capital costs ($100,000 to $235,000 per block) compared to conventional design. SEA streets improve performance as plantings mature, while traditional systems degrade w/time.
Permeable Pavement	Compared national maintenance and replacement costs for different pavement types.	Permeable pavement has nearly 2x longer asset lifespan than traditional pavement with lower maintenance costs.
Permeable Pavers	Compared life cycle cost of permeable interlocking concrete pavers to conventional asphalt pavement over 10.5 mile of urban roadway.	Net difference over lifecycle cost for permeable pavers saves $10.8M compared with asphalt, or approximately $1M per mile of road.
Street trees	Evaluated effects of street tree shade on 20% shaded asphalt concrete pavement performance.	Tree shade reduces pavement distress, resulting in cost savings for replacement of 60% over 30 years.

Reduced air and noise pollution

Green streets can reduce air pollution by encouraging alternative modes of transport (thereby reducing vehicle miles traveled and associated emissions) and through the interception and uptake of pollutants by trees and other vegetation (e.g., particulate matter, carbon monoxide, nitrogen dioxide). The effectiveness of GSI for this purpose depends on the nature of the urban environment, as well as the type and placement of GSI interventions. For example, several studies have shown that adding trees and some other types of vegetation in urban "street canyons" – roads in urban areas lined on both sides by tall buildings - can increase pollutant concentrations by further restricting air flow and exchange. Locating trees and other vegetated practices close to the roadway maximizes uptake of pollutants. Planners can increase the air quality benefits of green street projects with an understanding of these various factors.

There is a significant body of evidence showing that trees, hedges, and other forms of urban greenery can reduce traffic-related noise pollution, although much of the literature focuses on the value of green spaces, such as parks and green belts. The limited research that focuses specifically on GSI suggests that these practices have a positive effect on urban road traffic levels. In densely developed urban street canyons, where there is little space available for extensive GSI, green roofs have been shown to have a positive effect on noise pollution. In addition to measured noise pollution, the presence of greenery in the urban environment has been found to lead to perceptions of reduced noise levels.

Neighborhood revitalization and positive economic effects

GSI installations in the public right-of-way can directly benefit businesses and local economies. Greening shopping areas and commercial corridors can increase neighborhood aesthetics, which in turn increases rental rates and retail sales. The New York City Department of Transportation documented a positive effect on retail sales for businesses located on the city's "complete streets," which included pedestrian and safety improvements in addition to tree planting and GSI installations. In one example, retail sales increased by more than 100% post-construction relative to comparison sites. These benefits accrued to "mom and pop" shops, as well as larger retail stores.

The quality of life and neighborhood improvement benefits associated with green streets have also been captured by the effect on nearby property values, which reflect an individuals' willingness-to-pay (WTP) for these improvements. Table 4 presents findings from a sample of studies documenting these effects. It is worth noting that increases in property values can also have negative social impacts, including linkages to gentrification pressures and increases in property taxes which have been connected to displacement.

Table 4. Findings from select studies documenting the property value benefits of GSI within the public right-of-way

Location	Description	Results
Seattle, WA	Compared sales prices of homes in three residential green street project areas to comparable properties not located by green street improvements but within the same zip code.	Green street projects increased residential home sale **prices by 3.5% to 5.1%.**
Philadelphia, PA	Evaluated effect of GSI projects in the public right-of-way on residential property values.	GSI w/in public right-of-way can increase residential property values by **12.7%** for properties located within a quarter mile.
Portland, OR	Examined effect of green streets on residential properties within one quarter mile, as well as characteristics of the nearest green street facility such as facility type, the proportion of the facility covered by tree canopy, facility size, and landscape features.	On average, green street facilities add $8,870 (2014 USD) to home sales prices. Street trees reduce time on market by 1.7 days. Distance to facility, facility size, proportion covered by canopy, and design complexity positively affect increase in sale price.

QUANTIFYING AND MONETIZING GSI AND TRANSPORTATION PROJECT BENEFITS

Life cycle cost comparison and avoided cost analysis

Evaluating life cycle costs and accounting for any avoided gray infrastructure or other infrastructure investments is key to understanding the true value of green street applications. To understand tradeoffs, this evaluation should compare the lifecycle costs (and benefits) of alternative investments, accounting for any differences in the expected life of project assets. Figure 1 highlights key steps and considerations for comparing the costs and benefits of GSI and other infrastructure investments over time.

Figure 1. Steps and considerations for comparing the benefits and costs of alternative infrastructure investments over time

- **Define a green street project or program, including key outcomes.** It is important to have a relatively well-defined scenario for evaluation. If a project or program is still in the early planning stages, enough information is needed to develop high-level cost estimates and benefit calculations (e.g., identification of BMP types, volume of stormwater managed, and other key objectives that would be met).
- **Establish a baseline scenario.** Defining the baseline is often the key to revealing the benefits of a project or program. The baseline should reflect the steps that would be taken if the planned GSI or green street project is not implemented. This may include implementation of more traditional transportation network approaches or upgrades and/or installing additional stormwater management capacity elsewhere.
- **Evaluate life cycle costs over time under both scenarios.** Life cycle costs include costs associated with planning and design, construction, annual operations and maintenance, and infrastructure replacement. The assessment should explore assumptions related to the expected useful life of GSI relative to alternative investments, including non-stormwater assets (e.g., lifecycle costs associated with traditional asphalt compared to permeable pavement).
- **Evaluate benefits in context.** If minimal data is available, evaluating benefits in a broader context can be informative. For example, if the life cycle costs of a green street project are 30% higher than a traditional street improvement project, is the value of co-benefits greater than this additional amount? Similarly, a break-even analysis can provide context for key benefits - if the project avoided one accident per year or increased retail values in the area by 1%, would that be enough to “make the project worth it”? Sensitivity analysis can also help understand the effect of assumptions on the overall analysis

Evaluating additional co-benefits

Beyond avoided costs, the benefits of integrating GSI into the transportation network can be difficult to quantify. However, rules of thumb and simple approaches can be applied to evaluate key benefits within the context of overall costs:

- **Safety improvements:** The Federal Highway Administration (FHWA) has established standardized “crash costs” to help practitioners determine if road safety improvement projects are economically justified. These costs, which range from $15,100 (for a crash with no apparent injury) to $14.3 M in 2024 USD (for a crash that involves a fatality), can be applied to evaluate the safety benefits of green streets. Although this requires data on the type and severity of crashes expected with and without the project. Without this data, information on the economic cost of accidents can help to cast benefits within the context of total costs. For example, practitioners can explore the value of avoiding one accident per year or reducing crashes of a certain type by 10%.

- **Encouraging alternative modes of transport:** Green street networks can encourage commuters to walk or bike to school and work. This in turn reduces the amount of money needed for personal vehicle use and/or busing. Transportation is the second highest household expense in the U.S., accounting for 13% of annual household expenditures, on average (and lower income households dedicate an even higher percentage). Practitioners can make assumptions about the reduction in vehicle miles traveled because of green street improvements (i.e., based on the literature or reasonable threshold assumptions) and apply the federal mileage reimbursement rate of $0.67 (2024 USD) to estimate the value of these reductions.

- **Recreational benefits:** As noted above, green street projects can also encourage additional recreational trips (i.e., walking and cycling for leisure). Economists have developed methods for valuing individuals' willingness-to-pay to participate in these activities for use in benefit-cost analysis. For example, the U.S. Army Corps of Engineers publishes annual unit day values for different recreational values, including walking and biking. These values range from $5.20 to $15.60 per trip (2024 USD), for general recreation, depending on site-specific factors and the quality of the recreational experience.

- **Air quality benefits:** By encouraging alternative modes of transit, green street networks can reduce vehicle-related pollutants and greenhouse gas (GHG) emissions. Trees and other vegetation can also intercept and absorb these pollutants. The U.S. EPA and other federal agencies have developed standard approaches for quantifying air quality improvements (e.g., emissions avoided per vehicle mile traveled, pounds of pollutants absorbed by different vegetation) and monetizing the avoided health effects associated with them. These values can be applied to estimate the air quality benefits of green street projects.

- **Neighborhood revitalization/community uplift benefits.** The full value of green street improvements reflect not only the benefits described above, but also those described in other GSI Impact Hub guides, including several of the more intangible benefits that can be difficult to quantify; for example, the quality of life and mental health benefits that are often touted as being associated with larger scale GSI projects such as green streets. To capture the full value of the benefits provided by green streets and other GSI interventions, economists rely on methods that elicit an individual or household's willingness-to-pay (WTP) for these improvements through revealed preference or stated preference studies. Practitioners can apply findings from relevant studies to gauge the value of GSI/green street improvements.

Studies that demonstrate the increase in value for properties located near GSI improvements (see Table 4) are examples of revealed preference studies. A limited number of studies have examined WTP for GSI using stated preference techniques. One study in Northern New Jersey found a significant increase in WTP for infrastructure that reduced flood risk and provided multiple benefits compared to single-purpose projects. Specifically, residents were willing to pay $378.60 (2024 USD) for GSI located within a block of their home that results in lower levels of flood risk and CSO reduction and provides co-benefits related to air quality, water supply, habitat, and energy savings. This compares to $84.90 for infrastructure that only reduces flooding and CSOs (with no additional co-benefits).

When applying findings from WTP studies, it is important to remember that these findings typically represent WTP for a variety of co-benefits associated with GSI/green streets. It is therefore important to take care to avoid double counting.

PARTNERSHIPS AS PATHWAYS TO ACHIEVE GSI BENEFITS

Implementing GSI in urban rights-of way-or other transit spaces necessitates a process of navigating and resolving a complex regulatory and jurisdictional puzzle while meeting public needs and preferences. Partnerships between public agencies and community-based organizations can be instrumental in resolving this puzzle. The full Transportation guide relates lessons learned from conversations with utility representatives who have successfully implemented green street partnerships, providing insights into instances where multiple agencies overcame key challenges and developed successful partnerships to further green street implementation in their cities.

Table 5. Case Studies and Their Relevance to Transportation GSI Benefits

Case Study Location	Agency Lead	Lessons Learned
Denver, CO	Department of Transportation and Infrastructure	Partnerships with external entities with GSI expertise can build internal capacity and support for GSI projects. Teaming with other City departments can drive cost-effective implementation of GSI.
San Mateo County, CA	City/County Association of Governments (C/CAG) of San Mateo County	Creating a Sustainable Streets Master Plan brings together countywide complete street, GSI, and climate change goals to identify potential locations for sustainable street improvements that meet multiple government and community objectives (including regulatory requirements).
Grand Rapids, MI	Vital Streets Oversight Commission	Formal structure, with funding, can unite multiple city departments with a focus on integrating GSI into transportation capital projects.
Seattle, WA	Seattle Public Utilities	"Natural Drainage System Partnering Program" facilitates co-planning and co-funding of GSI projects to reduce stormwater pollution from area roads.
Wilmington, DE	Transportation and Economic Development Departments	A preference for GSI in US DOT funding enabled an initial investment in a riverfront transportation infrastructure project. Existing plans often have elements of GSI that can increase grant application competitiveness.

FUNDING GSI IN TRANSPORTATION PROJECTS

There are both challenges and opportunities for funding GSI projects within the transportation network. Transportation and stormwater departments may be restricted in the types of capital costs they are permitted to cover. However, the incorporation of GSI may open additional funding opportunities, particularly through collaborations between DOTs and other stakeholders.

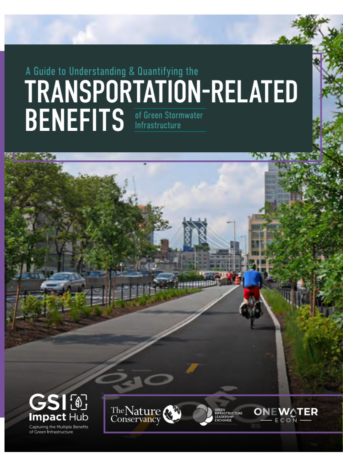
Transportation Grant Funding: GSI projects are often eligible for transportation funding because they improve transportation networks by mitigating street and alley flooding and provide other co-benefits. The U.S. Department of Transportation's (DOT's) Surface Transportation Block Grant Program (STBG) provides flexible funding to improve conditions and performance for Federally-funded highway, bridge, or tunnel projects on public roads, pedestrian and bicycle infrastructure, and intercity bus terminals.

Municipal Bond Financing: Transportation agencies and local governments may opt to fund roadway and other transit projects through debt financing, particularly by issuing municipal bonds. GSI elements incorporated into these projects are typically eligible for inclusion in transportation bonds or other municipal debt instruments. Under certain conditions, this can include GSI projects located on property that the agency or other public entity does not own or control. This allowance can be important for GSI projects constructed by DOTs and stormwater agency partners as off-site mitigation for roadway corridor stormwater impacts, or to facilitate the installation of GSI adjacent to the public rights-of-way.

Tax Increment Financing (TIF) Districts and Business Improvement Districts (BIDs): TIF and BIDs also offer opportunities for funding and financing GSI improvements along transportation corridors in BID/TIF District neighborhoods. While the statutes that authorize TIF programs differ from state to state, generally two approaches to utilizing TIF to support GSI are possible. First, eligibility and/or scoring criteria for applicants seeking TIF funding support for projects should prioritize the inclusion of GSI and other community resilience measures. Second, TIF funding can be used directly by the TIF agency to construct GSI projects that serve the overall infrastructure needs of a TIF district.

Co-funding structures: In some instances, stormwater and transportation agencies, as well as other public entity partners, may find it useful to create an independent entity (such as a Joint Powers Authority) to solicit, manage, and distribute funding for green streets and other transportation focused GSI projects. These formalized partnerships often have legal and financial capabilities that resolve funding roadblocks and restrictions.

Public-Private Partnerships: Transportation agencies are well accustomed to contracting for the design and construction of roadways and transit infrastructure. Some contracting models may be particularly appropriate for GSI-centered roadway and transit projects, particularly those that involve multiple municipal agencies and partners. Design, Build, Finance, Operate, Maintain concessions transfer responsibilities for these activities to private sector partners. DBFOM may be structured as a public-private partnership, or P3. Some P3s, particularly those known as Community-Based P3s, or CBP3s, feature outcome-based payment structures, conditioning repayment terms to the delivery not just of completed infrastructure but of specified outcomes that are valuable to the community.



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Please see the full guide to "Understanding and Quantifying the Transportation-Related Benefits of Green Stormwater Infrastructure" for citations to the sources referenced in this summary.

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