A Guide to Understanding & Quantifying the

TRANSPORTATION-RELATED BENEFITS of Green Stormwater Infrastructure

GSI Impact Hub

Capturing the Multiple Benefits of Green Infrastructure

The Nature Conservancy

Green Infrastructure Leadership Exchange

One Water Econ

Credit: Will Parson/Chesapeake Bay Program


PERMIT PARKING
EXCEPT HOLIDAYS
NON-PERMIT PARKERS
TWO HOUR LIMIT
NO PARKING

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Credit: Mark Skalny


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INTRODUCTION

Green stormwater infrastructure (GSI) can be used to manage stormwater runoff from transportation networks, while meeting other community goals. This guide describes the multiple benefits associated with integrating GSI into transportation projects and provides practical guidance for quantifying and achieving these benefits.

In large U.S. cities, 25% to 60% of land area is covered by impervious roadways, alleys, driveways, sidewalks, and parking lots.[1] These areas create significant volumes of stormwater runoff, carrying pollutants into local rivers and streams. Traditional transportation networks also contribute to air pollution, prioritize motorized vehicles over other forms of transit, and fragment and impair natural landscapes.

GSI can help to mitigate these impacts and provide additional environmental and social benefits compared to traditional (i.e., gray infrastructure) approaches for managing stormwater runoff within the public right-of-way (ROW).

> When incorporated into transportation design, GSI installations can increase driver and pedestrian safety, extend the life of transportation infrastructure, and reduce air and noise pollution, in addition to effectively managing stormwater.

More comprehensive "green street" and "complete street" approaches can improve mobility and pedestrian access, increase the viability of alternative forms of transportation, revitalize neighborhoods, and result in greater GSI co-benefits overall. Transportation-related GSI can also provide climate resilience benefits - where feasible within the public ROW, GSI can be added incrementally over time with designs that can be adjusted to account for changing conditions. In this way, GSI can complement large gray infrastructure solutions as part of long-term climate resilience planning.

GSI Impact Hub

This guide is a component 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 additional resources including:

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

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

Pairing GSI with planned road reconstruction or utility upgrade projects within the public right-of-way can result in overall cost savings for stormwater agencies and transportation departments. However, coordination across departments, program budgets, and competing

Credit: Kari Marciniak/TNC

priorities can be difficult to navigate. Challenges (and in some cases misconceptions) associated with implementing GSI and/or integrating green street concepts into roadway improvement projects include concerns about maintenance requirements, potential adverse effects to underground utilities or transportation infrastructure (e.g., negative impacts from tree roots), and more.

This guide aims to help stormwater practitioners successfully integrate GSI into local transportation networks with a particular focus on understanding and quantifying the multiple benefits of green street projects and demonstrating successful partnerships for implementation. It is organized as follows:

- **Section 2** provides a brief overview of the different ways that GSI can be integrated into transportation networks.
- **Section 3** highlights findings from the literature on the benefits of GSI installations within transportation corridors and more comprehensive “green street” and “complete street” projects.
- **Section 4** describes methodologies and rules-of-thumb for quantifying and monetizing the benefits associated with GSI transportation projects.
- **Section 5** includes case studies that demonstrate successful approaches to cross-departmental collaboration and stakeholder partnerships for implementing green street projects.
- **Section 6** outlines potential funding and financing strategies relevant to incorporating GSI into transportation infrastructure.
- **Section 7** offers conclusions and recommendations.

Key Questions Addressed in This Guide

- How do GSI and transportation infrastructure overlap?
- How does GSI benefit transportation infrastructure and users of transportation networks?
- How can I evaluate the multiple benefits of transportation/GSI projects?
- How have stormwater agencies successfully partnered with transportation departments and other entities to incorporate GSI into transportation plans and projects?
- What funding sources are available for integrating GSI into transportation planning and construction?

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GSI Practices that Benefit Transportation

Credit: Roberto Gonzalez

GSI PRACTICES THAT BENEFIT TRANSPORTATION

This section provides a high-level overview of the different types of GSI practices and strategies that are implementable within the public right-of-way and the context in which they apply.

GSI practices appropriate for transportation projects generally include adaptations of well-established best management practices (BMPs), such as street trees/tree wells, bioretention areas, and permeable/pervious pavement. Transportation-specific enhancements reflect designs that fulfill bicycle/pedestrian access objectives, enhance road safety, improve parking efficiency, 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.[2] 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. Bioswales, bioretention areas, infiltration trenches, and street trees may be better sited in medians and along the linear stretches of land alongside these roads. Shoulders and breakdown lanes offer potential locations for permeable pavement/surfaces but must be designed to support the safety of maintenance teams on high-traffic and high-speed corridors.[3]

The U.S. EPA's Green Streets Handbook provides comprehensive guidance on the GSI strategies and design considerations applicable to different types of transportation infrastructure, including arterial roads (highways and major thoroughfares), collector roads, local roads (residential neighborhood roads), alleys, and parking lots. As an example, Figure 1 shows an array of GSI strategies that EPA recommends for collector roads, which generally support moderate traffic through high density areas (e.g., mixed use, business districts). It is not the intent of this guide to provide detailed design guidance for green street projects - Figure 2 highlights a few additional, recent resources that contain more information on designing GSI projects within transportation networks.

Both the scale of implementation and type of GSI influence the range and level of benefits realized through green street applications. Single installation projects may be a cost-effective approach to addressing issues such as localized street flooding/drainage improvement along with bicycle/pedestrian safety at a particular intersection. When implemented as part of a more comprehensive complete street approach, GSI projects can achieve much greater benefits, including fostering climate resilience through urban cooling, traffic calming through corridors with high accident rates, enhanced community livability/connectivity, and high-volume stormwater management, among others. Overall costs may be reduced, and benefits increased, through a "dig once" approach when GSI investments are paired with other capital infrastructure upgrades. Integrating GSI into repair or retrofit projects also minimizes construction disruption and provides a holistic "finished" product (e.g., freshly paved street inclusive of utility upgrades, GSI, new pavement markings).[4] Similarly, the incorporation of different GSI strategies can help to achieve specific benefit outcomes. The next section describes these benefits in greater detail, including how GSI strategies and design elements can help to achieve them.

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.”

Note: This guide assumes the term complete streets to denote transportation design that incorporates traditional green street elements.

Figure 1. U.S. EPA illustration of a collector road through a neighborhood business district, with relevant GSI interventions.

Source: EPA Green Street Handbook (2021).
Note: EPA characterizes collector roads as those that have moderate to high traffic volumes, typically with multiple travel lanes. Collector roads often serve as routes for public transit and pedestrian corridors.

3 Benefits of Integrating GSI into Transportation Networks

Credit: Roberto Gonzalez

BENEFITS OF INTEGRATING GSI INTO TRANSPORTATION NETWORKS

This section highlights results from studies that demonstrate the benefits of GSI, green streets, and key elements of complete or sustainable streets for transportation networks and roadway users.

Benefits of integrating GSI into transportation networks include:

- Traffic calming and improved safety for drivers, cyclists and pedestrians
- Increased mobility and alternative modes of transportation (beyond safety improvements)
- Avoided gray infrastructure capital costs and decreased life cycle costs
- Reduced air and noise pollution
- Neighborhood revitalization and economic development benefits

This guide focuses on the more direct benefits of integrating GSI strategies into the streetscape environment through green and complete street approaches; however, the implementation of GSI can provide additional co-benefits, such as building energy savings, increased urban wildlife habitat, urban heat stress reduction (and other climate resilience benefits), and green jobs, among others. Several of these benefits are described in other co-benefit guides developed through the GSI Impact Hub.

3.1 Traffic calming and driver 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.

Over the past two decades, a considerable body of research indicates that traditional preferences for wide, high-speed streets with clear lines of sight may undermine, rather than promote, public safety. In a study from 2010, Macdonald noted the conflict between well-established approaches to transportation infrastructure planning and the integration of "green" or "sustainable" technologies that still exists today, stating: "Urban arterials with roadside trees, landscaping and pedestrian amenities — . . . where expectations of lower driver speed is communicated through design — are associated with fewer vehicle collisions than are streets without these design elements, particularly far fewer pedestrian and bicyclist injuries and fatalities."[5]

Figure 2. Green Street/Complete Street Design and Implementation Manuals

Green Street/Complete Street Design and Implementation Manuals

- American Rivers. *Sonoran Desert Green Infrastructure Resource Library: A playbook for transportation projects in Pima County communities (2020)* – Provides comprehensive information about GSI practice design, installation, and maintenance in western arid environments. Discusses funding options to support GSI implementation in transportation projects and provides guidance about policies that support the integration of GSI and transportation planning.
- California Department of Transportation (CalTrans). *Complete Streets: Contextual Design Guidance (2024)* - Identifies best practices and establishes standards for development of Complete Streets facilities to support the design of comfortable and convenient streetscapes by utilizing space-efficient forms of mobility such as people walking, biking, rolling, or accessing transit.
- National Association of City Transportation Officials. *Urban Street Stormwater Guide* - Provides national best practices for sustainable stormwater management in the public right-of-way, including approaches for inter-departmental partnerships, technical design details for siting and building bioretention facilities, and a visual language for communicating the benefits of such projects. Highlights effective policy and programmatic approaches for starting and scaling up GSI, provides insight on innovative street designs, and proposes a framework for comprehensively measuring performance.
- National Cooperative Highway Research Program. *Leading Landscape Design Practices for Cost-Effective Roadside Water Management (2020)* – National summary of how transportation agencies are applying GSI for roadside water management to mitigate adverse impacts of flooding, drought, and temperature extremes affecting transportation infrastructure.
- U.S. EPA. *Green Streets Handbook (2021)* - Intended to help state and local transportation agencies, municipal officials, designers, stakeholders, and others select, design, and implement GSI practices for roads, alleys, and parking lots. Provides background information on street and road typologies and offers a programmatic framework to use when identifying areas that can be initially designed or later retrofitted with GSI practices or systems. Also contains information about green street design considerations, pretreatment and stormwater management practices, and recommendations for external resources with additional detail.

Figure 3. Example of vegetated protective barriers for bike lanes

Sources: Sierra Club Santa Barbara-Ventura Chapter; CyclingWest

Several studies have examined the relationship between GSI interventions, traffic calming, and accident reduction. Findings of these studies generally suggest a positive correlation between certain types of landscape treatments and/or reductions in vehicle crashes. Reduced vehicle speeds also result in less severe injury outcomes when crashes do occur.[6] Trees and other green street elements may be associated with reduced crash rates because they provide an "edge effect" or psychological cue to drive more slowly.[7] Researchers have also noted that green street interventions can make streets appear narrower, resulting in reduced speeds. One study found that higher levels of greenery increased driver attention levels, which in turn decreased response time to emergency situations.[8]

In addition to slower speeds, street trees and other vegetation have been found to provide a calming effect on drivers. Study findings indicate that (1) exposure to natural roadside settings can decrease the magnitude of a driver's stress response, and (2) highway drivers with views of natural roadsides have displayed a higher frustration tolerance, a known precursor of road rage.[9] Table 1 provides examples of studies that document the role GSI practices can play in traffic calming and accident reduction.

GSI strategies that enhance the safety of sidewalks, other pedestrian areas, and/or bike lanes further contribute to public safety for all users. For example, vegetated barriers can improve pedestrian safety by blocking people from stepping into busy roadways or preventing street crossings at dangerous points. When implemented at street corners, curb extensions can decrease crosswalk length, while also forcing cars to slow down as they make turns.[10] The use of vegetation as a protective barrier separating bike lanes from vehicle lanes also improves safety and comfort for cyclists[11] (see Figure 3).

Finally, GSI and green street elements that reduce localized flooding – e.g., roadway flooding in areas where storm sewer capacity is limited or there are other drainage disruptions during rain events – can also prevent accidents and help to ensure safety across alternate modes of transport. Nearly 5,700 people are killed and 545,000 are injured in crashes on wet pavement annually.[12] The Federal Highway Administration (FHWA) reports that even a thin layer of water on roadways can initiate motor vehicle hydroplaning at speeds as low as 35 miles per hour. When a vehicle tire rides on top of this thin layer of water, the vehicle cannot be steered or stopped easily. Ponding or standing water may also cause some drivers, bicyclists,

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

BMP	Location	Description	Results	Study
Street trees and landscaped medians	Colorado	Developed statistical models based on spatial data to examine effect of green streets on crashes and injuries.	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.	Marshall et al. (2019)[14]
Various levels of greening	N/A	Measured driver reaction time by simulating emergencies on roads with five road levels of greening.	Increased doses of greening increased driver attention level and shortened reaction time during emergency incidents.	Chiang et al. (2022)[15]
Street trees & streetside landscaping	Florida	Modeled safety effects of three roadside design strategies: widening paved shoulders, widening fixed-object offsets, and livable-street treatments.	Livable street treatments with street trees have 40% fewer midblock crashes and 67% fewer roadside crashes compared to urban roadways. Wider shoulders increased roadside and midblock crashes; unpaved fixed-object offsets decreased roadside crashes but increased midblock crashes.	Dumbaugh (2006)[16]
Landscape improvements and street trees	Florida	Compared urban arterial road segments with and without landscape improvements.	Road segment with landscape improvements had 11% fewer mid-block crashes, 31% fewer injuries, and fewer fatalities (0 versus 6). Pedestrian and bicyclist injuries were also fewer in the improved road sections.	Dumbaugh and Gattis (2005)[17]
Street trees	N/A	Used driving simulator to analyze effect of street trees on driving behavior, safety perception, and speed in urban and suburban settings.	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.	Naderi (2008)[18]
Landscape improvements, street trees	Texas, urban roads	Evaluated crash rates on 10 arterial and highway sites before and after landscape improvements.	Across sites, crash rates decreased 46% over 3 to 5 year time span. Pedestrian fatalities dropped from 18 to 2.	Mok et al. (2006)[19]
Multiple GSI strategies, including street trees	Toronto urban roads	Evaluated impact of green streets on 5 arterial roads before and after implementation.	Mid-block accident frequencies decreased 5% to 20% Savings > $1.44 million within 3 years based on willingness-to-pay to avoid vehicle accidents.	Naderi (2003)[20]

or pedestrians to divert from their desired path, avoiding going through the water by encroaching on the opposing lane, thus endangering themselves and opposing traffic.[13] Localized flooding can also impede the ability to walk, bike, or access public transit stations particularly in underserved and lower income neighborhoods where residents rely more heavily on these alternative modes of transport.[21]

3.2 Increasing mobility and alternative transport

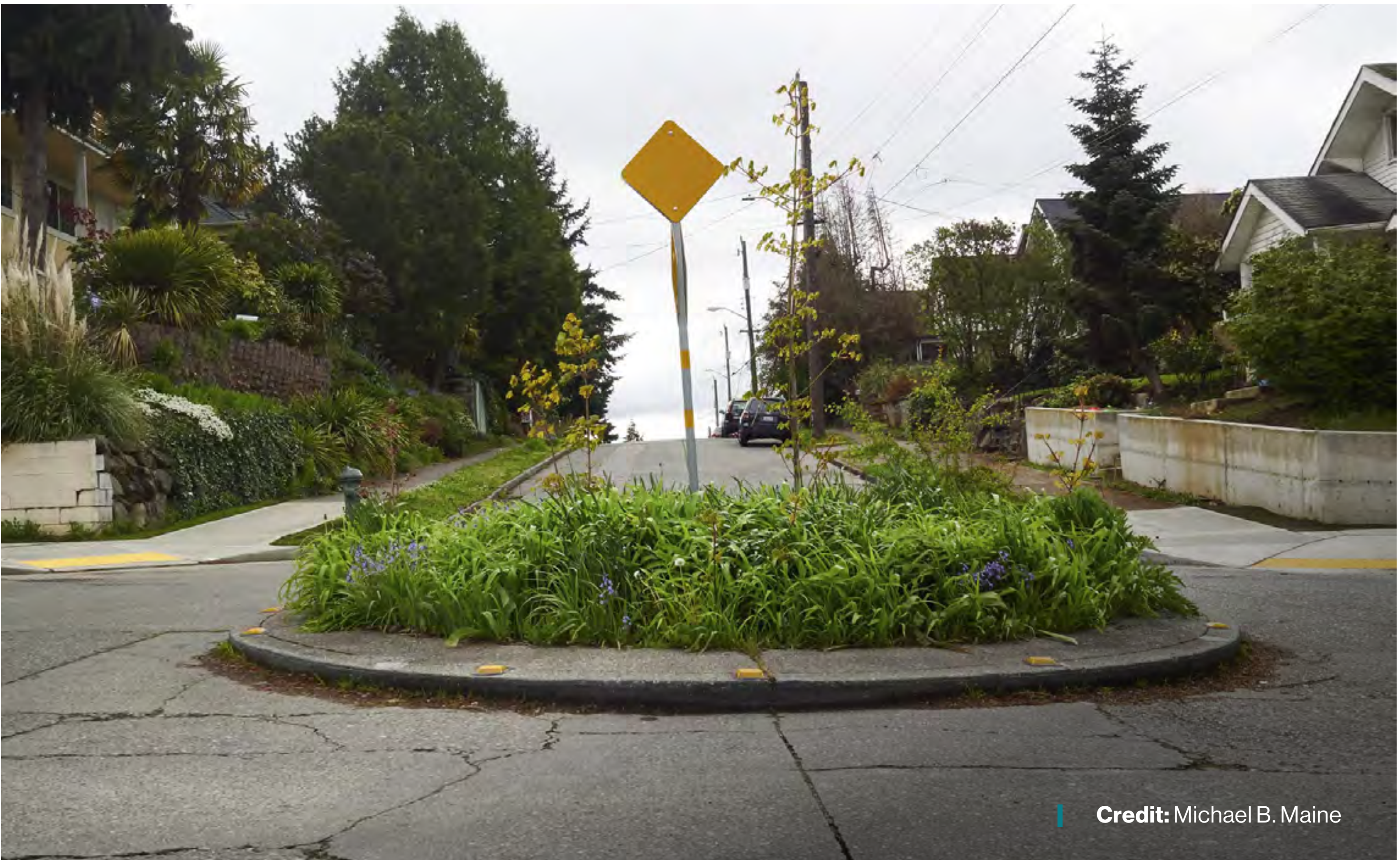
The safety improvements described above have obvious implications for pedestrians, cyclists, and public transit riders. However, several studies have identified additional factors that encourage these alternative modes of transport, including several associated with green street strategies.[22] A recent study in Europe evaluated factors influencing pedestrians' willingness to walk, grouping factors into four categories: physical characteristics of the sidewalk/street, comfort, safety, and attractiveness. Overall, attractiveness ranked higher than many of the safety factors; in particular, respondents ranked having a "high landscape or artistic value" as having the greatest influence.[23] Another study found that parents were more likely to walk, and let their kids walk to school, if the route had sidewalks, landscape buffers, and street trees.[24]

A review of studies examining the effect of street greenery on active travel notes several studies that 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. The authors surmise that the effectiveness of street greenery in promoting active travel is likely rooted in its capacity to enhance the visual appeal of urban environments, offering shade and cooler temperatures, which collectively contribute to increased comfort for pedestrians and cyclists.[25]

A 2020 study in Boston found that people prefer sidewalks and bike lanes with trees. In addition, study participants preferred the location of trees to be between bike lanes and the street, in part because this reduces the perception of traffic and pollution. The author also notes that "mature trees better cool the city. Planting trees between the bike lane and the street would also better shade the street, lessening urban heat island, and turn both sides of the street into wide shaded walking/biking promenades."[26]

FHWA notes that transit agencies play an important role in improving the safety and comfort of pedestrians, and further, that providing safe and comfortable routes to and from transit stops can help maximize ridership.[27] While route safety is important, some studies have found only modest or insignificant correlations between ridership and tree canopy/shade at transit stations, which may be attributed to the baseline level of transit dependency of riders.[28] However, a study in Tucson investigated the impact of thermal comfort perceptions on transit users' ridership experience and health. Survey results revealed that 82.4 % of users reported feeling hot and over half reported experiencing heat-related illness while at the streetcar stops. Additionally, 56 % of streetcar users identified the addition of more shade and greenery as a potential solution to improve their thermal comfort.[29]

Studies have shown that pairing infrastructure improvements (including GSI) with initiatives such as Safe Routes to Schools (see San Mateo County case study later in this guide) can further encourage walking and biking by improving safety and comfort for bicyclists and pedestrians at intersections near schools. A study of 801 schools in Washington D.C., Florida, Texas, and Oregon showed a 25% increase in walking and biking to school over a five-year period associated with education and encouragement programs, and an additional increase of 18% when paired with infrastructure improvements. This means that a school that combines infrastructure improvements with education and encouragement programs is likely to see increases in walking or biking of up to 43%.[30]



Credit: Michael B. Maine

3.3 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. Some studies show that GSI strategies and green street elements can result in cost savings. GSI installations can extend the asset life of streets, pavement, and/or drainage networks, resulting in lower lifecycle costs.[31] Overall cost savings can also accrue when GSI strategies are paired with planned transportation projects, resulting in more cost-effective applications compared to a siloed approach (i.e., by "digging-once").

The upfront costs associated with green streets can be higher than for traditional streets – by some estimates, the additional design considerations, labor and material, and initial maintenance needs associated with GSI strategies can add 12% to 25% to the cost of street improvement.[32] GSI integration can involve conflicts with underground utilities and other considerations that have the potential to increase costs. This is not a universal rule, however, as several studies and real world applications demonstrate cost savings. This is particularly true in cases where green street applications can avoid or reduce the need for traditional stormwater management practices, including culverts, curb and gutter treatments and/or underground piping.[33] A case study in Shawnee, Kansas for example, reported $2.1 million in capital cost savings per mile of road reconstruction for green streets compared to traditional streets because, under the green street option, the city was able to eliminate curbs, gutters, and enclosed storm sewers and reduce the overall road area.[34]

Specific green street elements can have lower overall lifecycle costs relative to their traditional (non-stormwater) alternatives.[35] For example, there is evidence that permeable asphalt can handle freeze/thaw stress better than traditional asphalt, extending its comparative useful life by up to 15 years in northern climates. Porous asphalt pavements can also develop fewer cracks and potholes than impervious asphalt.[36] These pavement alternatives may be particularly appropriate in parking lanes and lots where potholes are less likely to arise. Similarly, modern vacuum trucks can accomplish both porous pavement vacuuming and traditional street sweeping, reducing the need for specialized equipment. And in some cases, particularly where a more natural aesthetic is used, vegetated systems may require even less maintenance than traditional landscapes, such as turf grasses that require frequent mowing.[37] Some studies report that permeable concrete and permeable asphalt can last up to two times that of their traditional alternatives, resulting in significantly lower replacement costs over time.[38]

In some cases, GSI practices can enhance the longevity of transportation infrastructure. Street trees for example, can reduce temperature-related wear on asphalt streets, in turn reducing road maintenance and repaving costs.[39] According to a Center for Urban Forest Research report, 20% shade cover over a street improves pavement condition by 11%, saving 60% in resurfacing costs over 30 years.[40] A study in Modesto, California, found that streets shaded with small crowning trees required one less slurry seal application over 30 years, while large crowned trees cut slurry seal applications by 50%.[41] These benefits must be carefully evaluated for application in colder climates, where tree shading can present difficulties in snow removal and/or ice buildup in winter months. Additionally, consideration should be given to potential root impacts on streets, sidewalks and other surfaces as well as underground utilities. These impacts can, in some cases, be mitigated through appropriate tree species selection.[42] Table 2 presents findings from a sample of studies documenting the cost saving benefits associated with GSI and green street transportation alternatives.

To fully evaluate benefits, practitioners should also consider the avoided costs associated with alternative stormwater management practices that could be avoided or downsized due to GSI implementation. For example, as part of its Sustainable Streets Master Plan, San Mateo County California modeled the extent to which sustainable streets could manage increased runoff from roadways under future climate scenarios. Findings indicated that broad-scale implementation of green streets throughout the county could completely offset the projected increase in roadway runoff for the future 2-year design storm, while increased roadway runoff for the 5-year storm would be offset by 65%. These scenarios assume a major and long-term investment in GSI implementation, which is currently economically and likely technically infeasible from an engineering standpoint in a highly urbanized landscape, yet the analysis demonstrates the potential for reducing storm drain improvements that might otherwise be required to manage future precipitation impacts. While sustainable streets are less effective at mitigating projected increases in runoff associated with larger storms, they could help to offset or defer costs associated with upgrading the existing storm sewer system to handle larger storm events, particularly when targeted to specific locations and/or integrated into a larger GSI program.

Finally, reconsidering how municipalities evaluate maintenance costs can provide more comprehensive insights into the long-term costs of transportation GSI. A direct comparison of green vs. gray costs may show that vegetated systems are more costly to maintain. However, by considering the surrounding impervious area treated by GSI, the cost curves can change. Research indicates that on a per square foot of impervious area treated bioretention maintenance costs compare favorably with traditional subsurface systems.[48] Maintenance costs may also be influenced by location and practice type and need.[49]

Table 2. Findings from select studies documenting the benefits of GSI for reducing infrastructure costs and extending the life of infrastructure

BMP	Description	Results	Study
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).	U.S. EPA (2013)[43]
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 treat 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.	Wong and Stewart (2008)[44]
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.	Clements et al. (2021)[45]
Permeable Pavers	Compared life cycle cost of permeable interlocking concrete pavers to conventional asphalt pavement over 10.5 miles of urban roadway.	Net difference over lifecycle cost for permeable pavers saves $10.8M compared with asphalt, or approximately $1M per mile of road.	Applied Research Associates (2018)[46]
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.	McPherson and Muchnick (2005)[47]

Figure 4. Curb extension on Fleet Street in Baltimore.

Credit: Will Parson/Chesapeake Bay Program

As noted above, integrating GSI into scheduled transportation repair and rehabilitation projects can result in significant cost savings for stormwater management compared to a siloed approach. Research indicates that communities can save upwards of 30% to 60% on GSI-based stormwater management by integrating GSI into planned transportation, road reconstruction, utility restoration, or redevelopment projects. The World Resources Institute (WRI) highlights a project along Fleet Street in Baltimore's Highlandtown neighborhood, which was built when the sidewalk was redone in conjunction with the construction of a LEED Gold-certified building (Figure 4). WRI reports that by "digging once," the city was able to save time and money by coupling two projects together.[50]

An assessment of GSI programs in Onondaga County, NY also found significant cost savings by integrating GSI into planned projects. Rather than analyze the cost of the county's GSI by practice type, this study assessed costs across nine GSI implementation programs, such as green streets, vacant lot greening, and green schools. The team found that the most cost-effective projects were those integrated with the city's annual street construction work (costing $129,000 per impervious acre managed, 2015 USD). Green schools, some of which were integrated with school renovation projects, were the second most cost effective. The authors point out that by this definition of integration, the real costs of GSI are only those beyond the cost of the planned roadway improvements.

3.4 Reduced air pollution

Green streets can reduce air pollution by encouraging alternative modes of transport (thereby reducing vehicle miles traveled and associated pollutants) and through the interception and uptake of pollutants by trees and other vegetation. Pollutants from vehicle exhaust include carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter (PM), and volatile organic compounds (VOCs). Once emitted, some of these pollutants (i.e., NO2 and VOCs) combine to form ozone, or smog, on hot sunny days. The adverse health effects associated with pollution from vehicles are well documented; they contribute to a range of respiratory illnesses like asthma and bronchitis, cardiovascular disease, and even life-threatening conditions like cancer.[51] Children, older adults, people with preexisting cardiopulmonary disease, and low-income households are among those at higher risk for health impacts from air pollution near roadways.[52]

Roadways generally influence air quality within a few hundred meters – approximately 500 to 600 feet downwind from the vicinity of heavily traveled roadways or along corridors with significant trucking or rail activity. This distance varies by location and time of day or year, wind speeds, topography, nearby land uses, traffic patterns, and individual pollutants. Generally, the more traffic, the higher the emissions; however, certain activities like congestion, stop-and-go movement, or high-speed operations can increase emissions. Larger and older vehicles tend to produce more emissions.[53 54]

Trees and other vegetation intercept and uptake airborne pollutants, including PM, CO, NO2, and others. 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 vegetation, especially trees, 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.[55] Planners can maximize the air quality benefits of green street projects with an understanding of these various factors.

Trees are the most efficient vegetation for pollutant removal because of their large leaf surface area and the turbulent mixing produced by the air passing through and over them. In general, trees with greater structural complexity in their canopy, branches, and leaves capture more PM. Coniferous trees can be more effective than broadleaf trees due to their more complex shoot structure and fine needles, while larger trees remove more pollution because of their greater leaf surface area. Other GSI practices that can improve air quality include right-of-way bioswales, stormwater bump-outs, bioretention cells, and flow-through filter boxes. Including herbaceous vegetation in green street applications, along with trees and shrubs, can help improve PM removal rates. Locating trees and other vegetated practices close to the roadway maximizes the efficiency of interception and deposition of pollutants.[56]

Streets in urban and suburban areas can generally be classified as open roads or street canyons, at least to varying degrees. Open-road environments have lower-rise buildings and/or a lower building height to street width ratio, while street canyons have tall buildings on both sides and relatively narrow streets. When the building height to street width ratio reaches a certain threshold, trees can increase air pollution, as they reduce wind speeds and limit air exchanges above and below tree canopies. However, a reduction in tree density can lessen this impact. Findings from the literature indicate that low vegetation and hedges are ideal for street canyons, with studies reporting reductions in sidewalk air pollution between 24% and 61%.[57]

Some studies report that on open streets, dense vegetation can more effectively mitigate downwind pollutants because its low porosity limits the contaminants that pass through the vegetated barrier. A study along a highway in California found that roadside vegetation of sufficient height, thickness, and coverage achieved downwind air pollutant reductions of 50%, but that highly porous vegetation stands slightly increased downwind pollutant concentrations.

> **A study on the effect of different street tree layouts on pedestrians and cyclists' exposure to PM during urban commuting trips confirmed that trees can significantly reduce air pollution.**

These findings may be specific to higher-trafficked roads. In this study, medium spacing of trees (approximately equal to crown diameter) resulted in the greatest benefits, attenuating PM by 26% to 56% in the bike lane and 28% to 59% on the sidewalk, depending on particle size, in relation to on-street traffic-lane measurements.[58]

3.5 Reduced Noise Pollution

There is a significant body of evidence supporting the road noise reduction effectiveness of trees, hedges, and other forms of urban greenery. However, much of the literature focuses on the value of green spaces, such as parks and green belts, rather than on the quieting effect of GSI along roadways. Some inferences about GSI noise abatement can be drawn from research into urban trees, green roofs, green walls, and other networked or small-scale green spaces. In addition, the limited research that focuses specifically on GSI suggests that these practices have a positive effect on urban road traffic levels. When integrated into GSI projects, trees can mitigate noise via two main mechanisms: 1) by absorbing the energy of sound pressure waves, and 2) by redirecting and scattering the sound waves, acting as a shield in front of receptor locations such as, for example, residential buildings. However, noise reduction benefits are most closely associated with a scale of tree plantings that exceeds the size of typical linear GSI projects. The evidence suggests that urban greenbelts of at least 15 meters in width are necessary. A similar expanse of shrub layers, with heights either lower than 0.5 m or higher than 2 m can also attenuate road noise.

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. European researchers have documented the available evidence describing the effectiveness of green roofs at reducing urban street noise, noting that the planting substrate appears to absorb low frequency sounds while the plantings effectively dissipate exterior high frequency noise, particularly within building courtyards and "urban canyons."

In addition to measured noise pollution, residents of urban areas often suffer from perceived levels of excess noise. Interestingly, the presence of greenery in the urban environment has a positive effect on people's mental attitudes, leading to perceptions of reduced noise levels. Some research suggests that the ability of people to have a window view of multi-color, species diverse GSI can reduce perceived annoyance with urban noise levels.[64]

3.6 Neighborhood revitalization and positive economic effects

The accompanying Guide to Understanding the Job Creation and Economic Development Benefits of Green Stormwater Infrastructure (accessed through the GSI Impact Hub) describes the neighborhood improvement and economic development benefits that GSI projects can provide. These benefits can be particularly relevant when GSI is implemented at a larger scale, such as through a comprehensive green street project or program.

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. More recently, this result has been affirmed by studies showing that consumers are willing to pay a premium on products, visit stores and restaurants more frequently, or travel farther to shop in areas with attractive landscaping, good tree cover, or green streets.[66 67 68] The New York City Department of Transportation (NYCDOT) 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.[69]

> A keystone study from the early 2000s found that customers respond positively to shopping environments with more trees, expressing a willingness to pay more for products and services from businesses located in these areas.

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. The City of Seattle, an early pioneer in the development of green streets and low impact development projects, found a premium on homes located in areas where green street improvements were implemented. Specifically, compared to similar houses in the same zip-code, houses adjacent to Seattle's Street Edge Alterative (SEA) projects sold for 3.5 to 5% more following green street implementation.[70] 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.[71]

In 2016, the Sustainable Business Network (SBN) of Greater Philadelphia GSI Partners published a report documenting the economic impacts and benefits associated with the first five years of the Philadelphia Water Department's Green City, Clean Waters (GCCW) Program.[72] GCCW is Philadelphia's large-scale CSO control plan that focuses on GSI implementation. The study included an original analysis that estimated the effect of the City's completed GSI projects on nearby residential property values. These projects primarily consist of stormwater bump outs in the public right-of-way, stormwater planters, rain gardens, and stormwater tree trenches. Results of the analysis indicated that public projects that are not located at a park, school, or recreation center (and therefore more indicative of green street projects) increase residential property values within a quarter mile by 12.7%.

Credit: Rick Triana

4

Quantifying and Monetizing Benefits of GSI and Transportation Projects

Credit: City of Vancouver, BC

QUANTIFYING AND MONETIZING BENEFITS OF GSI AND TRANSPORTATION PROJECTS

The benefits of integrating GSI into the transportation network can be difficult to quantify. However, evaluating lifecycle costs and recognizing the avoided costs associated with green street approaches can reveal a project's or program's benefits and cost savings. Rules of thumb and simple approaches can be applied to evaluate key benefits within the context of overall costs. This section highlights these key concepts.

4.1 Life cycle cost comparison and avoided cost analysis

Evaluating life cycle costs and accounting for any avoided gray infrastructure or alternative stormwater management infrastructure is key to understanding the true value of green street applications. Steps for conducting these analyses are as follows:

- **Define a green street project or program, including key outcomes.** To conduct an economic analysis, 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 rough cost estimates and to inform 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 scenario should reflect the steps that would be taken if the planned green street project or program is not implemented. This may include the implementation of more traditional transportation network approaches or upgrades (i.e., without the integration of GSI strategies) and/or installing additional stormwater management capacity (e.g., storm drain, culvert, or pump station) elsewhere.
- **Evaluate life cycle costs over time under both scenarios.** Life cycle costs include planning and design, construction, annual operations and maintenance, and replacement costs. In comparing costs over time, it is important to apply an appropriate discount rate so that all costs are compared in today's dollar

terms. The Federal Office of Management and Budget (OMB) Circular No. A-94 provides annual guidance on discount rates that are used in cost-effectiveness and benefit-cost analyses of federal programs.

The assessment should explore assumptions related to the expected useful life of alternative investments and/or the asset life extension benefits described in Section 3, as applicable. Table 3 shows results from a literature review that compiled information on the costs and expected useful life of different permeable surface types compared to their traditional alternatives. As shown, in some cases permeable surfaces can last up to twice as long as their traditional counterparts, resulting in significant savings in the form of avoided replacement costs.

- **Evaluate benefits in context.** At this stage, it is important to cast benefits in context. For example, if the life cycle costs of a green street project are 30% higher than a baseline scenario that reflects a traditional street improvement project, does the value of additional co-benefits associated with the project cover this additional amount?

It can also be useful to conduct a break even analysis to examine benefits in relation to costs. For example, applying the valuation methods below for key benefits, if the project avoided one accident per year or increased property values in the area by even just 1% (above and beyond the baseline), would that be enough to "make the project worth it"? Sensitivity or scenario analysis can illuminate the effect of various assumptions on overall results, which can help to better understand overall benefits by providing upper and lower bound estimates.

Table 3. Maintenance and replacement costs for permeable and traditional pavement (2024 USD)

Pavement type	Maintenance costs ($/sq ft/yr)	Replacement costs ($/sq ft)	Expected Useful life (years)
Permeable Concrete	0.015	$ 4.87	20-40
Permeable Asphalt	0.015	$ 2.10	20-40
Permeable Pavement	0.028	$ 5.92	15-50
Concrete Sidewalk/Driveway	0.04	$ 6.76	30 - 40
Asphalt Street	0.07	$ 5.29	17.5
Asphalt Parking Lot	0.18	$ 6.73	15

Source: Clements et al. 2020

4.2 **Safety improvements**

Safety practitioners and researchers have established methods for evaluating "crash costs" to determine if road safety improvement projects are economically justified.[73] While the same methodology can be applied to evaluate the safety benefits of green streets, it does require data on the type and severity of crashes expected with and without the project. Even without this data, information on the full 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%.

In 2018, FHWA developed national crash costs for use in benefit cost analysis for roadway safety projects. This study yielded comprehensive unit crash costs by crash type/severity that can be adjusted for differences in the cost of living in different locations. The comprehensive unit costs reflect two categories of value:

- **Economic costs -** the direct and indirect monetary costs that result from crashes. They can include costs for police, medical, and fire-related emergency services, health care, and legal and insurance costs, as well as the value of lost wages and productivity for victims and others impacted by the crash and costs to employers resulting from victims' absence, and property damages.
- **Lost quality of life and fatalities -** the intangible consequences—such as the physical pain and emotional suffering of people injured in crashes and their families—comprise the other impacts of crashes. FHWA uses established methods including the Value of Statistical Life (VSL) and Quality Adjusted Life Years (QALY) to monetize these impacts (see text box).

Comprehensive crash costs are the combination of the economic costs and the monetized pain and suffering that result from crashes. Crash costs are most often reported by crash severity, which is based on established injury scales. To develop national crash costs, FHWA used the KABCO injury scale. Table 4 shows FHWA's estimated national comprehensive crash unit costs by KABCO crash severity level.

Valuing the "intangible" impacts of road accidents: Key Terms

Mortality risk valuation: Researchers and federal agencies quantify lost quality-of-life due to death or injury by estimating the value that people put on their lives. This is determined based on the price individuals pay to avoid risk of death or injury. It is derived from studies that evaluate marketplace choices such as deciding to purchase safer, more expensive protective gear or equipment.

Value of Statistical Life (VSL): The monetary value of risk reduction corresponding to the prevention of one fatality. The VSL is currently $13.2 million (2023 USD).

Quality Adjusted Life Years (QALY): Costs are determined based on a numerical scale for rating health-related quality-of-life impacts, with death equal to 0 and perfect health equal to 1. QALY is measured as a fraction of the VSL for a given analysis year based on that rating.

4.3 **Increased mobility and alternative modes of transport**

Green streets can encourage walking, biking, and transit ridership, and contribute to a network of safe routes that facilitate bike and pedestrian commuting (particularly when planned for that purpose). This results in improved public health outcomes, and, when more people use alternative modes of transportation, reduces congestion and vehicle-related emissions (see next section). In this capacity, the effect of green streets can be difficult to quantify without extensive studies and data. However, again, this benefit can be evaluated in context.

First, when designed appropriately, green streets can encourage outdoor recreational activity, including walking and biking for pleasure. Individuals value these activities for several

Table 4. FHWA recommended national KABCO comprehensive crash unit costs (2024 USD)

Severity	Comprehensive Unit Crash Costs	Severity Definition
Fatal injury (K)	$ 14,754,775	Injury that results in death within 30 days after the motor vehicle crash in which the injury occurred.
Suspected serious injury (A)	$ 845,350	Significant injury such as severe laceration, significant loss of blood, broken or distorted extremity, crush injuries, suspected skull, chest, or abdominal injury, significant burns, unconsciousness when taken from the crash scene, paralysis.
Suspected minor injury (B)	$ 259,000	Injury that is evident at the scene of the crash, other than fatal or serious injuries. Examples include lump on the head, abrasions, bruises, minor lacerations.
Possible injury (C)	$ 164,000	Injury reported or claimed which is not a fatal, suspected serious, or suspected minor injury. Examples include momentary loss of consciousness, claim of injury, limping, or complaint of pain or nausea. Possible injuries are those which are reported by the person or are indicated by his/her behavior, but no wounds or injuries are readily evident.
No apparent Injury/property damage only (O)	$ 15,500	No physical evidence of injury and victim(s) does not report any change in normal function. Often called PDO or property damage only.

reasons, including for physical health benefits and improved mental health. Because these activities are not traded in the market (i.e., there is no fee for participation), it can be difficult to establish the values associated with them. However, many researchers have conducted WTP surveys to estimate the value of a recreational experience across a range of activities. These studies yield what economists refer to as direct use values. Direct use values reflect the amount that individuals would be willing to spend to participate in a recreational activity if they had to pay for it. Total benefits are a function of direct use values and the additional outdoor activity trips taken as a result of the green street improvements.

Direct use values can range significantly depending on the availability of existing opportunities for similar activities, the type of recreational activities facilitated by GSI improvements (in this case walking/biking), the amount and quality of the space, and other local conditions. To account for these variations, the U.S. Army Corps of Engineers (ACOE) developed the Unit Day Value Method. This method relies on informed opinion and judgment to estimate the average WTP to participate in different recreational activities based on various factors (e.g., access, quality, substitutes available). A typical green street, which supports generalized recreation, would likely yield a direct use value of between $5.86 and $7.40 per trip (2024 USD). See the text box on how the ACOE method was applied in Philadelphia to estimate the walkability benefits associated with general urban greening under the city's Green City Clean Waters Program.

Beyond outdoor leisure activities, green street networks can encourage some 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).[74] Based on data from the U.S. Census American Community Survey (ACS), 77.5% of workers commute to work in a private vehicle (car, truck, or van). Of this group, 23% report a commute of less than 10 minutes, while 9% report a commute of 5 minutes or less. If one quarter of vehicle commutes that take 10 minute or less were substituted with walking or biking, 11.5 billion fewer miles would be driven. Based on the 2024 federal reimbursement rate for personal vehicle use for business ($0.67 per mile, which is intended to reflect the full cost of driving), this would save $7.23 billion per year in vehicle-related transportation costs. This equates to $255 per substituting household per year, on average.

Walking and biking also supports increased physical activity and decreases the risk of chronic disease and obesity. For example, walking one mile to and from school or work accounts for two-thirds of the recommended sixty minutes of physical activity per day. Studies have also found that children who walk to school have higher levels of physical activity overall; physical activity also improves academic performance in children.[75] These more intangible benefits associated with green streets can be better captured through studies that estimate WTP for green street improvements (see section 4.5) and/or described qualitatively.

Applying ACOE's Unit Day Value Method to estimate "walkability" benefits in Philadelphia.

A 2009 study on the triple bottom line (TBL) benefits of GSI-based alternatives for combined sewer overflow (CSO) control in Philadelphia applied the Unit Day Value Method to estimate the recreational benefits associated with its' significant planned increase in urban vegetation and tree canopy throughout the city (i.e., general urban greening). The authors of the study estimated that a scenario in which 50% of stormwater runoff from impervious area in the city would be managed through GSI would result in approximately 2.7 million walking trips per year (less than 2 trips per person per year, on average); this would amount to approximately $122.6 million in direct use value (present value) over the 40-year study period (updated to 2024 USD).

4.4 **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, when integrated into streetscape environments, can also intercept and absorb these pollutants. As described in Section 3.4, vehicle-related emissions contribute to adverse human health effects. The benefit of reducing these pollutants can therefore be valued based on associated reductions in health-related costs and/or WTP to avoid specific health outcomes.

The U.S. EPA and other federal agencies have developed standard monetary values for estimating the avoided pollutant-related health effects and other damages caused by emissions from vehicles, including NOx and $PM_{2.5}$. These estimates are derived from health impact functions, which translate air quality changes into health outcomes (and changes in health care costs) based on published studies. These models account for characteristics of the local population (e.g., age distribution, density) and baseline incidence rates for related health conditions.

Table 5. Avoided emissions and associated benefit values per 100 vehicle miles avoided

Pollutant/GHG	Value per ton (2024 USD)	Emissions per vehicle mile (grams per mile)	Value per 100 miles avoided	Source
Nitrogen oxides (NOx)	$16,632	0.12	$0.23	Wolfe et al. 2019; BTS [78,79]
Particulate matter (PM2.5, directly emitted)	$1,642,410	0.01	$1.09	Wolfe et al. 2019; BTS [80,81]
$CO2_e$ [a]	$250	400	$11.00	IPC , U.S. EPA [82,83]
CO	$159	3.65	$0.06	IPC, BTS [84,85]
Hydrocarbons [b]	$8,756	0.29	$0.28	U.S. EPA; BTS [86,87]
		Cost benefits per 100 vehicle miles avoided:	**$12.66**	

a. EPA recently (2024) updated the SCC. EPA does not value CO directly. CO has an atmospheric life of 1 to 3 months and is converted to CO2 over time (when it reacts with oxygen), the value per ton estimates for CO are therefore derived from the social cost of carbon. The SSC is adjusted to account for the relative molecular mass of CO within the CO2.

b. Hydrocarbons (HCs) are valued based on the benefit per ton estimate for volatile organic compounds (VOCs) because HCs emitted from vehicles are oxygenate VOCs

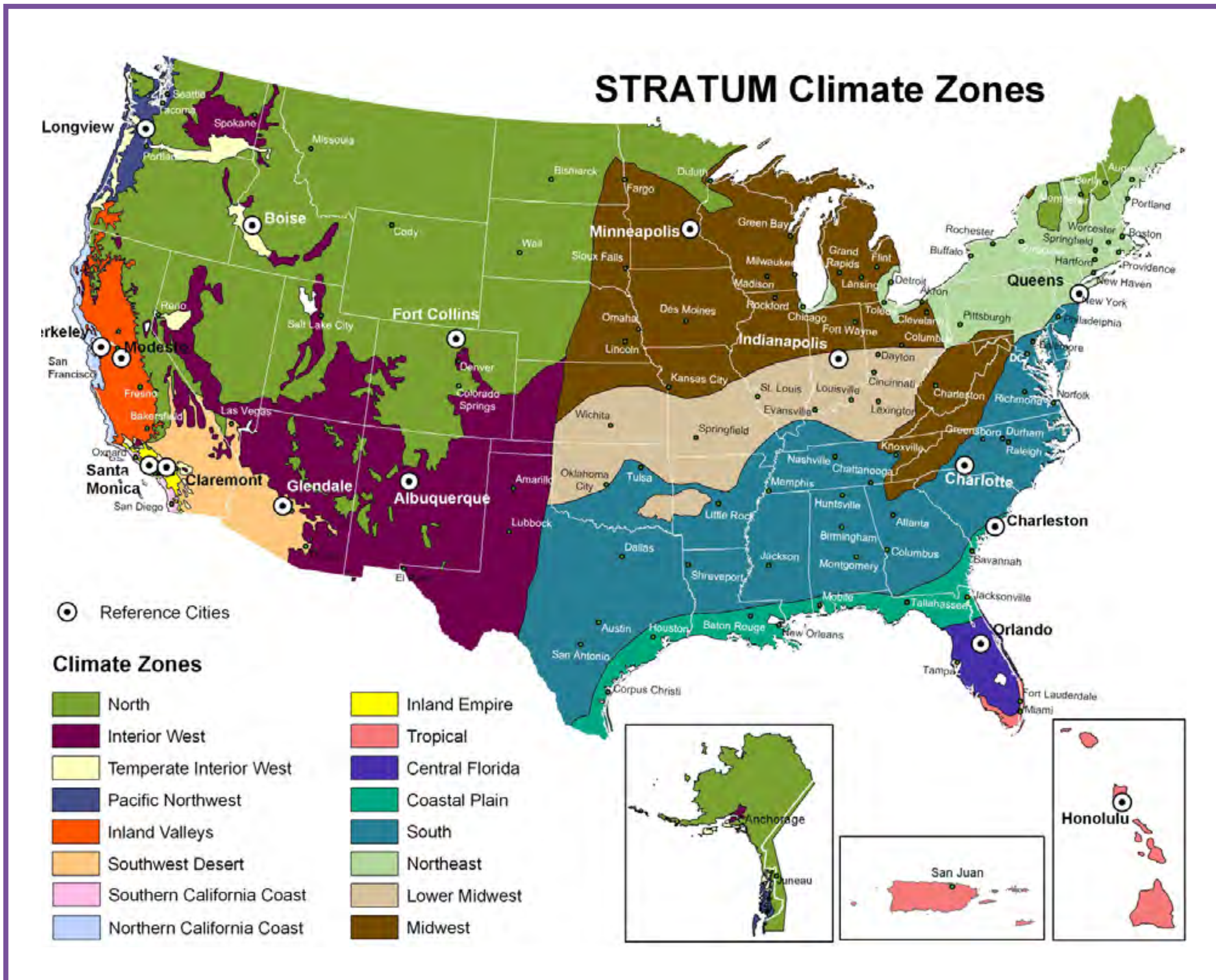
Similarly, reductions in GHG emissions are valued based on the long-term damages associated with incremental increases in carbon emissions. Often referred to as the social cost of carbon (SCC), these damages include but are not limited to the impact on agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.[76]

Table 5 shows national "benefit per ton" values for avoided vehicle emissions and calculated monetary values associated with 100 miles of vehicle miles traveled. For context, approximately 121 million people commute to work in a private vehicle (78% of all commuters). Most (89%) of these commuters report that they drive solo to work. Approximately 23% of these commuters drive ten minutes or less to their place of employment, while 9% drive five minutes or less. Replacing even 10% of the less than ten minute commuter trips with walking or biking would reduce vehicle miles traveled by 4.6 billion per year.[77] Based on the table above, the monetized value of health benefits associated with related air quality improvements would amount to $582 million per year.

Table 6. Annual air pollutant removal and carbon sequestration benefits from trees and other vegetation, by climate region, 2024 USD

Climate region	Benefits per tree (at year 30)	Benefits per 1,000 sq. ft. of GSI vegetation
Central Florida	$121.74	$ 27.57
Coastal Plain	$71.47	$ 28.79
Inland Empire	$57.04	$ 24.61
Inland Valleys	$42.93	$ 24.61
Interior West	$32.05	$ 21.38
Lower Midwest	$70.71	$ 25.47
Midwest	$106.22	$ 24.17
North	$93.17	$ 28.19
Northern California Coast	$54.06	$ 24.61
Northeast	$43.48	$ 24.70
Pacific Northwest	$139.93	$ 26.56
South	$230.63	$ 28.27
Southern California Coast	$27.84	$ 24.61
Southwest Desert	$50.36	$ 24.61
Temperate Interior West	$80.96	$ 28.19
Tropical	$36.62	$ 27.57

Figure 5. USFS climate regions



Credit: i-Tree

4.5 **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 WTP for these improvements through revealed preference or stated preference studies (see text box on the following page).

While WTP studies are a relatively common method for valuing environmental goods and services that are not traded in a marketplace, relatively few studies have examined WTP for GSI strategies specifically. There are at least a handful of notable revealed preference studies that estimate the value of GSI within the public right-of-way by examining its effect on nearby property values. Most studies show increases ranging from 2% to 5%; the two studies highlighted in Section 3, which are specific to green streets, found increases in property values for single family homes ranging from 3% to more than 10%. Other studies report increases of around 6% for multifamily homes.[88] WTP for GSI (as measured through property value increases) will depend on the project's design or nature and how well practices are maintained.

Table 7. Summary of findings from original revealed preference studies for GSI/green streets

Location	Description	Results	Source
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%.	Ward et al. (2008) [89]
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.	Econsult (2016) [90]
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.	Netusil et al. (2014) [91]
New York City, NY	Examined effect on retail sales for businesses located on "complete streets" that included tree planting and other GSI.	Complete street improvements can have significant, positive effect on retail sales. One example showed an increase of more than 100% post-construction relative to comparison sites.	New York City DOT [92]

Table 7 provides an overview of revealed preference studies that have estimated the benefits of green street improvements. Findings from these studies can be applied to properties within a study area to provide a rough estimate of the value of planned or existing improvements to nearby residents. Applying percentages from studies of one location to another has drawbacks in that it does not control for various influencing factors such as income levels and housing prices; however, it can be valuable for putting benefits in context.

Fewer studies have examined WTP for GSI using stated preference techniques, and several of these were conducted in areas outside of the U.S. One study in Northern New Jersey, however, found 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 $327.20 (2024 USD) for GSI located within a block of their home that results in high levels of flood risk and CSO reduction and provides co-benefits related to air quality, water supply, habitat, and energy savings. This compares $84.90 for infrastructure that only reduces flooding and CSOs (with no co-benefits). This study points to the value of co-benefits to residents, in particular air quality and water supply benefits, which were rated most highly in this study.

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. For example, the increases in property values associated with green streets may reflect the fact that they improve walkability and biking opportunities, in addition to providing visual appeal, among other benefits. In this case, WTP values cannot be added to monetized values for improved walkability/recreational opportunities as this would overestimate total benefits. To estimate the intangible benefits that are captured in WTP values, researchers often apply a fraction of total WTP, subtract out the value of benefits estimated in other ways, and/or use WTP estimates to reflect the total benefits (and/or as a benchmark against which to compare costs).

Economic methods for valuing non-market goods and services

Stated preference methods

Stated preference methods rely on survey questions that ask individuals to make a choice, describe behavior, or state directly what they would be willing to pay for a non-market good or service. This is often measured in terms of willingness to pay (WTP) per-person or per-household. These estimates can be extrapolated to a wider study population to provide an indication of total value.

An advantage of stated preference methods is that they include the ability to estimate both use values and non-use values. For example, they can be used to estimate WTP for water quality improvements by individuals who both participate in water-based recreation (i.e., use values) and those who do not, but who value these improvements for other reasons (i.e., non-use values).

Revealed preference methods

WTP can also be inferred from choices people make in related markets. Methods that employ this general approach are referred to as revealed preference methods because values are estimated using data gathered from observed choices that reveal the preferences (i.e., WTP) of individuals for non-market goods and services.

A common revealed preference method is hedonic pricing. Hedonic methods use statistical analysis to estimate the influence of different factors on observed market prices. For example, researchers employ hedonic studies to estimate WTP for GSI by comparing price differences between properties that that are located close to GSI improvements and those that are not. Hedonic models isolate the effect of GSI on a property's market value while controlling for all other factors.

5

Case Studies: Working with Partners to Integrate GSI and Transportation

Credit: Carly Siege/Chesapeake Bay Program

CASE STUDIES: WORKING WITH PARTNERS TO INTEGRATE GSI AND TRANSPORTATION

Successful implementation of green streets can be challenging as it typically requires extensive coordination across transportation agencies, stormwater departments, and other stakeholders. These partnerships can be difficult to initiate and sustain. This section highlights the experience of several utilities across the country in overcoming barriers to collaboration to implement successful green street projects and programs.

5.1 Roadblocks and Challenges to Green Street Partnerships

In many locations, the integration of GSI into street and roadway projects has a rich, decades-long history. Portland and Seattle, for example, were early adopters of green street approaches. However, physical constraints, regulatory requirements, and typical approaches to transportation projects can create enduring challenges for GSI proponents.[93] Individual department priorities and budgets are often siloed, and agency and department cultures vary, creating additional complexities. Adding to the complexity of cross-departmental collaboration is the sheer number of public agencies and public or private utilities whose roles intersect with implementing GSI within the public right-of-way. Figure 6 provides an example from Dallas, TX of the array of departments and interests at play within a typical street corridor.

Implementing GSI in urban rights-of-way or other transit spaces necessitates a process of navigating and resolving this complex regulatory and jurisdictional puzzle. Throughout the interviews with municipal stormwater leaders that informed this guide, the authors heard several accounts of the challenges faced by municipal stormwater staff as they sought to create and manage partnerships with their stormwater agency counterparts. These challenges can be summarized as:

- **Transportation project technical standards may create challenges for GSI implementation**. While stormwater agencies have generally made considerable progress toward an embrace of GSI in recent decades, the technical standards that typically govern transportation projects continue to emphasize practices that may be incompatible with GSI and/or are not being updated adequately to include green streets or GSI standards. Finding common ground over technical approaches can be difficult.
- **Incongruities between the priorities and timelines that drive project selection at the respective agencies.** Transportation and stormwater teams may have different goals and respond to different motivating factors (like

significant backlogs of basic road maintenance needs), resulting in a lack of alignment over project prioritization. Timelines and design requirements for developing transportation projects may differ between stormwater and transportation agencies.

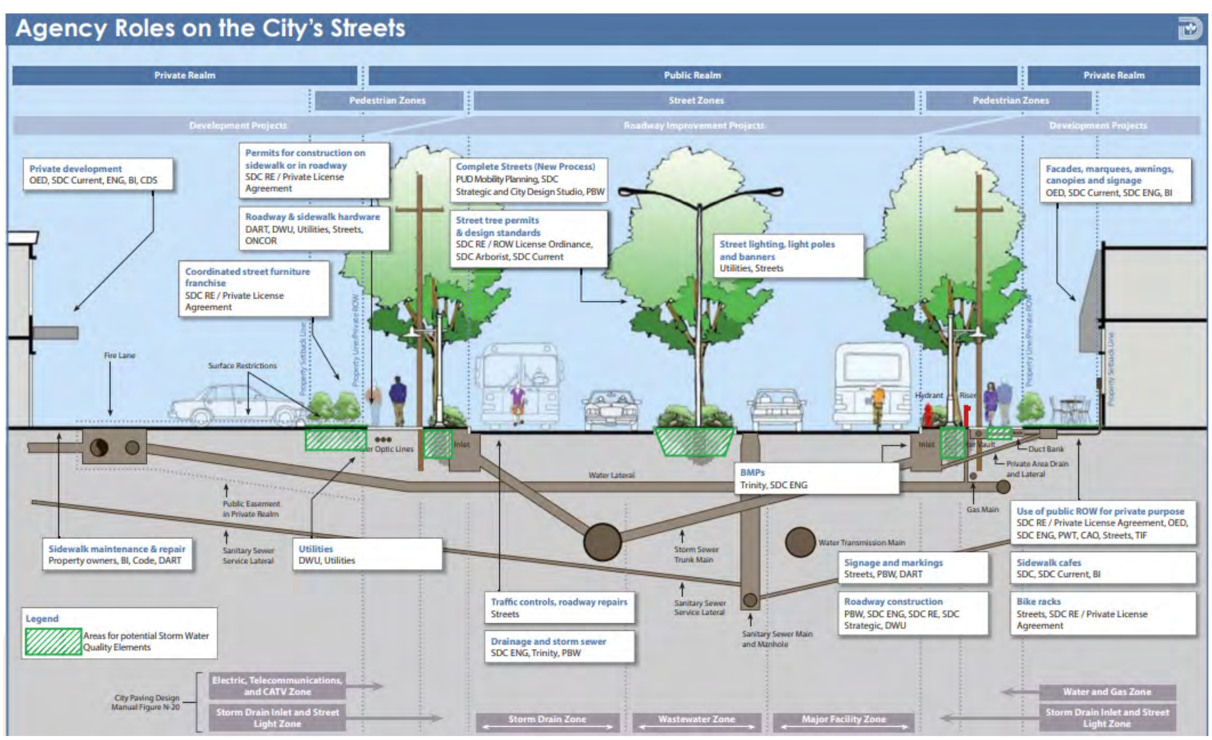
- **Funding restrictions, requirements, and eligibility.** Restrictions and limitations within the budgets of stormwater and transportation agencies, and their other public agency partners, as well as with respect to grant funding eligibility and scoring criteria, can frustrate efforts to co-fund GSI project implementation and maintenance.
- **Long-term maintenance obligations.** GSI elements of transportation projects can become "orphans," with unclear or undefined allocation of maintenance responsibilities and resources to ensure well-maintained facilities. Budget limitations may play a role in confounding ongoing maintenance, reducing the benefits provided by GSI projects over time and potentially causing hesitation to expand programming and projects in future.

The following section uses case studies from several cities across the United States to illustrate the resolutions that partnerships have found (or created) to overcome these challenges.

5.2 Partnerships as Pathways to Achieve GSI Benefits

Through a series of workshops and interviews, stormwater leaders from around the country expressed a need for case studies and best practices that highlight the value of partnerships for green street implementation and support overcoming some of the known or perceived barriers mentioned above. This section 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.

Figure 6. "Agency Roles on the City's Streets." Graphic from the City of Dallas' Complete Streets Design Manual, pg. 26 (City of Dallas, 2018)



CASE STUDY #1: DENVER, CO

CREATING AN INSTITUTIONAL STRUCTURE TO INTEGRATE GSI INTO TRANSPORTATION AND PUBLIC INFRASTRUCTURE

In 2019, Denver voters approved a reorganization of the City's infrastructure management departments, voting to create a Department of Transportation and Infrastructure (DOTI) out of the previous Department of Public Works. This new department is uniquely focused on jointly operating the city's transportation and utility infrastructure. With this reorganization, the new DOTI instituted a Division of Green Infrastructure to highlight the critical role of GSI in addressing water quality, flooding, and public health issues associated with Denver's transportation network.[94] The new departmental structure brings a focus on GSI to traditional transportation and public works projects and elevates GSI as comparable water quality and flood control infrastructure.[95]

The structure also serves as a foundation for establishing partnerships with outside entities. For example, having recognized a need to develop internal competency in GSI, DOTI established a deep collaboration with the Mile High Flood Control District (MHFCD), a regional agency charged with floodplain and stormwater management, stream restoration, and watershed planning across the Denver metro area. With MHFCD, DOTI co-developed a storm drainage design and technical manual and created a Green Infrastructure Implementation Strategy that identified priority green street opportunities and expected outcomes. The strategy provides a pathway for additional planning and project identification that embody data, aspirations, and goals that link multiple departments. DOTI is making progress on the strategy toward a goal of five miles of green streets per year as a pathway toward heat stress, flood risk, and water quality impairment reductions.

DOTI's Green Infrastructure Division has also built effective partnerships with Denver's Parks and Recreation Department to jointly implement GSI projects on park properties. DOTI has brought technical expertise to design GSI features in parks that also provide recreational amenities and water quality benefits. DOTI provides funding for projects to supplement Parks' budget. One example of this collaboration can be found in the La Lomita Park project in one of the lowest income neighborhoods in Denver with limited walkability. DOTI removed a concrete stormwater channel and detention structure and installed a wetland and walking trail, while Parks and Rec updated and installed park equipment, including a basketball court and nature play structures. The park now provides significantly improved water quality treatment for the surrounding 280-acre drainage area, in addition to enhanced recreation, and educational and community benefits.

In reflecting on successes and lessons learned, the DOTI representative we spoke with stressed the importance of leadership buy-in for furthering collaboration around GSI. DOTI benefited from upper management who supported GSI initiatives, including a Deputy Director who initially met with the GSI team two times per month to better understand how it works.

The GSI team did face skepticism from some transportation and infrastructure engineers who were not as familiar with GSI. Having standardized engineering criteria for designing and implementing GSI in an ultra-urban environment helped to answer many of their questions. Partnering with MHFCD to develop the standards also "elevated the GSI cause" as they are a trusted regional entity.

Robust monitoring helped to convince skeptics. The DOTI GSI team established a monitoring program for GSI projects through a partnership with the Colorado Department of Public Health and Environment (CDPHE). Five years in, the monitoring program has been key to demonstrating that the facilities are working effectively, while identifying areas for improvement. Having CDPHE as a third party auditor has created trust in the data. Overall, it took about two years to convince skeptics that GSI can serve as a comparable strategy to traditional approaches for managing flood risk and water quality.

Finding the right message to communicate to decision makers and stakeholders was also key. For example, staff found that clearly communicating the benefits of GSI and demonstrating its cost-effectiveness (especially when compared to benefits) helped to win approval for a stormwater fee with City Council. They also found that the term "water quality" resonated better with stakeholders than referring to stormwater management. Finally, having mapped layers on GIS, support from executives, and funding in place made these projects visual, digestible, and manageable for transportation staff.

Credit: GREATecology

CASE STUDY #2: SAN MATEO COUNTY, CA

INTEGRATING MULTIPLE AGENCY AND STAKEHOLDER OBJECTIVES TO PRIORITIZE SUSTAINABLE STREET PROJECTS

The City/County Association of Governments (C/CAG) of San Mateo County is a joint powers agency comprised of the 21 municipalities located within the County. The agency focuses on regional issues that affect the quality of life of county residents, including transportation, air quality, stormwater runoff, and solid waste and recycling, among others. C/CAG has staff dedicated to supporting road safety improvements, active transportation, and mobility. It also oversees a countywide stormwater program, so there is a natural connection between GSI and transportation.

In 2021, C/CAG adopted its Sustainable Streets Master Plan, which represents a multi-year planning effort to understand the potential for sustainable street projects in San Mateo County. C/CAG developed the Master Plan in collaboration with the State of California Department of Transportation (Caltrans) and multiple stakeholders, including representatives from regional transportation agencies and non-profit organizations. The plan was driven by recognition of the multiple benefits that sustainable streets can provide, from water quality improvement to multi-model transportation to climate resilience, a concept which had been evolving within agency for several years. It leverages efforts to identify opportunities to integrate GSI into planned street projects via local planning processes, as well as identifying hundreds of new opportunities for sustainable streets in proximity to schools (linking to the Safe Routes to School Program; see text box) and transit hubs.

The overarching purpose of the Master Plan is to bring 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 under the Municipal Regional Stormwater Permit.[96] A key goal was to identify practical and viable sustainable street project opportunities and to provide the tools and resources to support local agencies with funding and implementing projects. To do this, C/CAG and its partners developed a multi-phase outreach and community engagement plan, which included convening technical advisory and stakeholder advisory groups, with representation from multiple county and city departments, regional partners, and non-profit organizations to understand community priorities. Developing consensus around shared goals and a vision for sustainable streets was a significant component of success. The project team held four community engagement workshops as "pop-up" events in economically, socially, and culturally diverse areas of the county, and received 600 responses to a public survey about priorities and needs. Over 1,000 county residents, local and regional government officials, and stakeholders from government agencies and other organizations around San Mateo County participated in this process.[97]

To prioritize projects, C/CAG and its partners, including a cross-departmental, multi-disciplinary GSI project team, representatives from member agencies, and a Stakeholder Advisory Committee, defined three scales of sustainable street "project typologies" that integrate active transportation, stormwater, and climate change goals. Next, the planning team reviewed active transportation, streetscape, and other relevant plans throughout the county to identify planned projects that 1) fit into these typologies; and 2) had the scope and schedule or at minimum a foundational planning process that could be leveraged to integrate GSI. The team also identified new opportunities for GSI integration near schools and major transit stops.

Identified projects were further evaluated through the application of stormwater performance and feasibility criteria, as well as metrics related to social and environmental co-benefits. These criteria and metrics included scores for water quality, flood risk, water supply, climate change impacts, groundwater constraints, utility constraints, vulnerable community indicators, vehicle ownership statistics, urban canopy, and urban heat island effect (Figure 7). This process resulted in a prioritization score for each potential project. Projects with the lowest scores were removed from the list.

C/CAG municipalities reviewed the prioritized project lists for their jurisdictions and provided feedback on the opportunities. Out of approximately 800 initial project opportunities, over 500 advanced through the prioritization and review process. These opportunities will need additional analysis to determine feasibility, but they provide a strong starting place for municipalities looking to add project opportunities to their sustainable street networks. The project included concept designs for sustainable streets projects in 11 jurisdictions, and since then funding has been secured to advance several priority projects in underserved areas.

One challenge C/CAG identified for green street planning and implementation is that there is siloing in terms of how funding is managed for different projects. Within the agency and across municipalities, departments can be protective of funding available for transportation, especially with many competing priorities to upgrade mobility/accessibility and safety. This is in large part because there is an extensive need for transportation infrastructure improvements countywide, as well as a backlog of maintenance work that remains largely unfunded. GSI components can be viewed as competing for much needed funding, and generally there may be the perception that transportation funds "should" be used for transportation projects and not for water quality improvement. The perception of competing for limited resources and lack of shared vision around the benefits of integrated projects and pooling resources may lead to increased polarization and siloing. However, the sustainable streets planning process has opened minds and shifted thinking about future opportunities to co-fund or consider flexibility in funding. As a transportation agency and a countywide stormwater program, C/CAG has also benefited from being able to co-fund its own Integrated Safe Routes to School and Green Streets Infrastructure Projects Pilot Program, which was completed in 2024 and resulted in 10 multi-benefit projects throughout the county. These projects helped further clarify where the pressure points are for integrating GSI and active transportation projects, as well as the cost-effectiveness and community support for projects that integrate co-benefits.

San Mateo County Safe Routes to School

San Mateo County Safe Routes to School is a partnership between C/CAG, the California Office of Traffic Safety, CalTrans, and the San Mateo County Office of Education. This program works to encourage and enable school children to walk, bicycle, carpool and utilize public transit as a means of getting to school. Walk audits are used to identify where infrastructure, like GSI, can help decrease traffic congestion around school sites, reduce school-related travel emissions, and improve health, well-being, and safety of students while also addressing drainage and water quality issues.

Figure 7. San Mateo County Sustainable Streets Identification and Prioritization Method

Identify Project Typologies

- Sustainable Street Curb Extensions
- Sustainable Street Connectivity Improvements
- Sustainable Streetscape Redesigns
- Sustainable Street Frontage Improvements

Identify Project Opportunities

- Existing Active Transportation and Streetscape Opportunities
- New Opportunities Near Schools and Transit

Apply Stormwater Technical Suitability Criteria

- Runoff Capture Benefits
- Hydrogeological Conditions
- Additional Site/Constructability Characteristics

Apply Co-Benefit Criteria

- Vulnerable Community Indicators incl Low Vehicle Ownership
- Canopy Coverage
- Urban Heat Island Index
- Pavement Condition Index
- Pavement Quality Index

Identify Recommended Projects

- Prioritization Tiers
- Prioritization Scoring
- Stakeholder Feedback

Sources: San Mateo County Sustainable Streets Master Plan

Drawing on lessons learned from the agency's experience with sustainable streets, the C/CAG representative we spoke with recommends the following:

- **Encourage coordination across departments:** C/CAG developed a core Sustainable Streets team with representatives from planning, public works, transportation, parks and recreation, public health, and education, as well as a robust group of external stakeholders, to inform the prioritization process.
- **Evaluate existing funding options:** Review transportation funding options (e.g., grants) that allow or encourage GSI improvements, leverage these opportunities to do more GSI.
- **Find opportunities that already have momentum and identify opportunities to integrate GSI:** Review existing local plans, like bike/ped master plans, climate action plans, etc., for projects that have identified GSI opportunities or otherwise would be good opportunities to integrate if they do not already propose GSI. This reduces duplication and leverages prior work.
- **Understand community priorities and identify improvements that are in line with community needs:** Some agencies get pushback from communities due to limited parking spaces and constraints on public space. It is important to understand these perspectives, listen to concerns and communicate the benefits of planned GSI improvements within the appropriate community context. Community-based organizations can be an incredible asset.

Credit: City/County Association of Governments (C/CAG) of San Mateo County

CASE STUDY #3: GRAND RAPIDS, MI

PLANNING, PRIORITIZING, AND CO-FUNDING GSI PROJECTS

The City of Grand Rapids, like many older midwestern and eastern cities, had long struggled to reduce combined sewer overflows. Through the early 2000s, City leaders and wastewater staff invested in GSI to reduce inflows to the sewer system and into the newly separated storm sewer network. In 2010, as part of the sewer separation project, the City invested in underground infiltration and other GSI measures as part of a major park renovation. As the City continued to embrace GSI alternatives, a 2011 Notice of Violation from the state regulatory agency and a major flood in 2013 drove public and political attention to the role stormwater played in the health of the Grand River and the community. This attention resulted in additional funding resources for the City's stormwater department. Concurrently, a Sustainable Streets Task Force was created that brought together multiple municipal departments, county and state agencies, and community stakeholders. The efforts of the Task Force produced the Vital Streets Program, funded by a publicly approved extension of a sales tax measure, which emphasized the importance of integrating GSI into streets and mobility projects.

The Program continues to function under an oversight commission of representatives from local stakeholder organizations and the Michigan Department of Transportation, guided by a core team of staff from the City's engineering, streets, stormwater, and other City departments. The Vital Streets Oversight Commission provides oversight of program and project planning, implementation, and budgeting. In addition, a design team made up of City staff collaborates on the design of City transportation projects, meeting several times a month to, among other items, ensure that individual projects are designed to meet Vitals Streets objectives.

The Vital Streets team developed design guidelines for Vital Streets projects that require the incorporation of GSI into projects unless technical challenges make this approach infeasible. The guidelines serve not just as technical standards, but also as an informal "rulebook" for the Program in lieu of a formal inter-departmental MOU. In addition, a formal administrative policy requires that the design team come to consensus on each project, which in turn creates an expectation that each department must have "buy in" to the street design. The consensus-driven process has engendered a staff level openness to understanding the challenges facing each of the design team's departments.

Like Denver, Grand Rapids faced differences across departments in terms of "buy-in" or familiarity with GSI. Maintenance has also been a challenge. An early decision allocated maintenance responsibility for roadway GSI projects to the city's streets team, along with a staff position and budget for the purpose. However, this has proven to be a poor fit because that department does not have the requisite landscape and vegetation management expertise. The City's parks department would be well placed to take this on, but changing the institutional structure and shifting budget allocations remains a challenge. Allocating costs across departments was also trickier than expected. Design consultants fit GSI into the streetscape where it makes sense so it can be difficult to parse out stormwater versus transportation costs.

After ten years of the program, the representative we spoke with from Grand Rapids relayed several lessons learned for establishing successful cross-departmental partnerships. First, it is important to bring in all departments that might be affected in any way early on. This way, everyone can learn together. Starting with a large committee, including community representatives, helped to gain buy-in and ensure transparency in Grand Rapids. Once the program was more established, the Vital Streets Oversight Commission was whittled down to a more manageable working group. On the design team side, while the group is collaborative, it has also helped to have a higher level staff member who makes final decisions. Additional lessons learned and recommendations include:

- **Start small.** Don't take on too many projects in the first few years. Starting small can help to demonstrate project effectiveness and provide an opportunity to improve over time.
- **Figure out maintenance issues early on, as maintenance issues tend to compound over time.** Education and training for implementation and maintenance workers who aren't familiar with GSI principles should be integrated into every program.
- **Develop simple metrics that everyone understands and keep them consistent with other City plans where applicable** – for example, ensuring that the city's strategic plan utilizes the same GSI goals as Vital Streets. This can help gain buy-in and support for funding from upper management.
- **Keep reviewing relevant municipal plans for opportunities -** set a regular update cycle.

Credit: City of Grand Rapids

CASE STUDY #4: SEATTLE, WA

CO-FUNDING GSI ACROSS MULTIPLE AGENCIES

In 2013, the City of Seattle adopted a goal to use GSI to manage 700 million gallons of stormwater per year by 2025 through City capital investments, incentive programs, and stormwater code requirements. In 2015, the "Plan to Protect Seattle's Waterways" ("Plan"), Seattle's Long-Term Control Plan for reducing CSOs as required by EPA under Seattle's Consent Decree, included the Natural Drainage System (NDS) Partnering Program, that allowed Seattle to focus on water quality projects in their creek basins and defer working on CSO basins that were just slightly out of compliance. The NDS Partnering Program has a regulatory requirement of providing water quality treatment for 44 acres of effective impervious area. The intent of the NDS Partnering Program is to provide water quality treatment with roadway bioretention that is implemented through shared projects within SPU and between SPU and other City agencies that address multiple problems and offer multiple benefits, including: greener, more attractive neighborhoods, lower risk of flooding, additional natural habitat for native plants and animal species, healthier creek ecosystems, calmer traffic patterns, and more street trees.[99] SDOT was identified as a key potential partner is this effort.

The NDS Partnering Program is implementing GSI retrofits in three major creek watersheds

Figure 8. North Thornton NDS 30% Design: SDOT Partnership Opportunity Summary Table, 2023.

Cost per Block (2025 $'s)[1]

BLOCK 9	Category	Stormwater $1,035,000		Transportation $266,000	Shared[2] $810,000	Total $2,111,000	SPU Total $1,316,000	SDOTTotal $795,000
	Sub-Category	GSI (WQ)[3] $459,000	Conveyance $576,000	Sidewalk $266,000	Shared $810,000			
BLOCK 14	Category	Stormwater $293,000		Transportation $123,000	Shared[2] $407,000	Total $823,000	SPU Total $515,000	SDOTTotal $305,000
	Sub-Category	GSI (WQ)[3] $160,000	Conveyance $139,000	Sidewalk $123,000	Shared $407,000			
BLOCK 15	Category	Stormwater $403,000		Transportation $148,000	Shared[2] $365,000	Total $916,000	SPU Total $620,000	SDOTTotal $295,000
	Sub-Category	GSI (WQ)[3] $210,000	Conveyance $193,000	Sidewalk $148,000	Shared $365,000			
BLOCK 48	Category	Stormwater $456,000		Transportation $412,000	Shared[2] $501,000	Total $1,369000	SPU Total $808,000	SDOTTotal $561,000
	Sub-Category	GSI (WQ)[3] $230,000	Conveyance $220,000	Sidewalk $412,000	Shared $501,000			
BLOCK 45	Category	Stormwater $2,432,000		Transportation $309,000	Shared[2] $1,132,000	Total $3,873,000	SPU Total $3,111,000	SDOTTotal $762,000
	Sub-Category	GSI (WQ)[3] $1,772,000	Conveyance $660,000	Sidewalk $309,000	Shared $1,132,000			

Notes:

1. Cost per Block includes soft cost (assumed to be 90% of hard costs per Cost Factsheet (Jacobs, 2022)) and a 15% contingency reserve, rounded to the nearest $1,000
2. Cost share is calculated per big item as described in SPU/SDOT MOA (SPU, 2018)
3. Water infrastructure improvements, including main and service relocates are included in the GSI cost sub-category (these improvements facilitate GSI installation)

within the City: Longfellow Creek, Thornton Creek, and Pipers Creek. Where project sites are able to be co-sited with SDOT, SPU and SDOT rely on an overarching memoranda of agreement (MOA) that spell out roles and responsibilities and cost-share allocations between the departments based on a standard model that all parties have agreed upon.[100] The agencies also develop project specific MOAs that addresses the specifics of each project.

SPU reports that having a cost-share model in place before implementing any projects was helpful as it facilitated project specific discussions without the agencies having to "nickel and dime" every project. Since initiating the cost share MOA, the City has realized that collaboration can reduce overall project costs. Figure 8 illustrates potential cost shares between SPU and SDOT for a number of potential NDS project blocks in the North Thornton Basin.

Getting the initial partnership structure right has been a key lesson learned for SPU. The up-front MOAs for each project have eased agreements about timelines and project implementation responsibilities. MOA discussions also help define each partnering department's expectations and desired outcomes early in each project's lifespan.

Recognizing that each department prioritizes projects, locations, and infrastructure investments differently, and then coming to agreement on where there is good alignment has helped gain leadership approval and support. A recent project located in the city's Longfellow Creek Watershed demonstrates the multiple benefits and co-funding opportunities that the NDS partnership leverages (see text box on following page).

Differences in funding, standards, and permitting processes across departments has created some challenges. SPU relies on rate revenues for funding, while SDOT relies on the city's general funds and can be more "strapped for cash." Meeting the city's standards for transportation infrastructure can be difficult and expensive for both agencies. There is sometimes tension between departments on figuring out how each department can meet each other's standard and still achieve the project goals without making things overly expensive. In some cases, successful projects have been easier to achieve in areas involving "informal streets," where there is no existing drainage or transportation infrastructure and it is often easier for agencies to deviate from the standards and find creative solutions to reduce technical, financial, and institutional barriers.


Credit: Seattle Public Utilities

Seattle Public Utilities: Co-funding green street improvements in a key watershed

Longfellow Creek flows through urbanized neighborhoods in West Seattle; approximately one-third of the creek is channeled through underground pipes beneath the urban landscape. However, it is an important salmon-bearing tributary in the Lower-Duwamish River basin.

SPU is partnering with Seattle Department of Transportation (SDOT) to ensure that GSI projects in the Longfellow Creek watershed provide multiple benefits. These agencies are implementing three projects in the area that will collectively manage 5.8 impervious acres:

- The 24th Ave SW project, which includes GSI installations (e.g., trees, bioretention) and a partnership with SDOT to build sidewalks along 4 city blocks and pedestrian upgrades.
- The Sylvan Triangle project, a relatively small project that includes GSI installations and street tree plantings at a busy intersection.
- The SW Kenyon St project, which includes streetside upgrades, significant stormwater management, and other improvements that serve the community, including a connecting pathway across Longfellow Creek and a community gathering space (see early rending below).

In addition to SPU and SDOT, project funders include the King County Flood Control District and the Levy to Move Seattle, a $930 million voter-approved levy that provides funding to improve traveler safety, maintain streets and bridges, and invest in reliable affordable travel options. The City's Office of Arts and Culture will incorporate art installations at one of the project sites through 1% for Arts, a city ordinance that sets aside 1% of capital improvement project funds for the installation of artworks.

A Water Research Foundation project on quantifying and monetizing the multiple benefits of GSI used this project as a case study. It was found to provide significant benefits in terms of encouraging pedestrian/cycling activity, recreation, water quality, and neighborhood revitalization, among others. The project's return on investment was estimated to be 1.5, when accounting for these benefits.

Credit: Michael B. Maine

CASE STUDY #5: WILMINGTON, DE

INTEGRATING MULTIPLE AGENCY AND STAKEHOLDER OBJECTIVES TO PRIORITIZE SUSTAINABLE STREET PROJECTS

All too often, well-intentioned municipal planning documents detail projects that go unrealized for lack of funding. As funding opportunities arise, retrieving these plans can open opportunities not just for project implementation but for cross-departmental collaboration to attain established municipal goals.

A preference for GSI within the criteria for a 2021 US DOT RAISE grant led the City of Wilmington's (DE) Transportation Director to obtain funding for the city's Riverfront Transportation Infrastructure Project. Because the RAISE grant emphasized and funded a GSI component of the larger project, it (as well as other funding opportunities) created mutually beneficial outcomes for the City's transportation, stormwater, and economic development departments.[101] Plans for the Riverfront project had previously linked municipal departments (DOT, sewer, environment, economic development, parks) with state agencies as well as private and public sector stakeholders.

The success of the Riverfront project has fueled continued engagement between these actors, particularly as additional grant announcements create potential funding for plans the City already has 'on the books.' Renewing interest in previously completed plans, some decades old, has allowed the City to move forward on revitalization projects without incurring new consulting costs, and to opportunistically respond to emerging funding notices. By creating a matrix of existing plans from each municipal agency, the city was able to identify intersections of interests and goals. When funding solicitations require a comprehensive approach to project planning, the City draws upon this matrix and use it to build out grant application narrative. An advantage of cross-departmental partnerships that the city has realized is being able to allocate grant funds to the municipal department best placed to manage project implementation. For example, in the case of the Riverfront project, the Riverfront Development Corporation (RDC), a state-created entity, had an agreement with Delaware DOT that permitted RDC to hold contracts with construction companies in a manner that allowed for project implementation independent of the broader statewide capital planning schedule. Having flexibility to administer grant funding is also beneficial because different City departments have different standards for spending – for example, DelDOT cannot afford to run the project due to administrative requirements.

One of the more interesting lessons from Wilmington's experience is their success in marrying the financing opportunity presented by Delaware's Clean Water State Revolving Fund (CWSRF) with the state and city's transportation objectives. In addition to accessing this water infrastructure funding for the GSI components of a transportation project, transportation/public works has been able to bring matching funds for stormwater facility maintenance. Together, these funding sources contribute not only to a successful multi-purpose infrastructure investment but also toward meeting the city's CSO consent decree obligations.

Leveraging grant funding opportunities across agencies

Economic development offices can be eligible for grant and other funding sources that typically aren't accessed by DOTs; likewise, DOT-led GSI implementation can contribute to the outcomes associated with these funding sources. It is worth noting that the federal Economic Development Administration (EDA) requires funding applicants to have a Comprehensive Economic Development Strategy (CEDS). Elements of the Long Range Transportation Plans and regional transportation improvement programs that are required for federal transportation funding can be comparable to CEDS elements and incorporated into EDA applications.

Sources: Flynn 2023; Walzer 2009


Credit: John Hinkson/TNC

5.3 Other examples of partnerships addressing GSI implementation challenges

5.3.1 Long-term maintenance

Few transportation agencies have maintenance crews that are trained in GSI practices, plantings, and maintenance. Instead, GSI maintenance is often undertaken by crews that have typically been responsible for pavement condition, striping, lighting, snow removal, trash pick-up, sweeping, and other tasks. GSI maintenance also takes a lower priority for crews and agencies who tend to respond to public complaints about road condition. Addressing these shortcomings will require that maintenance considerations are integrated into the project planning process at an early stage, that training in the specific aspects of GSI maintenance occur at all staff levels, from supervisors to line staff, and that adequate funding for both training and maintenance be built into agency and project budgets.[102]

Incorporating maintenance considerations into project design is critical. Reducing the cartway and vegetating the ROW along high-speed and high-traffic corridors may present safety challenges for maintenance crews. Designing appropriate safety protections for maintenance staff activities and vehicle parking is critical.

Partnerships between public agencies and other entities can bring necessary GSI maintenance training and capacity to transportation projects and programs, as well as support green jobs and skills development for economic benefit to local communities if built into a workforce development program. Cooperative agreements with NGO or private sector partners can complement public agency programs, bringing GSI specific expertise and staff resources to close capacity gaps or complement agency staff.[103] One example of inter-agency collaboration to resolve GSI issues is the Green Infrastructure Vision promoted by the Southeast Michigan Council of Governments (SEMCOG). This Vision established a region-wide process for implementing GSI practices within transportation projects and solidified support for GSI maintenance at local and regional levels.[104]

5.3.2 GSI Training and Education

Because of their primary focus on roadway safety and traditional transportation infrastructure design and engineering, transportation agency or department staff and engineers may lack an effective competency in the design, implementation, and benefits of GSI.[105] The Denver case study, above, showcased the value of bringing in an external partner with deep GSI expertise to more effectively cultivate GSI integration with transportation projects. Fostering intra- and inter-departmental partnerships can also create beneficial resources for DOT engineers and staff.

For example, changing regulatory requirements that emphasized post-construction stormwater management created challenges for Alabama DOT engineers. In response, the Department drew upon its internal resources, particularly its Office of Environmental Coordination, to provide technical education to DOT design, construction, and maintenance staff and to develop and refine BMP standards that reflected GSI best practices while satisfying transportation project standards.[106] Alabama DOT now has standard infiltration designs as well as internal systems for guiding project engineers through post-construction stormwater BMP selection and design.

5.3.3 Equity Considerations

The intersection of equity, transportation, and GSI is poignant. Low-income communities are more likely to rely on public transportation, bicycles, or walking as a mode of transit.[107] These methods of transportation can be adversely affected by extreme rain events but can be improved in safety by incorporating green elements into complete streets to increase resiliency and reliability on these alternative modes of transportation.[108] Equitable transportation ensures that the benefits reach the most vulnerable and historically under resourced communities and that burdens created by transportation planning, projects, and priorities neither unfairly burden a group of people by a lack of access to adequate transportation nor negatively impact communities by proximity to major transportation infrastructure and the associated environmental and social externalities. If done carefully, with proper community engagement and participation among community members and representatives, incorporating GSI into transportation planning can create a more equitable process for implementing infrastructure and help increase transportation access as well as mitigate negative effects of pollution, traffic accidents, and noise. The following resources are among those that may be useful to GSI and transportation planners:

- City of Portland and Multnomah County Climate Action Plan: Plan calls for use of GSI and urban forest canopy cover in underserved communities, prioritizing areas where transportation concerns are greatest with high concentration of lower-income residents.
- Mid-South Regional Greenprint plan utilizes GSI as foundation for improving social equity, transportation, and public health; seeks to connect a network of trails, greenways, parks to increase transportation opportunities in underserved and disadvantaged communities.
- Urban Transportation System Flood Vulnerability Assessment in Low-Income and Minority Neighborhoods. Crosson et al. (2020) conducted a flood vulnerability assessment of the City of Tucson, Arizona's multi-modal transportation system in low-income and minority neighborhoods. The authors found that GSI solutions did not address mobility issues that result from extreme flooding. Rather than municipalities selecting areas that have the highest volumes of flooding or the highest volume of resident complaints, funds for GSI should be invested in low-income neighborhoods subject to moderate flooding to achieve the greatest improvements in multimodal access. They identified priority locations for Tucson to invest in improvement and are now working with city and regional agencies to implement those findings.


Credit: Pima Association of Governments

6

Funding and Financing Opportunities

Credit: Hannah Letinich

FUNDING AND FINANCING OPPORTUNITIES

This sections details opportunities for funding and financing GSI projects within the transportation network.

Transportation budgets and funding sources may be restricted in the types of capital costs they are permitted to cover. Or, as mentioned above, priorities may not be aligned among transportation and water quality programs. Long-term maintenance of GSI may not be compatible with DOT or streets department maintenance procedures, contracting authorities, or budgets. Conversely, stormwater agencies may face obstacles to funding GSI that are part of a streetscape renewal or reconstruction. And, even where funding is available for capital work, necessary maintenance is often left unfunded. Partnerships and creative budget management may, however, open new financial pathways for transportation projects to cover a broader range of GSI costs, or to leverage multiple funding sources to achieve greater benefits with integrated projects. Additionally, incorporating GSI may generate new funding opportunities, particularly when GSI incorporation into project design and implementation is the result of collaboration between DOTs and other stakeholders, such as community-based or regional resilience organizations. This section briefly describes funding and financing strategies that can be leveraged to support transportation network GSI implementation.

6.1 Transportation Grant Funding

GSI projects may be eligible for transportation funding because they improve transportation networks by mitigating street and alley flooding and provide other co-benefits (e.g., neighborhood revitalization). It is critical to enumerate these as goals when developing the project to minimize disruption to Categorical Exclusions approval and other transportation permitting processes. Examples of relevant funding approaches are highlighted below:

- 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.
  - Transportation Alternatives Program (TAP) is a set aside of the STBG. This program provides funding for smaller activities that encourage "transportation alternatives," including "off-road trail facilities for pedestrians, bicyclists, and other non-motorized forms of transportation." TAP funding could be used to pay for GSI components of trails and sidewalks such as permeable pavements. Example projects include:

- Santa Monica Urban Runoff Recycling Facility (SMURRF) plant sells recycled dry-weather runoff to Caltrans for landscape irrigation along Santa Monica Freeway (per USDOT 2007).
- Rock Creek Watershed Enhancement Program in Maryland constructed channel restoration and habitat improvements and installed ponds to manage runoff from State Routes 185 and 97.

- The Congestion Mitigation and Air Quality (CMAQ) program allocates federal funding for infrastructure projects that reduce congestion and improve air quality. Bicycle transportation and pedestrian walkways are eligible uses of the money, and can be designed to include GSI features, such as permeable surfaces for trails, and bioswales and bioretention for areas adjacent to trail surfaces.
- Rebuilding American Infrastructure with Sustainability and Equity (RAISE) as part of Bipartisan Infrastructure Law (formerly TIGER and BUILD) supports projects that enhance transportation infrastructure with a focus on sustainability, equity, and economic benefits, and GSI may be an eligible cost.
- Surface Transportation Environment and Planning Cooperative Research Program (STEP): FHWA administers environment and planning research funds to improve understanding of the complex relationship between surface transportation, planning, and the environment. This funding can be used for project implementation.

6.2 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, potentially offsetting local agencies' requirements for GSI project implementation and maintenance.[109]

Debt financing should be thought of as an important option for creating sufficient capital for investments in up-to-date transportation networks, particularly because they create sufficient one-time resources for investments in major projects or multiple projects included in a CIP. In addition, financing spreads the debt burden across time, which allows the project(s) to be paid for by the people who benefit across the lifetime of the constructed infrastructure. Debt financing requires a dedicated, sustainable source of revenue for repayment of the bond principal plus interest. Often a tax or rate increase will provide that source of income. Many states require that voters approve general obligation, highway user revenue and utility revenue bonds which creates both an obligation for transportation agencies to obtain voter approval and an opportunity to engage the public in ways that promote better understanding of stormwater impacts and the benefits of reducing them through GSI approaches.

There are at least three approaches to funding GSI through bond financing. The first is dedicating transportation-related bond issuances to fund roadway and non-roadway transit projects. As the bond package is designed and drafted, it is important to include the capital costs of any associated GSI components and to specify that bond revenues are to be allocated to GSI features. A second approach would be to include transit corridor GSI projects as eligible features within a non-transportation bond, such as a park, flood control, or even school bond. GSI practices are appropriate for managing runoff from constructed features of many capital improvements associated with recreational, flood control, and educational developments. Finally, municipalities may consider a bond issuance that is specifically intended to fund GSI projects, either as a "stand alone" effort or perhaps as part of a broader investment package intended to fund climate resiliency projects. This approach may be supported by a local "green infrastructure" fee or sales or income tax dedication.

6.3 Tax Increment Financing (TIF) Districts and Business Improvement Districts (BIDs)

Tax Increment Financing (TIF) is a form of "value capture" that monetizes the increase in property values created by infrastructure investments. At its core, TIF districts raise money for capital projects associated with redevelopment programs by borrowing against future property tax revenues, with the documented expectation that those revenues will increase above the baseline, pre-project receipts.[110] TIF is a widespread strategy for supporting urban redevelopment projects. It is favored for its flexibility – funds raised through TIF can be deployed for singe projects, bundles of projects, or across a broad infrastructure program.[111] Enhanced Infrastructure Financing Districts (EIFDs) are a relatively recent variation on TIFs used in California. Their usefulness to finance GSI has been explored in a report from the WaterNow Alliance and the City and County Association of Governments of San Mateo County.[112]

Business Improvement Districts (BIDs) operate on similar principles, raising revenue from an assessment against in-district business properties to fund improvements within the district. Typically, BIDs cover costs associated with upkeep of public spaces, landscaping, and property redevelopment subsidies. They can, if the assessment raises sufficient revenue, be a source of cost-share for GSI projects within the rights-of-way or on transit improvements.

BIDs and TIF also offer significant opportunities for funding and financing GSI improvements along transportation corridors in BID/TIF District neighborhoods. TIFs have been used extensively in Chicago and other cities to build public infrastructure. Many municipalities around the

Co-funding based on co-benefits

Co-funding GSI projects can be particularly appropriate when they serve the interests of multiple public agencies and stakeholder groups. EPA's Green Streets Handbook provides useful examples of where GSI might overlap with multi-agency community improvement initiatives or programs.

Example Community Improvement and Green Infrastructure Collaboration Opportunities

- Bicycle, pedestrian, transit or greenway planning
- Urban forestry stewardship initiatives
- Safe Routes to School initiatives
- Emergency vehicles and routes
- Stormwater master planning
- Open space planning
- Street repaving projects
- Utility infrastructure improvements
- Capital improvement projects
- Community/private connections
- Climate change resiliency or sustainability designs

Source: U.S. EPA 2021

country utilize some form of TIF to support public and private redevelopment projects and associated infrastructure improvements. Because property taxpayers are the ultimate source of revenue for TIF programs, there can be considerable social and political support for using TIF to support investments for multi-benefit infrastructure, including GSI. 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.

6.4 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 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.

In California, transportation departments, regional planning entities, and other public agencies commonly form Joint Powers Authorities, or JPAs, to jointly plan, fund, and implement projects. JPAs, allow various public agencies, such as state departments, counties, cities, and school districts, to create a legal entity designed to focus on a specific project or common problem. The language in the state law authorizing the formation of JPAs explicitly allow the participating public agencies to "jointly exercise any power common to the contracting parties," which includes, but is not limited to, "levy[ing] a fee, assessment or tax." As one example, the San Joaquin Council of Governments uses a JPA model to plan, fund, and implement a comprehensive transportation improvement vision funded by Measure K, a local, voter-approved sales tax extension. Projects implemented with Measure K support include complete streets, bicycle/pedestrian enhancements, and streetscape improvements.

Joint Benefits Authorities (JBAs) are a new approach, based on a Joint Powers Authority model, which is currently being piloted with leadership from the World Resources Institute (WRI). The Joint Benefits Authority brings city departments together, in partnership with the community, to finance and deliver infrastructure that transforms neighborhoods and builds resilience in the face of climate change. A JBA would be jointly funded by the individual city departments that forms the Authority and with additional resources from grants and philanthropic support. The costs to each department will be based on the benefits they receive through the project implementation. The goal is for each department to reduce their overall costs by working together and sharing in project development, delivery, and operations costs. (World Resources Institute, n.d.)

This model is being piloted in San Francisco through a partnership between the San Francisco Public Utilities Commission (SFPUC), WRI, and two private partners with innovative finance expertise, Liquid Assets and Encourage Capital. SFPUC is exploring a multi-agency collaboration with the Port of San Francisco, the San Francisco Municipal Transportation Authority, and San Francisco Planning to pilot the JBA in the southeast waterfront along Islais Creek. The pilot JBA would deliver a set of adaptation projects to protect the Islais Creek shoreline and the surrounding area from flooding and sea level rise through 2100 and showcase inter-departmental collaboration on important projects that foster climate change resilience.

6.5 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 (DBFOM) concessions transfer responsibilities for these activities to private-sector partners. A common feature of DBFOM contracts is that they are typically financed, partially or totally, by debt leveraging revenue streams dedicated to the project, such as tolls, user fees, or availability payments. Future revenues are leveraged to issue bonds or other debt that provide funds for capital and project development costs. Public-sector grants may provide cost-share and, in some cases, private partners may make equity investments. DBFOM may be structured as a public-private partnership, or P3. Some P3s, particularly those knows 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. These can be related to water quality goals, community development or local employment delivery, or other beneficial outcomes. This model has been well established in Prince George's County, Maryland where the Clean Water Partnership, a CBP3 between the County and Corvias Infrastructure Solutions, has delivered GSI projects, met stormwater management targets, and achieved economic and business development goals.

Credit: City of Vancouver, BC

Credit: Will Parson/Chesapeake Bay Program

7 Conclusion

Credit: Green Infrastructure Leadership Exchange

CONCLUSION

This guide compiles results from a wide range of academic and transportation sector research to help practitioners make the case for incorporating GSI into the transportation network through complete street or sustainable street approaches.

These types of projects can improve vehicle and pedestrian safety, increase mobility and alternative modes of transportation, decrease life cycle costs compared to traditional (siloed) approaches for transportation and stormwater management projects, and provide neighborhood revitalization and economic development benefits. The range of benefits associated with green street projects can be difficult to quantify and monetize; however, relying on standard methods and findings from the literature, practitioners can cast benefits in context of overall costs.

Implementing green street projects and programs can be difficult because of the number of partners and agencies typically involved in streetscape planning, including transportation, stormwater, planning, public works, and others. This creates challenges related to:

- Differing levels of acceptance of GSI as an appropriate strategy to manage roadway runoff.
- Incongruities between the priorities that drive project selection at the respective agencies and within communities.
- Conflicts over funding and dealing with limited resources for local governments.
- Long-term maintenance obligations.

This guide highlights case studies from across the country that have experienced these challenges and implemented creative solutions for overcoming them. These examples show that cross-departmental collaboration and stakeholder engagement can result in sustained solutions for green street implementation, although it is not an easy endeavor in many locations. The degree to which partnerships can be effective at reducing technical, practical, and financial obstacles depends greatly on the ability of individual staff champions to advance a shared GSI agenda and the degree to which agency structures can ease partnerships.

Through the process of reviewing the available literature, several research gaps and uncertainties emerged:

- Data on cost savings associated with paired stormwater/transportation projects is not widely available/accessible.
- Life cycle costs of transportation GSI need further research and dissemination.
- Research on the nexus of GSI, transportation, and equity planning is needed to understand and quantify how each element builds on and enhances co-benefits, without unintended consequences (such as displacement).
- Surveys and recommendations about transportation agency maintenance of GSI would be useful to close the knowledge gap about best practices and trainings approaches.

Credit: Green Infrastructure Leadership Exchange

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GSI Impact Hub

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