A ROAD TO A GREENER DEVENS:

Implementing Green + Complete Streets Policy on Goddard Street

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The Devens Enterprise Commission

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Glossary

In order to facilitate the ease of reading of this report and in the spirit of democratizing knowledge of green and complete streets to a variety of audiences, our project team has developed a glossary of key concepts and terms. Readers are encouraged to refer back to this glossary throughout the report for what we believe are jargon-free explanations of some of the technical terms contained in this report.

Biophilic: A combination of both the natural world and living things (bio) and the connections with and love of nature (philia) (Beatley, 2016).

Complete street: A street that prioritizes safety and accessibility for all users of our roadways such as pedestrians, cyclists, transit riders, motorists, emergency vehicles and for people of all ages and abilities (Devens Enterprise Commission n.d.).

DEC: Devens Enterprise Commission

Design charrette: A collaborative meeting in which people with different backgrounds come together to discuss ideas to design and plan. The Field Project team had a design charrette with Nitsch Engineering.

DPW: Department of Public Works; Public works is the combination of physical assets, management practices, policies, and personnel necessary for government to provide and sustain structures and services essential to the welfare and acceptable quality of life for its citizens (MMA n.d.). Devens DPW is responsible for managing all activities and functions associated with the maintenance of all facilities, roads, grounds, fleet, animal control, sports fields, and disposal of property within Devens (DPW n.d.).

Green street: A stormwater management approach that incorporates vegetation (perennials, shrubs, trees), soil, and engineered systems (permeable pavements), to slow, filter and cleanse stormwater runoff from impervious surfaces (streets, sidewalks) (US EPA 2015).

Green and Complete Streets (GCS): Green and complete streets integrate stormwater infrastructure, shade trees and landscaping to more closely mimic natural hydrology into safe, accessible, connected networks of roadways and paths. GCS practices aim to create safe and accessible pathways for all users while protecting the natural environment and enhancing the social environment (Devens Green and Complete Streets Policy 2021).

Goddard Street: The street the Tufts Field Project team will assist in designing at Devens.

Green Infrastructure (GI): Reduces and treats stormwater at its source (US EPA "Why You Should Consider Green Stormwater Infrastructure for Your Community" 2021).

Green Stormwater Infrastructure (GSI): Designed to mimic nature and capture rainwater where it falls (US EPA "Why You Should Consider Green Stormwater Infrastructure for Your Community" 2021).

Gray infrastructure: Conventional "gray" stormwater is designed to move urban stormwater away from the built environment and includes curbs, gutters, drains, piping, and collection systems. Generally, conventional gray infrastructure collects and conveys stormwater from impervious surfaces, such as roadways, parking lots and rooftops, into a series of piping that ultimately discharges untreated stormwater into a local water body. (US EPA 2015d).

Impervious surfaces: Man-made surfaces that allow little to no stormwater runoff infiltration into the ground. They are the main contributor to excess stormwater runoff and can cause water quality problems. Examples include streets, pavements, driveways, walkways. Impervious surfaces can lead to increased flooding as well (US EPA 2015b).

LID stormwater: Low impact development. Another method that looks at urban runoff and protecting water quality from urban runoffs (US EPA 2015c).

MassDevelopment: The state's development finance agency and land bank, works with businesses, nonprofits, banks, and communities to stimulate economic growth (MassDevelopment n.d.)

MS4s: Municipal Separate Stormwater System. They are designed or used to collect or convey stormwater (i.e., storm drains, pipes, ditches) (US EPA 2015a).

Nitsch Engineering: A civil engineering firm in Massachusetts.

Porous pavement: interchangeable with permeable pavement. A water permeable structure that allows rainwater to pass through it into the ground below. Examples include sidewalks, roads, parking lots (Ferguson 2006).

Shared Street: Also known as woonerf, a street shared among pedestrians, bicyclists, and motor vehicles. The street is designed without a clear division between pedestrian and auto space (i.e., no continuous curb), so motorists are forced to slow down and travel with caution. (Collarte 2014).

Stormwater runoff: is generated from rain and snowmelt; flows over land and impervious surfaces, such as paved streets, parking lots, and rooftops, and does not soak into the ground. Runoff can contain harmful pollutants, which is why it is important to employ management practices to control stormwater and prevent pollution at its source (US EPA 2020).

Triple bottom line: Quantified and monetized financial, environmental, and social costs and benefits (R.13.004 US EPA 2013, p. 20).

Urban Heat Island: occurs when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat. This effect increases energy costs (e.g., for air conditioning), air pollution levels, and heat-related illness and mortality (US EPA 2021).

Yield Street: designed to serve pedestrians, bicyclists, and motor vehicle traffic in the same slow speed travel area (Goodman & United States Federal Highway Administration 2016).

Executive Summary

Executive Summary

When was the last time you took a close look at the roads you travel along every day? Each line in the pavement, each traffic sign, each parking space, they were all intentional choices made by a street designer. Some have been designed for people; they are spaces where children play, vendors draw crowds, friends meet, and people want to spend time. Others have been designed for cars, perpetuating a design culture that prioritizes convenience for private vehicles, while sacrificing many of the things we know make streets inviting places to be. But in light of recent advances in street design, this dichotomy has become a false one; planners and policymakers can advance street designs that are as functional as they are human-scale, as friendly for cars as they are for all other roadway users, and for the environment.

The paradigm of green and complete streets, a street typology which aims to create safe and accessible pathways for all users, while protecting the natural environment and enhancing the social environment, accomplishes each of these goals. But for many communities, this concept remains unfamiliar, often overshadowed by questions about its efficacy, long-term maintenance, and concerns about its potential to increase project costs. For many developers and engineers, conventional road designs may be perceived to be the easiest to design and permit, and for public works directors, traditional streetscapes are familiar and therefore easiest to maintain.

This report shows how Devens, Massachusetts might overcome these concerns and implement a green and complete street on a residential road in their growing community. Informed by an extensive literature review and careful examination of the limited but expanding number of green and complete streets case studies nationwide, the Tufts Field Project team and their project partner, the Devens Enterprise Commission, collaborated to develop innovative designs for the soon-to-be constructed Goddard Street. These street designs demonstrate the ability for green and complete street concepts to be advanced in a suburban context. While we hope, once built, the street itself will bear witness to the benefits of the framework of green and complete street design, this report also includes various guidance materials, which might allow you to articulate the associated costs and benefits of this type of street as you advocate for similar designs in your community.

Not sure where to start? While Devens is unique, an incubator for cutting-edge land-use and planning policies, there a number of lessons from this report which can be applied your communities also. We recommend focusing first on your neighborhood context: what are the unique needs of your community? How can you maintain affordability and access for your neighbors? These questions can often only be answered through community engagement, education, and outreach. The roadways of your community can be sustainable, livable, and safe, but without maximizing green and non-vehicular road spaces, these goals can be harder to attain. While final designs are context-dependent, ultimately, all communities, including yours, can experience the benefits resulting from green and complete streets.

Figure 1. An aerial view of the Emerson Green Community in Devens, MA (Source: Emerson Green, https://www.emersongreen.com/community/)

Introduction

Introduction

Imagine that you are walking or rolling down the middle of a snow-free roadway in winter just after a nor'easter. There is no black ice, no hidden puddles of slush, just a cleared, open pathway of porous asphalt, swept once by the plow. The road is wide enough for a fire engine and level with the sidewalk, one shared space for all roadway users. The edges of the road are lined with native plants and recede slightly below the shared street, where you see any remaining snowmelt flow into the green bioswales on each side. Overhead are trees, bare from leaves now, but in the spring will create a lush, green canopy covering you and the pathway from the quickly-coming summer sun. There are no powerlines overhead for the trees to compete with. Continuing up the serpentine pathway, you see an open park with benches, a community garden, and a play area on heated solar roadway panels. The LED lights from the solar roadway are lit in a pattern for hopscotch and a basketball key under a hoop at the end of the block. There are planters at the corners of intersections acting as bollards to slow down traffic as well as a green, interactive feature where residents can plant perennials, herbs, or edible plants. This walkthrough is our design proposal for a livable, green, and complete Goddard Street in Devens, Massachusetts.

The concept of green and complete streets is a living and dynamic one, the bounds of which are still being defined. It is a relatively new policy approach for urban and environmental design and development, borne out of elements of complete streets and green streets, but is more than a combination of the two. A green and complete streets policy aims toward symbiosis, a mutually beneficial and sustainable relationship between our natural environments and built spaces. Green and complete streets aim toward connectivity between our transportation options and our lived experiences. It puts people at the center of design and seeks for residents to have the right to use our streets in the same way automobiles do today. Green and complete street designs look toward connecting our spatial safety with our health, helping us realize that the networks of pathways and roads which we design to take us to and from destinations can themselves be destinations for environmental and community sustainability.

Car-centric streets have been the dominant street design for the last eight decades (Norton 2015). While first thought of as providing ease of access by allowing residents to drive from their home to their place of employment or school quickly, the continuation and expansion of auto-centric policy and design has resulted in increased pollution, urban and suburban sprawl, and traffic fatalities, especially among pedestrians, senior citizens, and children (Norton 2015). Considering how much space a personal vehicle takes up on the road and how low typical vehicle occupancy rates are, car travel is also an inefficient means, both in person throughput and environmental impact, of transporting people compared to train, bus, or bicycle travel. Car-centric design has also encouraged housing segregation by race, gender, and social-economic status (Rothstein 2018).

Since the mid-1980s, alternatives to car-centric urban design and development have been gaining prominence, including New Urbanism. New Urbanism emphasizes walkability, narrow streets, an abundance of trees and vegetation, and a focus on environmental, economic, and housing sustainability, which when applied can serve to reduce or eliminate the need for private vehicles and allow residents to have healthier lives with an increased sense of community (bsummers 2015). Within this emphasis on human-scale, neighborhood-level design, there is an increased call for resident participation and the potential for place-making and social justice through sustainable development.

As COVID-19 has changed the commuting patterns for workers, with a significant portion working from home either entirely or partially, the need for a more pedestrian and cycling-friendly environment has correspondingly increased (Wang et al. 2021). Since social and physical distancing has become a normalized mode of operating for neighbors and businesses, there is also an increased demand for more amenities catering to residents utilizing a community's public spaces at all hours of the day (Zie et al. 2020).

Devens provides a unique opportunity to discover the best practices for green and complete street design concepts, and how to implement a people-first residential development that reflects the changing patterns of residential, community, the changing patterns of residential, community, and transportation needs. By combining green and complete streets, shared streets, biophilic designs, and public health, Goddard Street can serve as a living prototype for new developments to learn how to create streets where people are the primary domain and cars are invited guests. Re-thinking the design of new developments is vital as the demand for housing increases. This project will provide guidelines and potential implementations for both Goddard Street and other developments at-large with the hope for wider adoption.

Site Description

Devens is located in north-central Massachusetts at the location of the North and Main posts of the former United States Army garrison at Fort Devens. The base was established in 1917 as a temporary cantonment for training soldiers bound for the frontlines of World War I and later became a permanent installation in 1932 (Base Realignment and Closure Environmental Office 1996). The base was recommended for closure by the 1991 Base Realignment and Closure (BRAC) Commission (Base Realignment and Closure Environmental Office 1996). Subsequently, the base was closed in 1996 and, at that time, the three towns whose land comprised the North and Main posts, Ayer, Harvard, and Shirley, voted to cede their local development authority over the land in favor of a centralized, one-stop permitting agency (McMorrow 2011). That one-stop permitting agency is the Devens Enterprise Commission, which was established by an Act of the Massachusetts State Legislature in January of 1994 (Chapter 498 of the Acts of 1993)and is who the partner for the Tufts Field Project team.

Since the closure of Fort Devens in 1996, the Devens Enterprise Commission has been sustainably redeveloping the community in alignment with the Devens Reuse Plan (McMorrow 2011; Base Realignment and Closure Environmental Office 1996). This master plan largely envisioned Devens as a commercial and manufacturing hub and capped housing at 282 units (Vanesse Hangen Brustlin Inc. 1994). Despite this legislatively-imposed cap on housing, production of new residential units has continued at Devens within the 282-unit confine, with a significant new housing development breaking ground at Emerson Green in October of 2015 (New England Real Estate Journal 2015). This development, spearheaded by the developers at NOW Communities and architects and designers at Union Studios, will create 124 new homes at Devens, including single-family units, duplexes, and a multi-family apartment complex (New England Real Estate Journal 2015). The development is intentionally designed with environmental sustainability and energy efficiency at the forefront, while also creating a pedestrian-friendly, green, and vibrant community through the layout and orientation of the parcels within the neighborhood ("Emerson Green: Community" 2020).

Goddard Street, one of the seven streets within Emerson Green, will house 18 single-family units. The Devens Enterprise Commission has enlisted the support of the Tufts Field Project team and Nitsch Engineering to re-imagine Goddard Street from the conventional design proposed for the street to a green and complete design. The developer's permit plan set describes the soon-to-be-constructed Goddard Street as a 44' right of way, with a conventional streetscape design, including two 11' travel lanes, two 5' sidewalks, and two 5' grass strips dividing the sidewalk from the curb. Figure 2 shows the current plan for Goddard Street.

The MassDevelopment Board of Directors and Devens Enterprise Commission adopted a green and complete streets policy in the fall of 2021, which combines complete streets policies with green streets policies, and calls for those policies to be integrated into the planning and design of all public and private projects (Devens Green and Complete Streets Policy 2021). The new development at Goddard Street presents a unique opportunity for the Devens Enterprise Commission to implement this new policy in a way that can demonstrate its effectiveness and replicability, both for other streets in Devens but also more universally. To this end, in addition to supporting the design of Goddard Street itself, the Tufts Field Project team has been tasked to develop educational materials which can be used to inform key stakeholder groups such as developers and their engineers, public works directors, and the general public about implementation best practices and the benefits of constructing green and complete streets.

The Tufts University Department of Urban and Environmental Policy and Planning has had a long-standing relationship with the sustainable redevelopment at Devens. In 1993, the late Professor Herman Field, a resident of Shirley and founder of the Tufts University Graduate Program in Urban and Environmental Policy, orchestrated the initial design charette for envisioning the reuse of the former Fort Devens. In 2008, a Tufts UEP Field Project team authored a report titled "Power Down Devens: Revolving Loans," which explored how Devens could use a revolving loan fund to support its redevelopment goals. More recently, Peter Milliken, advised by Professor Justin Hollander Ph.D. FAICP, who in his own right has published research using data from Devens, conducted thesis research using eye-tracking emulation software to understand the ways biophilic and sustainable transportation components within street design impact how roadway users experience a street (see Milliken 2019 and Hollander et al. 2020).

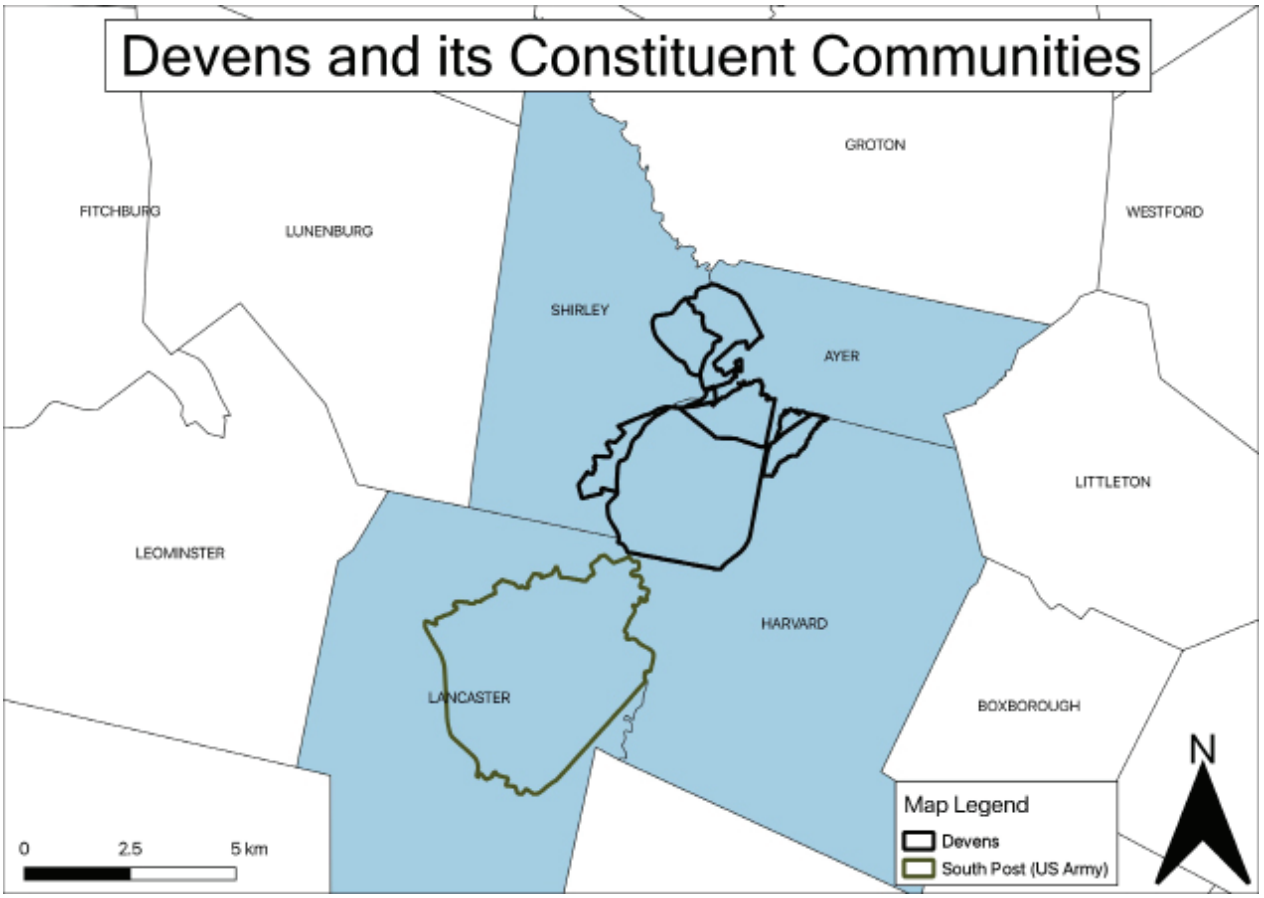


Figure 2. Map of Devens and its constituent communities (Source: Devens Field Team)

Figure 3. Map of Emerson Green Development (Source: Emerson Green)

Figure 4. The Tufts UEP team joins Devens DEC for a walk down an undeveloped Goddard Street (Source: Devens Field Team, January 27, 2022)

Figure 5. Looking east towards an undeveloped Goddard Street (Source: Devens Field Team, January 27, 2022)

Figure 6. Construction of houses for Phase 2 of the Emerson Green Development (Source: Devens Field Team, January 27, 2022)

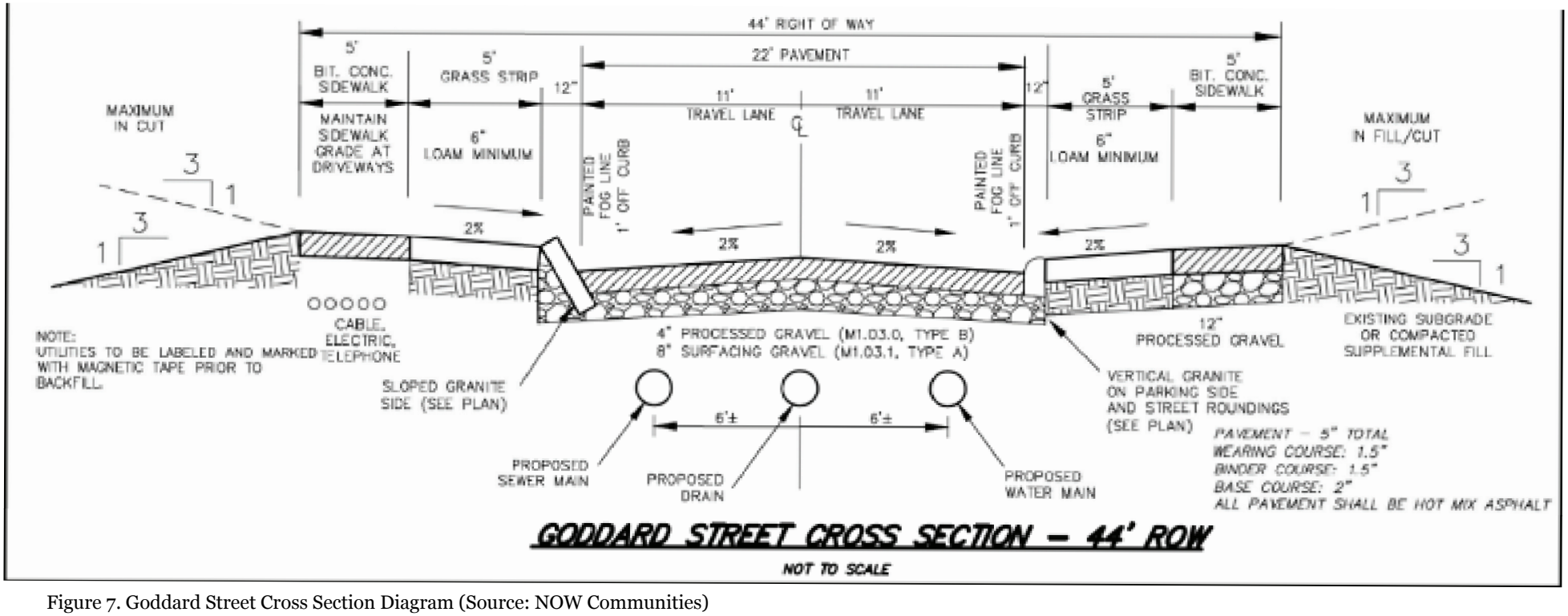


Figure 7. Goddard Street Cross Section Diagram (Source: NOW Communities)

Methodology

Our research methodology focused on two central themes: the design and implementation of green and complete streets and their long-term and short-term costs, benefits, and maintenance. Each stage of the methodology builds on the subsequent stages, as our project team integrated our initial literature review into design ideation, from which we evaluated costs, benefits, and generalizability.

Our project research questions were:

- What are the best practices for the design and implementation of a green and complete streets policy?
- How can those best practices be applied to the design of Goddard Street?

Part 1: Synthesis of Design Best Practices: Literature Review

Our research began by studying various street typologies and the design elements contained within them. Our goal was to identify a set of best practices for street design generally and to understand how those best practices could be utilized in the design of Goddard Street. To accomplish this, we conducted a literature review and consulted street design guides published by various agencies and advocacy groups. These included one guide published by the Environmental Protection Agency (EPA) focused on green streets and another by the National Association of City Transportation Officials (NACTO), which focused on complete streets. Simultaneously, we aggregated peer-reviewed scholarly publications on specific elements within these design guides, which offered further commentary on the effectiveness and ideal use cases for many of the design elements. From this literature review, we developed a "menu of options," which synthesized our research. This document included a list of possible design elements for Goddard Street, photographs or drawings of their application within roadways, a description of the features and materials need to construct each element, as well as preliminary findings on any element-specific design considerations (see Appendix A).

Part 2: Development of Concept-Level Design Sketches: Design Charette

Following our literature review, the Tufts Field Project team conducted two design charettes, one internally and one with our project partner, the Devens Enterprise Commission, and their partners, Nitsch Engineering and the site developer from NOW Communities, Dan Gainsboro. These charettes were spaces for brainstorming ways to integrate the design best practices from our literature review into concept-level sketches of Goddard Street. Following the design charette process, the Tufts Field Project team formalized the generated paper and pencil sketches into three different concept designs, each with unique cross-section and eye-level renderings (See Figure 4). These renderings laid out the allocation of space within the right of way and proposed

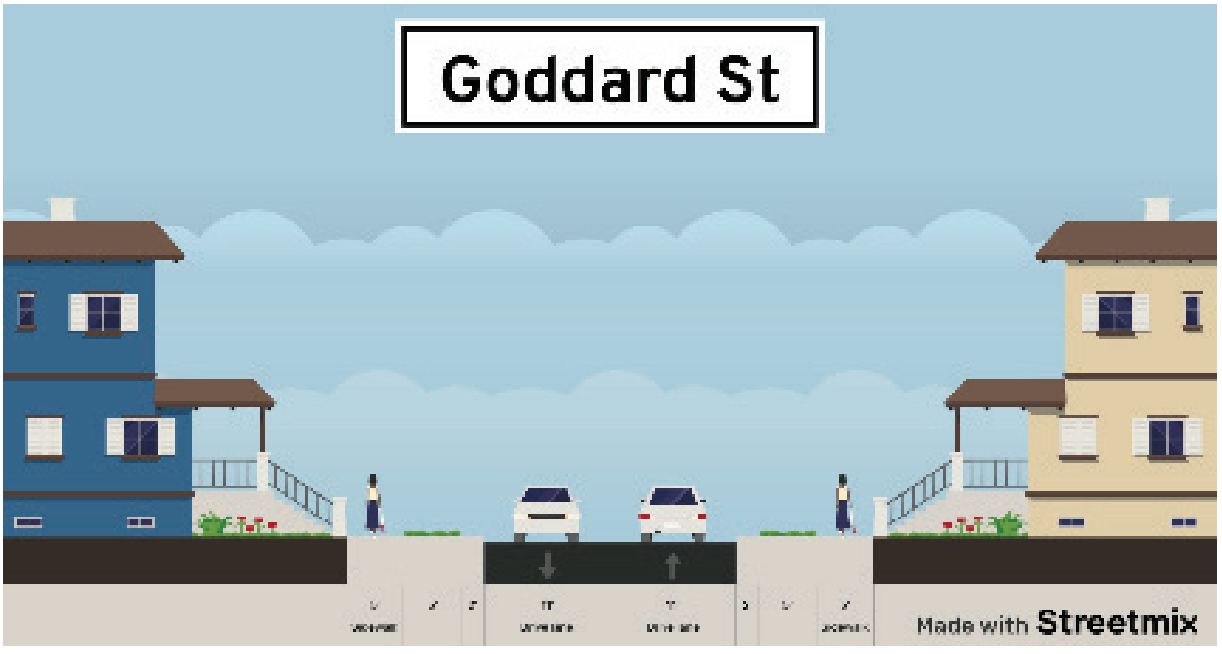


Figure 8. Permit Set Cross-Section View of Goddard Street (Source: Devens Field Team)

locations for specific elements from our "menu of options" along the length of the roadway.

Part 3: Evaluation of Costs and Benefits: Review of Case Studies, Stakeholder Analysis, and Further Literature Review

Our research continued by reviewing existing case studies to explore working examples of green and complete streets. Reviewing these case studies was particularly important because local and site-specific factors can influence the costs and maintenance of green and complete streets. Our case study review and discussions with our project partners, engineering team, and site developer helped us understand the various costs and benefits for different stakeholder groups. For public works departments, for example, a street must be designed with consideration of the type of maintenance to be performed, the frequency of maintenance and available personnel, the cost of component replacements, and whether specialized equipment or training will be required to maintain any unique street elements that might differ from a conventionally-designed street. To this end, we also consulted with Shane Melone, the Devens DPW Director, to understand the specific constraints his department might face.

Our analysis had to expand beyond a strictly economic exercise of quantifying construction and maintenance costs, instead factoring in not easily quantifiable attributes such as public health, street safety, and well-being. With our understanding of different stakeholders' priorities, we created guidebooks to directly address challenges and benefits for three central audiences: operations and maintenance departments, developers and planners, and the residents and roadway users. For each group, we addressed economic, social, and environmental costs and benefits as they applied to their interests and how those might compare to costs associated with conventional design and gray infrastructure.

Figure 9. Design charrette with Nitsch Engineering, Devens Enterprise Comission, and Tufts field project team.

Literature Review

This literature review explores academic and gray literature on street design elements used in residential environments. In this review, the Field Project team highlights the drawbacks of conventional street designs and introduces the concepts of complete streets, shared streets, green streets, green and complete streets, and public health. In addition, this literature review explores the benefits of these street design concepts in terms of safety, health, and aesthetic values. It also includes implementation examples of these concepts in the United States and internationally.

Conventional Street Design

Historically, the design of roadways has been an exercise in balancing automotive throughput with local access and has often been heavily influenced by adjacent land use (American Association of State Highway and Transportation Officials 2004). Because sprawling land use development patterns have largely separated residential, commercial, and industrial zones, roadway network design have focused on moving automobiles from local residential roads onto larger and faster roads that can quickly connect travelers to commercial or industrial areas (Spielberg and Chellman 1997). As a result, local roads are often not designed for internal connectivity but rather for their external connections to larger adjacent roadways (American Association of State Highway and Transportation Officials 2004). Grounded in conventional street design is the assumption that individuals have access to one or more cars, and aside from short and local trips, most people will move from place to place in their vehicle (Spielberg and Chellman 1997). The result is many of the conventional street designs we see across the United States today: a large, central space dedicated, by design, exclusively for automobiles and in some cases, dedicated sidewalks for pedestrians. These roadway designs are often poorly suited for more vulnerable roadway users, like cyclists, pedestrians, children, elders, and people with disabilities (Hillier 2004).

Context-Sensitive Design

Beginning in the 1960s, communities throughout the United States began to push back against large-scale transportation projects that disrupted their neighborhoods and had clear negative impacts on the population residing near the locations of these projects. One of the ways transportation engineers and planners responded to the demand of communities for more holistic approaches to transportation projects was through context-sensitive design. Starting in the 1990s, numerous pieces of legislation passed that centered the design of transportation projects around their environmental context. The 1995 National Highway Designation Act called explicitly for project designs that consider "the constructed and natural environment of the area; the environmental, scenic, aesthetic, historic, community, and preservation impacts of the activity; and access for other modes of transportation" (Federal Highway Administration 2001). The "Thinking Beyond the Pavement" workshop hosted in 1998 by

<Conventional Street Design>

<Human-Centered Street Design>

Figure 10. A conventional street design (left) and human-centered design (right) (Source: Choi, Jaisung, Sangyoup Kim, Dongchan Min, Dongmin Lee, and Sungkyu Kim. "Human-Centered Designs, Characteristics of Urban Streets, and Pedestrian Perceptions," Journal of Advanced Transportation 50, no. 1 (2016))

the Maryland State Highway Administration helped start a trend of context-sensitive design approaches throughout the United States (Federal Highway Administration 2001). This approach had a more considerable emphasis on community involvement through community engagement mechanisms such as public design and project reviews, visualization tools, and more transparent decision-making (Federal Highway Administration 2019).

Complete Streets

The paradigm of complete streets seeks to shift the focus of street design from a traditionally auto-centric approach to one that designs streets for the safety and accessibility of all roadway users, regardless of their mode of travel, age, or ability (Active Transportation Alliance 2014). Complete streets typically include safe and accessible places for all cyclists, high quality, safe, and accessible pedestrian facilities, as well as a roadway design that accommodates vehicular users, such as cars, trucks, commercial vehicles, emergency vehicles, and public transit (Active Transportation Alliance 2014). While some advocates may advance complete street designs primarily for the safety of more vulnerable users within the roadway, such as pedestrians and cyclists, there are numerous other benefits to implementing complete streets, including in non-urban contexts (Calloway 2020). Complete street designs can improve public health by providing safe and accessible places for more active modes of transportation and recreation, which can increase physical activity (Zaccaro & Atherton 2018). Complete streets can also improve equity, as people without cars or who are unable to drive will have an increased ability to get around safely (Prytherch 2021). This type of street can also increase local connectivity, especially in non-urban areas, where neighborhoods might otherwise be only accessible by car (Marcus 2019) and can encourage mode shift, which can reduce congestion and reduce fuel usage, decreasing carbon emissions (Glazener & Khreis 2019).

Figure 11. A complete street on Western Ave in Cambridge, MA provides an accessible road for all users. It includes a designated sidewalk, bike lane, and clear crosswalks and signage. (Photograph by Anthony Crisafulli Photography. Source: Halvorson, https://www.halvorsondesign.com/western-ave)

Incomplete Streets

When reviewing the design framework of complete streets, it is important to also consider what the implications of having incomplete streets are, especially in terms of social and environmental justice. Poorer people and people of color tend to bear disproportionately the burdens of air and noise pollution and other road safety and health hazards compared with wealthier neighborhoods (Kawachi 2005). When neglected communities, neighborhoods utilized as centers of industrial development, or communities used as pass-through transportation corridors are approached with plans or visions of walkable, complete streets, there can be understandable skepticism from residents about the intended outcome. Complete streets and bikeable and walkable neighborhoods have historically been parts of a narrative of privilege. For example, creating bike lanes in a neighborhood of "non-cyclists" begs the question of who the bike lanes are for. In Portland, Oregon, for example, residents in a predominantly Black community with a history of disinvestment were resistant to proposed neighborhood road improvements, including dedicated bicycle lanes, seeing them as "instruments of gentrification" (Agyeman 2013). This example points to how complete street visions can feel incomplete when affected communities are not recognized or included in the deliberative process.

Walking is good for physical health, and the use of public transit is better for environmental health compared to the use of personal automobiles for travel. However, walkability has become commoditized. Real estate agents in the United States use the "walk score" as an index of neighborhood desirability, as a measure of convenience to local services, such that walkability has become an indicator of socioeconomic status, increased property values, and driven up housing costs (Agyeman 2013). The framework of complete streets assumes that everyone in the community should have equal access to, and a right to, the roadways within their neighborhoods. But missing from that framework often are broader conversations about how socioeconomic status, racial discrimination in the housing market, barriers to vehicular and home ownership, and many other exogenous forms of systemic oppres-

sion, in addition to mode of transportation, also dictate roadway access.

Roadways, since early organization of modern civilization, have been conduits through which people connect to their governments, places of business and trade, agriculture, leisure activity, and to other people (Agyeman 2013). When highways proliferated and suburbia took shape in the United States through the 1950s, automobile drivers emerged as the default users of streets (Flint 2006). This auto-normativity, where the default is the car, was and in many places still is the norm in city and town planning and street design (Agyeman 2013). Automobility can now be recognized as a driver of social and physical separation, an expression of racialized segregation and anti-urban ideology, and embodiment of the policies of divestment from transit systems benefiting city life (Rothstein 2018; Henderson 2007). According to evidence from the National Household Travel Survey, in 2003 Pucher and Renne point out that trips made by walking are lower for white people than for people of color (Asian, Black, Hispanic), making up 8.1% of trips compared to 12-13% for the three groups. The difference between racial groups is even more significant for use of transit systems, where Black people for example, are eight times as likely as white people (4.2% vs. 0.5%) to use transit public transit (Pucher, 2003). From this point of view a move away from auto-normativity toward complete streets, shared streets, walkable, or transit-oriented design has implicit anti-racist, social justice, and inclusion elements (Agyeman 2013).

To truly democratize our shared spaces and to fulfill the goal of green and complete streets as human-scale, environmentally-oriented designs, we must center social equity as early as possible in the design process. There are four guiding principles to developing just and sustainable communities, which continue to evolve based on discussion, lectures, and texts by Julian Agyeman, Robert Bullard, and Bob Evans. The first supporting pillar is that a planner should focus on improving quality of life and wellbeing. Within this principle is a specific focus on equity and openness to forms of happiness and life satisfaction not tied to the accumulation of wealth. The second principle for sustainable communities is meeting the needs of both present and future generations. This allows us to focus on distinguishing human needs from wants and desires, and to consider if we can move toward a post-material/post-capitalist society, disentangling our identities from what we own. The third pillar centers justice and equity through recognition in process, procedure, and outcome. As mentioned above, it is vital that we recognize what issues we are trying to address through planning and design, recognize who will be affected and how by the changes we propose to make, what are the outcomes, and how do we measure them. This is a continual process to be coupled with a proactive understanding of historical, geographical contexts, and personal and community capabilities. Civil and political participation arises out of our being seen and recognized as people with interests in and ideas about how our environments are shaped. Finally, the fourth principle guiding sustainable and just development is the necessity to live within our ecosystem limits. In order to sustain our communities, we must have healthy air to breathe and water to drink, and consider the limits to consumption needed within an extractive economy (Agyeman 2013).

Green and complete streets policies would best serve the communities and overall health of the environment by adhering to these concepts of just sustainabilities – focus on quality of life and well-being; meeting the needs of present and future generations; justice and equity through recognition in process, procedure, and outcome; living within ecosystem limits (Agyeman 2013). As green and complete streets practices become more normalized, we are tasked with recognizing who is benefiting from this investment in our built spaces, and who is being

Figure 12. A shared street intended for all modes of transportation (cars, pedestrians, bikes, etc.) to use the same space. (Source: Global Designing Cities Initiative, https://globaldesigningcities.org/publication/global-street-design-guide/streets/shared-streets/)

left out.

Shared Streets

The concept of shared streets originated in the city of Delft in the Netherlands in the 1960s. Residents were upset about cut-through traffic in their neighborhood, and they replaced their straight, brick streets with serpentine paths to slow vehicles down (Appleyard and Cox 2006). This initiated the concept of the woonerf (residential yard in Dutch), in which streets are designed to create a communal"living yard" where the living environment, people, and vegetation are prioritized over vehicular infrastructure (Appleyard and Cox 2006). Since its adoption by the Dutch government in 1976, more than 6,000 woonerfs have been implemented in the country (Hockenos 2013).

Figure 13. Play street for children on Sixth Street and Avenue C, New York City. (Photograph by Dorothea Lange. Source: Library of Congress, https://www.loc.gov/item/2017762940/)

In a street designed as a woonerf, the street is shared among pedestrians, cyclists, and motor vehicles, with the priority of each user in that order. The street is designed without a clear division between any street uses (no continuous curb), which forces vehicle drivers to slow down and travel with caution (Collarte 2014). This is accomplished by using elements such as street furniture (planters, street trees, benches) and spaces for social interaction, such as spaces for children to play or adults to congregate, in formal and informal ways (Collarte 2014). The use of color and texture is also important and has clear, distinctive entrances to signal motor vehicle drivers that the nature of the shared space environment (Collarte 2014).

The main idea of the woonerf has been exported to numerous countries. One of the more notable examples of this idea is home zones in the United Kingdom. Created in the 1990s, while primarily similar in concept to woonerfs, the purpose of home zones was less centered on creating a sense of communal space and more on reducing vehicular crashes and easing traffic (Appleyard and Cox 2006).

In the United States, shared street concepts have been in use for decades, under different names. Cities such as New York City and Philadelphia have designated "play streets" around schools that lack sufficient playground or gym space, restricting vehicular access during certain daytime hours (Appleyard and Cox 2006). Two developments in Boulder, Colorado, in the 1980s incorporated aspects of the woonerf concept into their street design (Alan M. Voorhees Transportation Center 2004).

Numerous benefits have been noted after the implementation of woonerfs, home zones, and shared streets. Below are some of the more notable:

- ### Safety

Street safety on shared streets is primarily accomplished through physical street design. Street design elements used to achieve this are bottlenecks, textured surface material, and speed bumps (Alan M. Voorhees Transportation Center 2004). In addition, traffic calming measures should not be applied in a consistent matter but instead should use inconsistency and uncertainty in design to keep drivers alert and reduce speeds (Alan M. Voorhees Transportation Center 2004).

Another critical consideration to ensure street safety is limiting the space dedicated for motor vehicles. In the United Kingdom, home zone streets are recommended to have traffic lanes that are 9.9 feet in width, with passing bays of 20 feet every 130 feet to accommodate emergency vehicles (Appleyard and Cox 2006).

- ### Health and Active Living

Older residents stand to greatly benefit from shared

Figure 14. Home zone in Plymouth, United Kingdom. (Photograph by Adrian Trim. Source: Neighbourhoods, https://neighbourhoods.typepad.com/neighbourhoods/2004/03/home_zones_and_.html)

Figure 15. A residential shared street design (Source: National Association of City Transportation Official, https://nacto.org/publication/urban-street-design-guide/streets/residential-shared-street/)

street designs. Specifically, a report on the perception of older people after street safety interventions in Sweden showed that there was strong support for infrastructure that included even pavements and lower curbs, as it increases accessibility for older people using mobility devices (Ståhl, Horstmann, and Iwarsson 2013). In a study comparing the activity levels and quality of life of older people that live on streets that received home zone redesigns with streets that did not, older people that lived on home zone streets reported significant improvements in the easiness of walking and higher levels of active participation (Curl, Ward Thompson, and Aspinall 2015). This was attributed partly to post hoc perceptions after implementing the home zone street design, as residents of the redesigned streets reported higher levels of activity but not an increase in time or frequency of outdoor visits (Curl, Ward Thompson, and Aspinall 2015).

For children, parents who live on home zone streets are more likely to allow their children to play out on the street than parents who live on conventional streets (Biddulph 2012). A study comparing two streets in Cardiff, Wales, one conventional street and another redesigned as a home zone street, found that children stayed longer and engaged in play activities on the home zone street compared to the conventional street (Biddulph 2012). In addition, children using the home zone street used the entire street width to play and did not relegate their activity to the space closest to buildings.

- ## Improved Aesthetics and Increase in Home Values

Retrofitted shared streets have increased attractiveness among the road's existing residents. Seventy percent of residents living on a woonerf in the Netherlands, and 80% of residents living in home zones in the United Kingdom find their streets attractive or highly attractive (Collarte 2014). In addition, parents prefer the look of home zone streets compared to conventional streets (Biddulph 2012). In the Netherlands, homes located in woonerfs have 10% to 15% higher home values than non-woonerfs homes (Appleyard and Cox 2006). This phenome-

Figure 16. A concrete bollard with an integral steel pipe. (Source: Landscape Architect, https://landscapearchitect.com/ladetails/landscape-product/bollards-illuminated/wayne-tyler/240-series-barriersecurity-concrete-bollard)

non raises concerns about gentrification, which is why we recommend, especially in retrofit cases, that developers and planners prioritize maintaining affordability for resident residents.

• Drawbacks

While perceptions of improved walkability and active participation have been noted after home zone redesign streets, there were no noted benefits to health and quality of life (Curl, Ward Thompson, and Aspinall 2015). One of the suggestions to ensure positive impacts on health and quality of life is for street designs to be more comprehensive, with curbless shared streets, providing provision for blind and visually impaired people, and dedicated seating (Curl, Ward Thompson, and Aspinall 2015). In addition, designing a shared street does not automatically create a sociable environment. Boulder's Bridgewalk shared street neighborhood, shared vehicular, pedestrian space is not as widely used as developers initially intended (Alan M. Voorhees Transportation Center 2004). The community has backyards, porches, and other areas for people to congregate.

Common traffic calming measures like cobblestones and speed tables can create noise pollution when motor vehicles travel through them (Alan M. Voorhees Transportation Center 2004). In addition, some of the materials used for traffic calming measures in shared streets may have additional maintenance costs. In Boulder's Bridgewalk, concrete bollards that were hit and cracked by motor vehicles would also create cracks on the concrete surface of the roadway (Alan M. Voorhees Transportation Center 2004).

Green Streets

Green streets differ from conventional streets, incorporating green infrastructure directly into the right-of-way (Rodriguez-Valencia 2021). When green street elements are included in street design, they provide an opportunity to manage stormwater onsite, as compared to conventional street design practices, which manage stormwater through sewer and pipe systems (R. 03 US EPA 2015). Many different design elements can be included in green streets, though the Devens Green and Complete Streets policy specifically highlights three: green stormwater infrastructure, shade trees, and the use of recycled materials (Devens Green and Complete Streets Policy 2021). Green infrastructure used in urban environments has been shown to reduce urban heat island effect, stormwater run-off speed, and urban noise, and assist in improving quality of life (Rodriguez-Valencia 2021).

• Stormwater management

Green stormwater designs can often include porous or permeable pavement, bioretention elements, or swales, all of which are designed to increase the permeability of the right of way, increase rainwater infiltration, decrease local flooding, and naturally cleanse rainwater of pollutants (R. 03 US EPA 2015).

Stormwater management is an important management technique, as it reduces the amount of runoff and runoff pollution. Stormwater runoff is generated from rain and snowmelt and often contains harmful

Figure 17. Examples of green infrastructure used for stormwater management. (Source: Qi, Wenchao, Chao Ma, Hongshi Xu, Zifan Chen, Kai Zhao, and Han Hao. "A Review on Applications of Urban Flood Models in Flood Mitigation Strategies." Natural Hazards 108 (August 1, 2021).

Figure 18. Example of street trees and vegetation. (Source: United States Environmental Protection Agency. "Green Streets: A Conceptual Guide to Effect Green Streets Design Solutions Residential Streets, Commercial Streets, Arterial Streets, Alleys." (August 2009)).

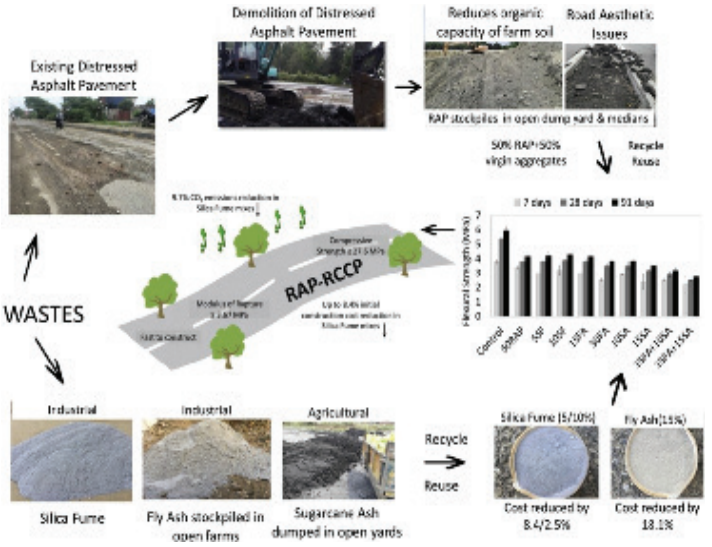


Figure 19. The recycled and reused materials lifecycle in roadway construction. (Source: Debbarma, Solomon, G. D. Ransinchung R.N., Surender Singh, and Surya Kant Sahdeo. "Utilization of Industrial and Agricultural Wastes for Productions of Sustainable Roller Compacted Concrete Pavement Mixes Containing Reclaimed Asphalt Pavement Aggregates." Resources, Conservation and Recycling 152 (January 1, 2020).

pollutants. Green infrastructure utilizes technologies and approaches to best manage runoff through infiltration, evapotranspiration, and capturing and reusing stormwater to maintain or restore natural hydrologies (US EPA OMS 2015). Stormwater management is an opportunity to prevent pollution at its source and an element to tackle in building sustainable, resilient communities.

Historically, impermeable surfaces have been located on top of green space, which causes many problems, such as in hydrological cycles (NACTO p.6 2017). This means that gray infrastructure such as gutters, sewers, tunnels, impermeable parking lots, or sidewalks are near green spaces. This presents a challenge as communities face increased frequency, duration, and intensity of storms. During severe storms, combined stormwater runoff and sewage flows can exceed the capacity of the system, discharging into surface water bodies before being treated. For these reasons, it is important to protect water quality and to build infrastructure that helps reduce runoff volume and filter its pollutants. Stormwater management is an important function of local public works departments and with the increase in urbanization, gray infrastructure is no longer desirable due to its high maintenance and replacement costs, economic losses from storms, public health risks, the prevalence of urban flooding, and the increasing frequency of storm surges (NACTO 2017, p.6).

One solution to many of these deficiencies is to implement green stormwater infrastructure (GSI). GSI reintroduces ecological functions back into the built environment, intercepting stormwater before it reaches gray infrastructure. It also infiltrates some water. The investment in GSI compliments gray infrastructure and can even extend the life of capital streets and sewer projects (NACTO 2017, p.6). Studies conducted are in alignment with the literature; green stormwater infrastructure not only controls stormwater volume and timing but also promotes ecosystem services, which are the benefits that ecosystems provide to humans (Prudencio and Null 2018). Other co-benefits of GSI are traffic calming and the addition of urban greenery.

Although there are apparent benefits to green stormwater infrastructure, there are also barriers to the implementation of this stormwater management approach. Local and site-specific factors, such as land value, space limitations, existing utilities, and environmental conditions, influence the costs (The Real Cost of Green Infrastructure 2015).

- ## Street Trees and Vegetation

There is a growing recognition that nature plays an essential role in sustainable cities (Seiferling 2017). In order to incorporate more nature into landscapes, many have used spaces along streets as a place to plant trees and vegetation (Seiferling 2017).

- ## Recycled Materials

Due to the limited supply of natural resources and the high amount of waste produced by society, the idea of using recycled materials in construction has

been introduced as a potential solution (Skotnicki 2021). This concept is another possible component of green streets. Some examples of using recycled materials in practice include using recycled rubble materials from reclaimed asphalt pavement (RAP) and portland cement concrete (PCC) (Berthelot, 2011). Recycled materials can also be implemented in mineral-cement emulsion (MCE) mixtures (Skotnicki 2021). However, there are doubts regarding the integrity of reused and recycled materials. The ingredients in MCE mixtures can lead to shrinkage and cracking in the pavement. To tackle this problem, there have been attempts to use a cement binder made of recycled materials in MCE mixtures. This was found to be useful in increasing the durability of these materials (Skotnicki 2021). Additionally, a study conducted in Saskatoon, Canada, found that using recycled RAP and PCC materials on a road was, in fact, effective and durable (Berthelot 2011). However, it is still important to note the ongoing debate about the effectiveness of recycled and reused materials in roadway construction.

Green and Complete Streets (GCS)

Green and complete streets are aptly named; they are a combination of both green streets and complete streets. Through our literature review, it became clear that the concept of green and compete streets is still emerging (NACTO 2017). These terms, when found in the literature, are most often used separately, either as "green streets" or "complete streets" (Smart Growth America 2022). Green and complete streets integrate stormwater infrastructure, shade trees, and landscaping to more closely mimic natural hydrology into safe, accessible, connected networks of roadways and paths. GCS designs aim to create safe and accessible pathways for all users while protecting the natural environment and enhancing the social environment (Devens Green and Complete Streets Policy 2021).

Throughout our literature review, we also aimed to more deeply understand the benefits of green and complete streets. While some benefits, such as safety, have previously been discussed, one specific benefit, public health, warrants additional review.

Public Health

Public health is the science of protecting and improving the health of people and their communities, often through educational programs, promotion of healthy lifestyles, and research and policy recommendations. The goal of the field is to work towards limiting health disparities, promote equity, quality, and accessibility, and prevent problems from either happening or recurring (What Is Public Health 2022).

Public health benefits are often associated with green spaces and nature. As planners, developers, and engineers become more holistic in their construction of the built environment, these benefits are becoming top of mind as research highlights a positive relationship between green spaces and public health benefits. Aspects of the living environment can affect the health and well-being of people, particularly children and adolescents (Van den Berg, Hartig & Staats 2007). As urbanization increases, people have a greater likelihood of living in areas with fewer green spaces. Research shows a positive relationship between green space in people's living environment and the positive effects it has on physical and mental health (Mass et al. 2006). To further investigate the benefits of green space in the living environment, researchers have looked at how green spaces can affect feelings of social safety, aggression and violence, school and work performance, life satisfaction, and even life outlook.

Broadly speaking, natural spaces can often be perceived as unsafe places (Jorgensen, Hitchmough & Calvert 2002). Due to this, researchers have conducted studies to better understand the relationship between the availability of green space and people's feelings of safety. There are two ways to define safety: objectively and subjectively. Objective safety is measured by facts and figures, whereas subjective social safety is perceived safety experienced by the individual (Maas et al. 2009). This literature review focused on subjective social safety. Social safety is the safety resulting from human behavior and interactions between people in public spaces (Van den Berg, Hartig & Staats 2007). Feeling safe is important for well-being, quality of life, and good health (Maas et al. 2009).

A study conducted by Maas et al. (2009) looked at whether the percentage of green space in a resident's living environment affects their feelings of social safety positively or negatively. The researchers evaluated how green spaces and opinions vary between urban and rural areas, what groups are more vulnerable, and the different types of green spaces. Results from this study found that the type of green space is relevant. Open green spaces increase feelings of social safety as opposed to closed spaces because of higher visibility of potential dangers. There is a positive relationship between open green space in the living environment and feelings of social safety, where closed green spaces were only negatively related to feelings of social safety in very urban areas. Urban green spaces are often regarded as unsafe due to poor standard of maintenance (Jor-

gensen, Hitchmough & Calvert 2002) and because they can provide potential hiding places for criminals (Herzog and Chernick 2000).

One may think that those living in urban areas with more green space would feel less safe than people living in rural areas with more green space, but that is not necessarily the case. The study found a significant positive relationship between green space and feelings of social safety at all levels of urbanization, except in very strongly urban areas (Maas et al. 2009). People tend to feel safer when they have more green space in their living environment, but not in very urban areas. Results also show that women with more green space in their living environment feel safer but the relationship is not significant in very urban areas, and elderly people feel safer when there is more green space, except in very urban areas (Maas et al. 2009).

Associated with the feelings of social safety is a reduction in feelings of fear and violence. As mentioned previously, green space is often implicated as a screen for criminal activity. It must be acknowledged that the scientific findings are not conclusive and may even seem inconsistent or conflicting in this part of the literature review, but some patterns and relationships appear across several studies: the presence of nearby nature may positively influence social interactions and lessen aggressive and violent behavior (Wolf 2010). Specifically, Principles of Crime Prevention Through Environmental Design (CPTED) suggests how to achieve safer places through the management of vegetation to create a reassuring environment to reduce fear and increase citizen surveillance (Wolf 2010).

A study conducted in residential neighborhoods in Portland, Oregon, found that property crimes were less frequent when there were trees in the right of way and more abundant vegetation around a house (Donovan and Prestemon 2012). Another study (Kuo & Sullivan 2001) found that residents living in relatively barren buildings reported more aggression and violence than did their counterparts in greener buildings. The literature suggests that high settlement density and urban stressors (such as noise, fear of crime, and crowding) can impose psychological demands that people find excessive (Van den Berg, Hartig & Staats 2007). One outcome of mental fatigue may be increased outbursts of anger and even violence (Kuo & Sullivan 2001). Contact with nature appears to help mitigate mental fatigue, which in turn may reduce aggression and violence (Kuo and Sullivan 2001). This study reported levels of mental fatigue to be higher in barren buildings, with aggression accompanying mental fatigue. Research in environmental psychology suggests that

	Conventional Streets	Green Streets	Complete Streets	Green/Complete Streets
Comfortable/Safe Bike and Pedestrian Access	Low	Medium/Low	High	High
Stormwater Management	Low	High	Low	High
Community Health Positive Impacts	Low	Medium/High	Medium/High	High
Public Open Space Generated	Low	Medium/High	Medium/Low	High
Reduction of Urban Health Island Effect	Low	High	Low	High
Short-Term Cost Maintenance/Operation	Medium/Low	Medium/High	Medium/High	Medium/High
Long-Term Costs Maintenance/Operation	Medium/High	Medium/Low	Medium/Low	Medium/Low

Table 1. Synthesis Table of Literature Review (Source: Devens Field Team)

people's desire for nature, to be surrounded by nature, or to have any contact with nature serves as an important adaptive function known as psychological restoration (Van den Berg, Hartig & Staats 2007). Contact with natural environments is an effective way of obtaining restoration from stress and mental fatigue compared to an ordinary built environment. Urban life and urban stressors are motivating people to look for areas with more green space (Kuo and Sullivan 2001). The challenge that remains is designing communities that balance the built environment, settlement density, and satisfaction with green space.

With more than 80% of the United States population living in cities and towns, today most work and study primarily involve mental and cognitive processes (Wolf, Krueger & Flora 2014). Due to technological innovation and advancements, human productivity has shifted primarily indoors (Wolf, Krueger & Flora 2014), separate from the natural environment. This makes concepts like biophilic design even more critical to public health. Biophilic design is defined as the combination of both the natural world and living things (bio) and the connections with and love of nature (philia) (Beatley 2016). Many studies suggest that being near nature is better for mental and physical health. It is shown to increase happiness, improve health, and foster more generous, creative, and compassionate people. This reaction to nature all ties back to the concept of biophilia and how we as humans have coevolved with the natural world (Beatley 2016). Therefore, from a biophilic lens, adding nature and vegetation to roadways can produce many benefits for both people and the environment.

Literature Review Summary

The concepts that have been introduced in our review allow for the evaluation of the benefits and challenges of designing and implementing green and complete streets. The literature is clear that complete streets, green streets, and shared streets individually provide benefits to public health, benefits for our natural environment, and positive impacts on local economies and community life. Table 1 below synthesizes some of these benefits.

There is a long history of using street design to make streets safer, aesthetically pleasing, and friendlier to non-motorized users. Humans have a shared desire for connection to nature and we know how to produce built environments that work symbiotically with the natural world. While conventional street design has been centered on automobile travel, complete street elements provide opportunities for higher levels of activity and safer passage for those walking or rolling and can increase access when we add shared street elements. When green streets elements are included, communities realize the benefits of interacting with their natural environment. Economic benefits accompany each of the elements through more efficient and lower costs of maintenance and replacement and improved access to broader mobility networks.

By combining the concepts of green, complete, and shared streets, we can center the natural environment and peoples' safety and connectivity as a holistically beneficial design approach, providing more access and control over our outdoor built spaces. Continuing research into any one of these concepts would benefit the field of urban and environmental development and help further the discussion of the green and complete streets policy approaches. We encountered some discussion of complete streets as a potential driver of equity but we must acknowledge that our literature review only briefly explored questions of equity, especially around ideas like green gentrification. Further exploration is warranted into what communities, institutions, or populations are benefiting from the emergence of and investment in these designs. Best practice for community and people-centered planning and design requires that the community is engaged and participating as early in the process as possible.

Implementing Best Practices: Project Deliverables

Our final deliverables include guidebooks (Appendices X-Z) that educate different audiences on green and complete streets, a preliminary cost estimate of GCS components, a GCS menu of options, and visual elements that show our three proposed street designs. The guidebooks will document best practices for implementing green and complete streets elements, including implementation cost and impact on roadway operation and maintenance. The guidebook materials can be a foundation from which the included techniques, practices, and connections to resources can be used to teach three target audiences – public works agencies, developers and their engineers, and the general public - how they might support communities interested in developing green and complete street neighborhood designs. Our preliminary cost analysis compares estimated costs between conventional streets and green and complete streets, along with long-term maintenance and operations considerations. Our "menu of options" shows different GCS components that could be implemented on a green and complete street. The menu of options examines costs, materials, and ben-

efits. Finally, the visual elements include cross-sections of the proposed street design, drawings of individual GCS components, eye-level renderings, and plan view concept drawing.

Cost Comparison

A challenge for planners recommending low impact development (LID), green infrastructure (GI), and green and complete streets design to municipalities, developers, and public works departments is comparing the often unknown upfront and long-term costs associated with these technologies compared with well-known conventional or gray infrastructure techniques (Shapard 2013; The Real Cost 2015). There are some common perceptions regarding LID and green and complete streets construction that may discourage the use of these techniques. Some of those perceptions are: the difficulty of developing estimates of capital costs and operations and maintenance of LID techniques, uncertainty about effectiveness, that the up-front cost for LID is more expensive than that of traditional infrastructure, and the difficulty of monetizing or quantifying the environmental and social benefits of these relatively new techniques (US EPA, R. 13.004, 2013).

With these perceptions in mind, we searched for examples of successful complete or green street projects, case studies, and recommendations for how to evaluate the costs, benefits, and life-cycle estimates of GCS design. We found that many treatments for green and complete streets can be relatively inexpensive and may equal the cost of traditional infrastructure. This is not to mention added benefits for maintenance, health, and safety. For example, painting a more visible crosswalk using a different pattern, color, or type of paint will cost ostensibly the same as a conventional pattern, while having the added benefit of increasing the visibility of pedestrians, slowing cars, creating a sense of place, and making the way safer for all. Another inexpensive option to slow traffic and introduce "greening" could also be to add a painted corner bump-out with a planter box or cement planter barrel at intersections (MassDevelopment 2022).

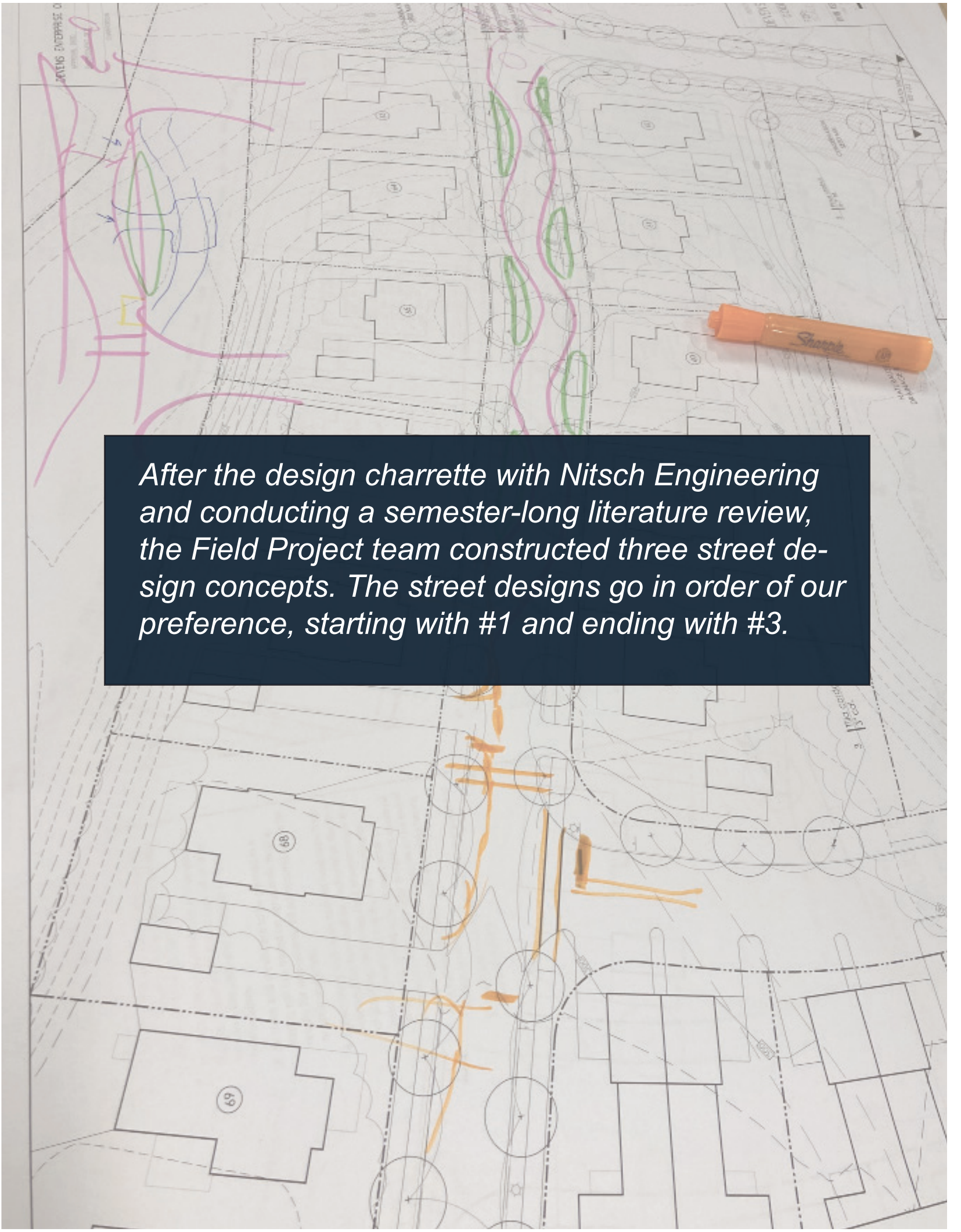
Since green and complete streets is an emerging concept, the literature lacks many standardized approaches, and there is limited information about best practices to quantify environmental and social benefits which may serve to mitigate the perceived expenses of LID and GI design (Paul 2001; US EPA, R. 13.004 2013). To address this deficit and visualize a cost comparison mechanism to differentiate between conventional and green and complete design treatments, the Devens Field Project team created a green and complete streets "menu of options" that shows different street components for the Goddard Street design. The menu of options explores a preliminary estimate of the cost, material, and benefits of each GCS component. Nitsch Engineering will provide a final cost comparison, which will evaluate the cost of building the final design for Goddard Street, which can be compared to the cost of building the plans proposed in the permit set.

MENU OF OPTIONS CHART

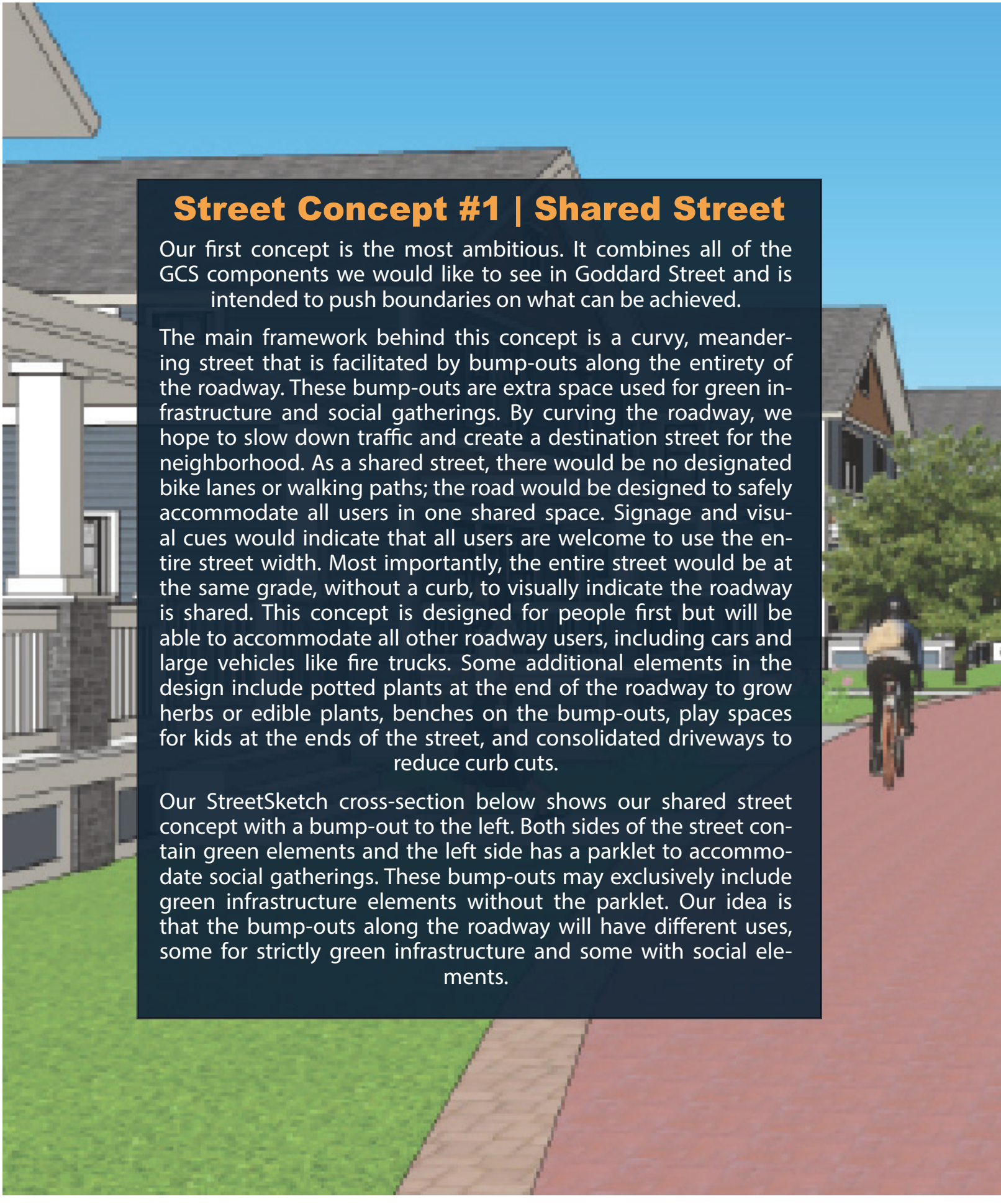
Component	Avg. price ($ Low $$ Medium $$$ High)	Exact Price (Thousands USD)	Material	Green	Place making	Slows Traffic
Green bump-outs/Chicanes	$ to $$	2-26	Concrete or granite curb			
Parklets	$ to $$	2-26	Concrete, pavers, or porous pave-ment			
Raised cross-walks	$ to $$	5-30	Pavers			
Shared street	$	--	Porous pavement or asphalt			
Play street	$ to $$	--	Paver or solar roadway			
Mini round-about	$$$	150	Concrete or granite curb			
Raised planter	$	--	Clay			
Bicycle Racks	$	.06-3.6	Metal			
Solar Street	$$$	--	Solar roadway material			
Consolidated driveways	--	--	Proposed ma-terial or solar roadway			
Raised Inter-section	$$ to $$$	12.5-115	Pavers			
Bench	$	.2-6	Metal			

Table 2. Menu of options for complete and green street elements including cost and materials (Source: Devens Field Team)

Street Design + Visuals



After the design charrette with Nitsch Engineering and conducting a semester-long literature review, the Field Project team constructed three street design concepts. The street designs go in order of our preference, starting with #1 and ending with #3.



Street Concept #1 | Shared Street

Our first concept is the most ambitious. It combines all of the GCS components we would like to see in Goddard Street and is intended to push boundaries on what can be achieved.

The main framework behind this concept is a curvy, meandering street that is facilitated by bump-outs along the entirety of the roadway. These bump-outs are extra space used for green infrastructure and social gatherings. By curving the roadway, we hope to slow down traffic and create a destination street for the neighborhood. As a shared street, there would be no designated bike lanes or walking paths; the road would be designed to safely accommodate all users in one shared space. Signage and visual cues would indicate that all users are welcome to use the entire street width. Most importantly, the entire street would be at the same grade, without a curb, to visually indicate the roadway is shared. This concept is designed for people first but will be able to accommodate all other roadway users, including cars and large vehicles like fire trucks. Some additional elements in the design include potted plants at the end of the roadway to grow herbs or edible plants, benches on the bump-outs, play spaces for kids at the ends of the street, and consolidated driveways to reduce curb cuts.

Our StreetSketch cross-section below shows our shared street concept with a bump-out to the left. Both sides of the street contain green elements and the left side has a parklet to accommodate social gatherings. These bump-outs may exclusively include green infrastructure elements without the parklet. Our idea is that the bump-outs along the roadway will have different uses, some for strictly green infrastructure and some with social elements.

Figure 20. Plan-view for street concept #1. The green sections indicate green infrastructure/bump-outs. The grey sections indicate a yielding space for vehicles (Source: Devens Field Team)

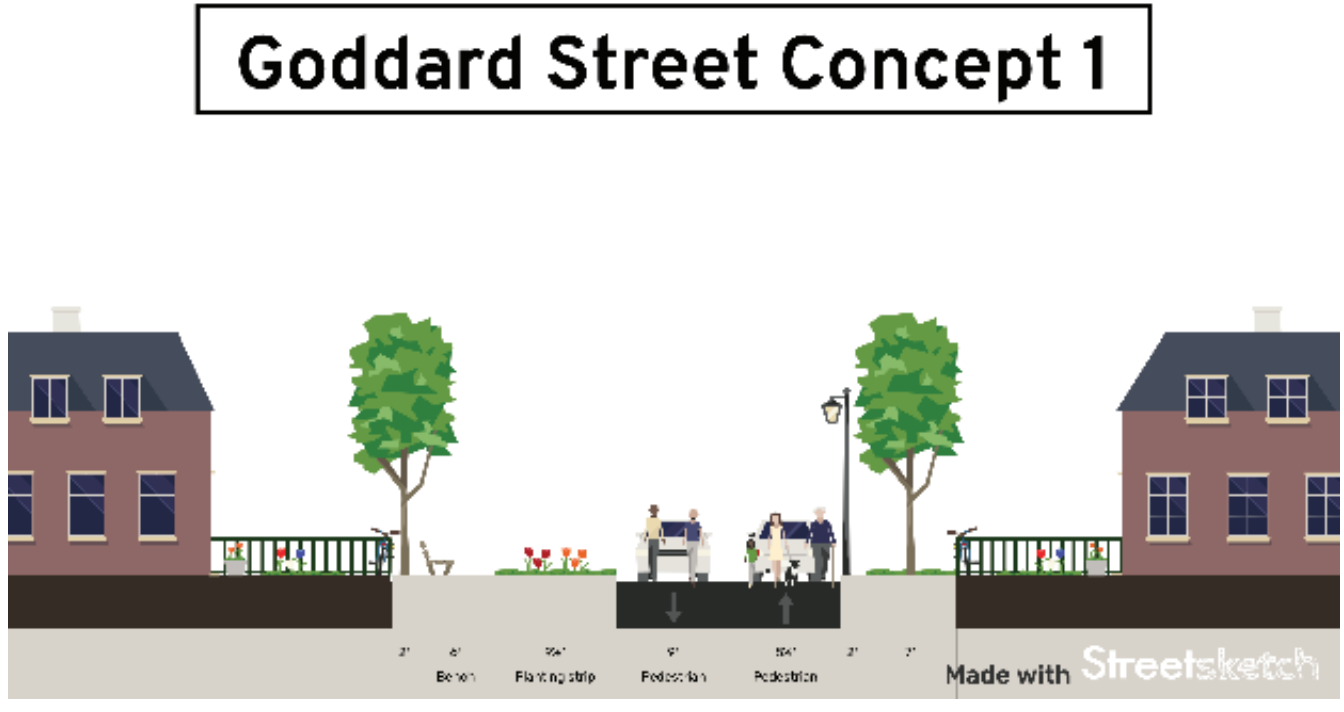
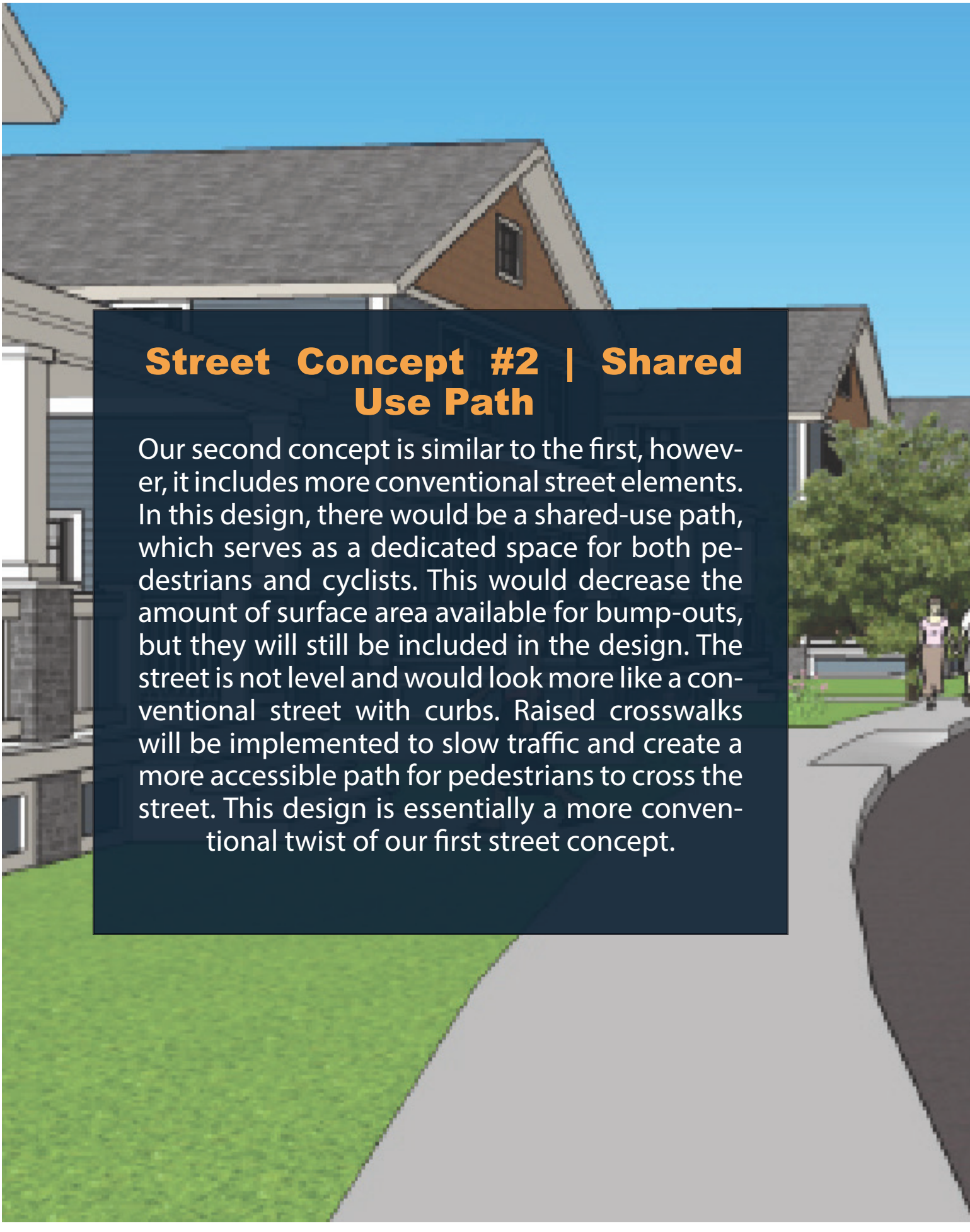


Figure 21. Cross-section view for street concept #1. The green sections indicate green infrastructure/bump-outs. The grey sections indicate a yielding space for vehicles (Source: Devens Field Team)

Figure 22. Eye-level rendering of street concept #1. Design elements presented include shared street/yield zone, green bump-out/chicane, raised planters and parklet (Source: Devens Field Team).



Street Concept #2 | Shared Use Path

Our second concept is similar to the first, however, it includes more conventional street elements. In this design, there would be a shared-use path, which serves as a dedicated space for both pedestrians and cyclists. This would decrease the amount of surface area available for bump-outs, but they will still be included in the design. The street is not level and would look more like a conventional street with curbs. Raised crosswalks will be implemented to slow traffic and create a more accessible path for pedestrians to cross the street. This design is essentially a more conventional twist of our first street concept.

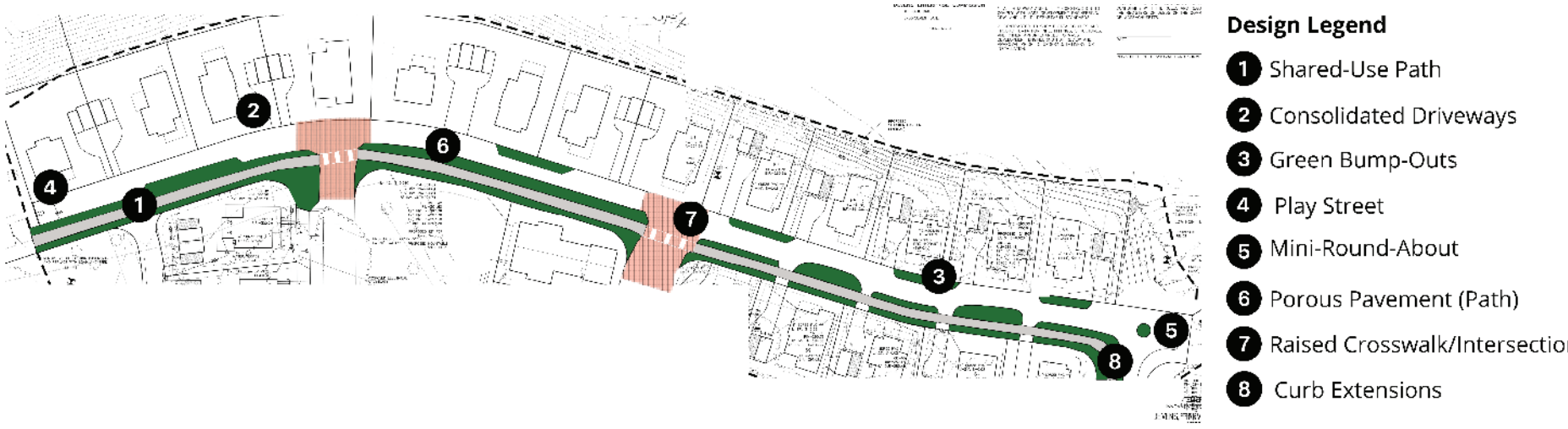


Figure 23. Plan-view for street concept #2. Includes a separated shared-use path for pedestrians and raised intersections (Source: Devens Field Team).

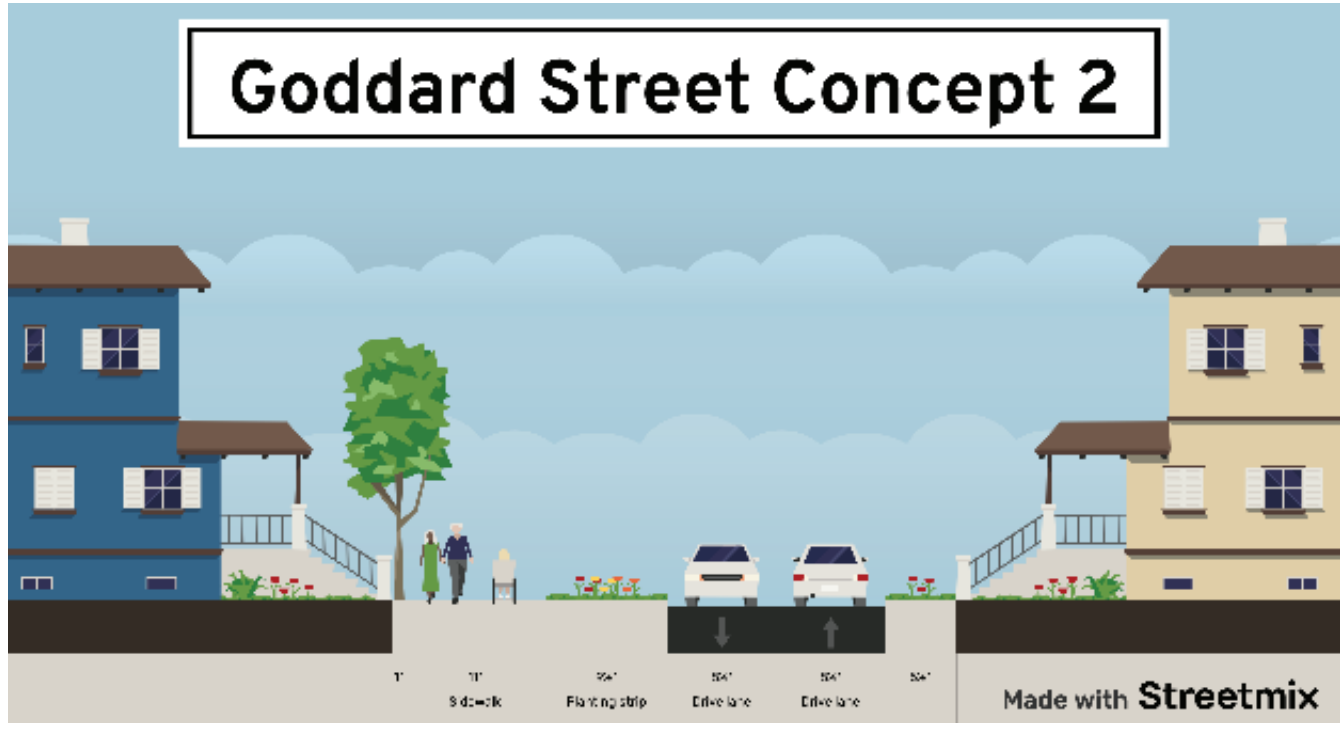
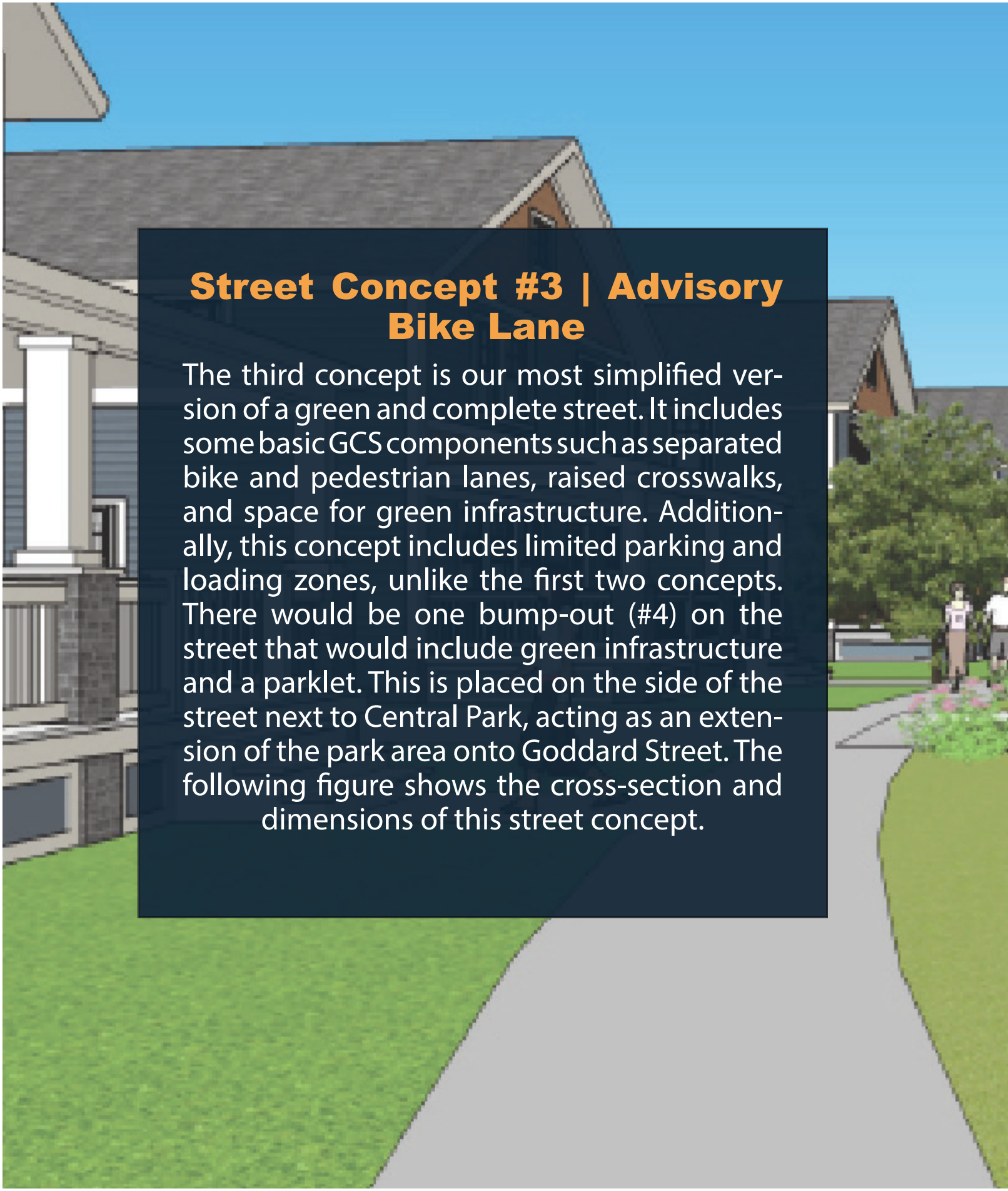


Figure 24. Cross-section view of street concept #2 (Source: Devens Field Team).

Figure 25. Eye-level rendering of street concept #2. Design elements presented include a shared-use path an green bump-outs (Source: Devens Field Team).



Street Concept #3 | Advisory Bike Lane

The third concept is our most simplified version of a green and complete street. It includes some basic GCS components such as separated bike and pedestrian lanes, raised crosswalks, and space for green infrastructure. Additionally, this concept includes limited parking and loading zones, unlike the first two concepts. There would be one bump-out (#4) on the street that would include green infrastructure and a parklet. This is placed on the side of the street next to Central Park, acting as an extension of the park area onto Goddard Street. The following figure shows the cross-section and dimensions of this street concept.

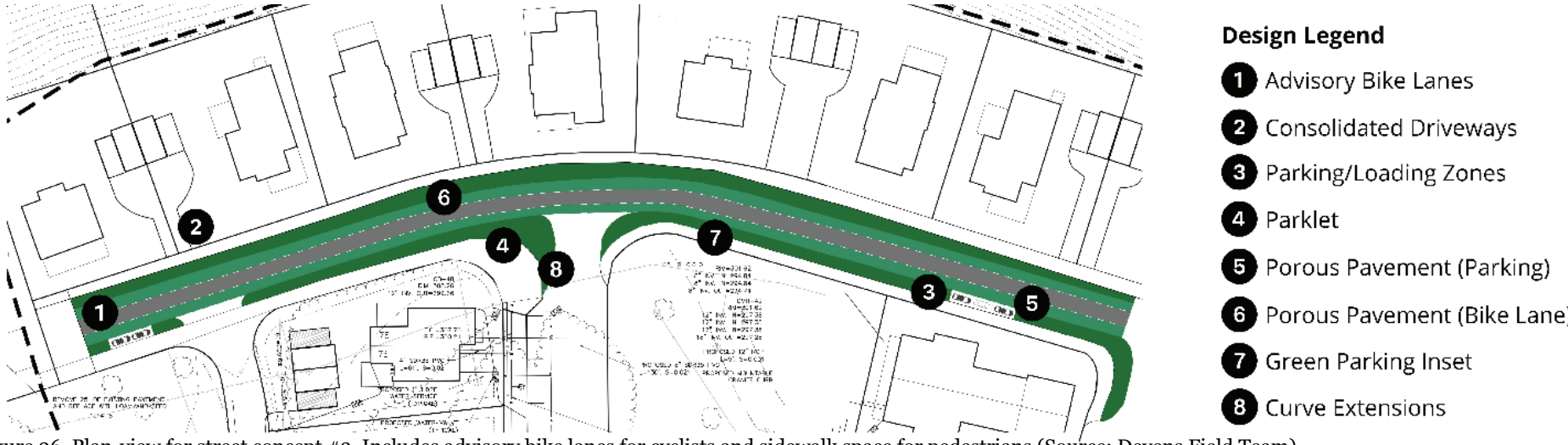


Figure 26. Plan-view for street concept #3. Includes advisory bike lanes for cyclists and sidewalk space for pedestrians (Source: Devens Field Team).

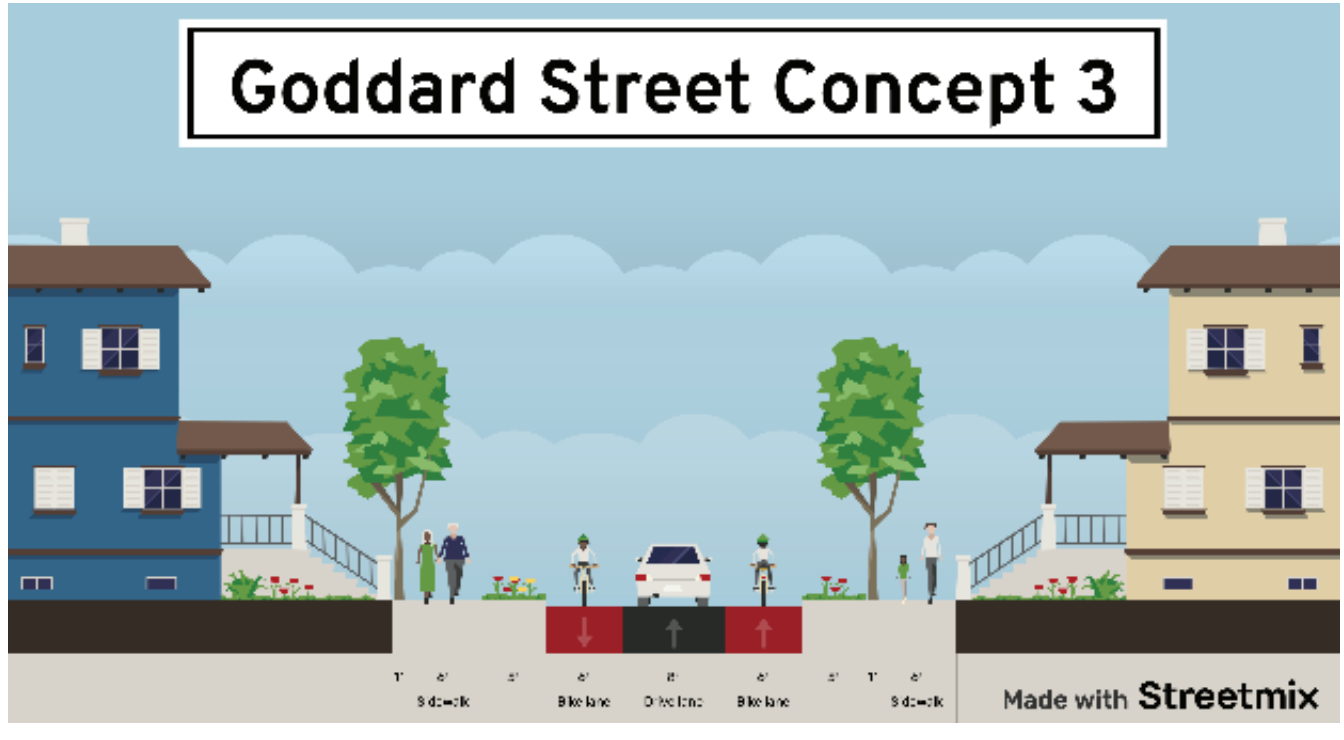


Figure 27. Cross-section view of street concept #3 (Source: Devens Field Team).

Figure 28. Eye-level rendering of street concept #3. Design elements presented include advisory bike lanes and green infrastructure (Source: Devens Field Team).

Recomendations + Key Takeaways

Recommendations/Key Takeaways

Our recommendations are in two parts. First, we have recommendations that apply specifically to the future of our project in Devens. Second, we have general recommendations for implementing green and complete streets in any neighborhood or city, including retrofits.

Goddard Street Recommendations

Street Design

The Tufts UEP team recommends the implementation of concept #1 on Goddard Street. We believe this design includes the most valuable green and complete streets elements that will improve livability in this neighborhood and best achieves the stated vision and purpose of Devens' Green and Complete Streets Policy. However, we have also received useful feedback from the Emerson Green planner and architect, Don Powers, that guided our two alternate designs. These designs are intended to provide alternate options that address home value, maintenance, and other hesitations.

Community Engagement

Since the design and implementation of Goddard Street will occur before residents move in, this project was not able to directly engage with the residents. Once construction is complete and all residents have moved in, however, we recommend surveying the residents on their perception and utilization of Goddard Street. A survey from the residents would help guide future projects in the Emerson Green community and Devens as a whole. Additionally, data from abutting residents can be useful in convincing others to pursue similar green and complete streets projects in different communities.

Construction Funding

The MassDOT Complete Streets funding program provides guidance and construction funding (up to $400,000) to municipalities in the Commonwealth of Massachusetts to encourage a policy-based approach to building safe, reliable, and interconnected transportation systems. Following our attendance of the MassDOT Complete Streets Funding Program training, we recommend that the Devens Enterprise Commission submit their August 2021 Devens Green & Complete Streets policy to MassDOT to complement or replace the 2017 Complete Streets policy on record (Tier 1). After submissing the updated policy, the DEC is advised to update the Prioritization Plan (Tier 2). MassDOT training facilitators recommended that the best path toward approval to fund Tier 3 construction projects would be to update and indicate progress on the municipality's prioritization plan. Finally, since we have passed both the April 1 timeline for prioritization plan updates and the May 1 deadline for the Tier 3 funding application, we recommend focusing on the October 1 deadline or Round 2 of FY2023 funding. For detailed steps to apply for FY23 funding, see Appendix E.

High Level Recommendations for GCS Projects

When implementing or designing a green and complete street, there are some general recommendations we think should be considered. These five high-level recommendations cover what we believe to be the most important aspects of a green and complete street project: green infrastructure, accessibility, affordability, community, and context.

1. Maximize Green Infrastructure: Key to the "green" in green and complete streets, we suggest maximizing green infrastructure due to the large number of benefits it brings. By implementing green infrastructure, a street can naturally cleanse stormwater and reduce flooding (R. 03 US EPA 2015). Additionally, it can reduce the urban heat island effect, stormwater run-off speed, and urban noise, and assist in improving quality of life (Rodriguez-Valencia 2021).

2. Ensure Accessibility for All Users: Key to the "complete" in green and complete streets, accessibility for all users must be kept in mind throughout the design process. A street is not complete if certain people are unable to use it safely. The benefits of an accessible and complete street include safety, increased opportunity for activities such as walking and biking, increased equity among users, local connectivity, and decreases in carbon emissions (Zaccaro & Atherton 2018) (Prytherch 2021) (Marcus 2019).

3. Maintain Affordability for Residents: Green and complete streets designs need to benefit residents in all types of communities – urban, suburban, and rural – and among diverse populations. The goal of a green and complete streets policy is to improve people's lives and contribute to the well-being of

Figure 29. Diagram of recommendations for implementation of green and complete streets (Source: Devens Field Team).

communities and their natural environments. We can explicitly recognize that desirability to live within a walkable, safe, green and complete street may increase property values for owners, taxes revenues for governments, and housing costs for renters. Improving the lives of residents and neighbors must include ensuring they can stay in their homes and benefit from green and complete streets nearby. Policies for affordable housing requirements for developers and consideration of alternative forms of homeownership will allow green and complete streets to be drivers of transportation and housing equity as well as community and environmental care.

4. Engage and Educate the Community: When possible, it is best practice to receive input from the community on the design and implementation of a green and complete street. As users of this street, their input will pave the way for a more successful and community-friendly design. Additionally, educating the community on green and complete streets provides meaningful interaction on why our community members should care about these roadways and what benefits they will gain from having a green and complete street in their neighborhood.

5. Consider Location and Context of Street: Is your street urban, suburban, or rural? Is your street flat or at a gradient? Who lives on or near this street? What modes of transportation will be using this street? What is the climate and weather like in your area? What is the natural flora and fauna of your area? Questions like these are important to ask when designing a green and complete street. The answers to these questions, and others that specifically address your local context, will guide how to design the best street for your neighborhood community.

Along with these, informational guidebooks can be used to foster the engagement process. When creating guidebooks, it's essential to use contextual information about a project's community to explain each com-

ponent's implementation. Guidebooks should also demonstrate successful implementation of green and complete streets projects, providing visuals.

Creating a green and complete street guidebook for your city or town can provide educational and informational materials directly to the community. This can help increase education on green and complete streets and hopefully lead to the implementation of more green and complete streets in your community.

Recommendations for Retrofits

Our project worked on an undeveloped and new street. However, existing streets can also be retrofitted to be green and complete. Through our literature review and lessons learned from the project process, we have recommendations for municipalities considering a retrofit. Three key considerations include community engagement, equity, and education.

It is essential to empower the community when retrofitting, especially historically underrepresented roadway users, as well as marginalized and vulnerable populations. Adopting a people-centered approach demonstrates the good intentions accompanying the retrofit and the support available to residents of the community. Some engagement tips are the following:

- Understand the community you are working in and use multiple media types and languages to disseminate information.
- Speak to the community on their level, and explain why retrofitting is important and how they can get involved.
- Allow people to ask questions and have examples of demonstration projects on hand for people to see and feel what the project may look like.
- Interview residents and conduct surveys.
- Ensure residents that their voices are being heard and their input is valuable and will be considered. Listen to understand the perspective and the diversity of lived experiences your community holds.
- Provide opportunities for residents to understand the process and changes to come. To the greatest extent possible, involve residents in the design process early on and throughout. Demonstrate how feedback was incorporated into updated street designs.

A common challenge in community engagement is that holding a public meeting is often not the best way of engaging the community (How to Involve Residents in Retrofitting 2021). This is because attendees often do not represent the diversity of the affected community and often it's the "loudest voices" that speak up, which leaves other prospective unheard. A solution is to have "drop-in days" where the design team is available to the community. People have the opportunity to speak with the experts and to learn from them, allowing for better understanding and for concerns to be expressed.

Conclusion

Broader Implications / Limitations

This project's scope has provided a distinctive perspective on how planning decisions are considered and implemented. Devens operates in a unique context where planners and site developers are open to implementing innovative designs to ensure that Devens serves as a green and sustainable development model. However, some particular elements of this project are unique to Devens that may not directly translate to other developments.

This project involves designing a street from the "ground up" in a completely new development. This has provided the opportunity to propose the most forward-thinking green and complete street design elements based on international designs. However, we recognize that the setting of this project is not the norm, and a considerable number of green and complete street projects will be centered on the conversion of existing streets and communities. In addition, Devens Enterprise Commission and NOW Communities have expressed excitement at the possibility of green and complete streets elements being implemented on Goddard Street. However, the same might not be said for other developers and municipalities, which may not have the knowledge or interest in adopting these policies.

Given that the residents and users of Goddard Street have not yet moved into homes in the development, community engagement considerations have not played a significant role in this project. In existing communities, a dedicated community engagement process will need to be implemented to understand residents' priorities and be sensitive to the context of each specific community. Frequent community engagement should be a key component for any planner interested in retrofitting a street using green and complete streets policy. We recommend using charettes and public outreach to inform the community and get their input during each stage of the designing process. In addition, equity should be an essential factor during the public outreach process, taking into consideration the following aspect: time, day, and location of meetings, languages used in printed materials and live events, hosting information sessions in "non-traditional" community spaces frequented communities who are often underrepresented in the public outreach process.

Areas for Further Inquiry

Green and complete streets policies and implementation have the potential to reshape how we design for and interact with our natural and built environments. More inquiry into social justice and equity outcomes of green and complete streets design and construction would help in understanding what populations benefit from these policies and who is left out. Additionally, as this street typology becomes more common, further exploration will be needed to understand the impact of project costs as designs become more standardized.

Within the scope of this project, the Devens Field Project team did not refine our designs past a conceptual level. Nitsch Engineering will provide the final design for the roadway, which is soon-to-be constructed.

Final Thoughts

It's time to reimagine our roadways. For far too long, roads have served only automobiles, designed exclusively for vehicle throughput and speed. Planners have created roads that have bisected neighborhoods, made communities inaccessible without a car, and worse, created roads with conditions so extreme that injuries and fatalities for vulnerable roadway users are not uncommon. But we also know roads can be joyful, community-oriented, green spaces, and this report has presented countless examples of such roadways throughout the United States and throughout the world. We are confident, that by advancing the concept designs presented in this report, Devens can join a growing movement of communities transforming its residential roadways to be more sustainable and people-focused.

As a leader in sustainable redevelopment and as one of the first communities in Massachusetts to implement a green and complete streets policy, Devens is uniquely positioned to be among

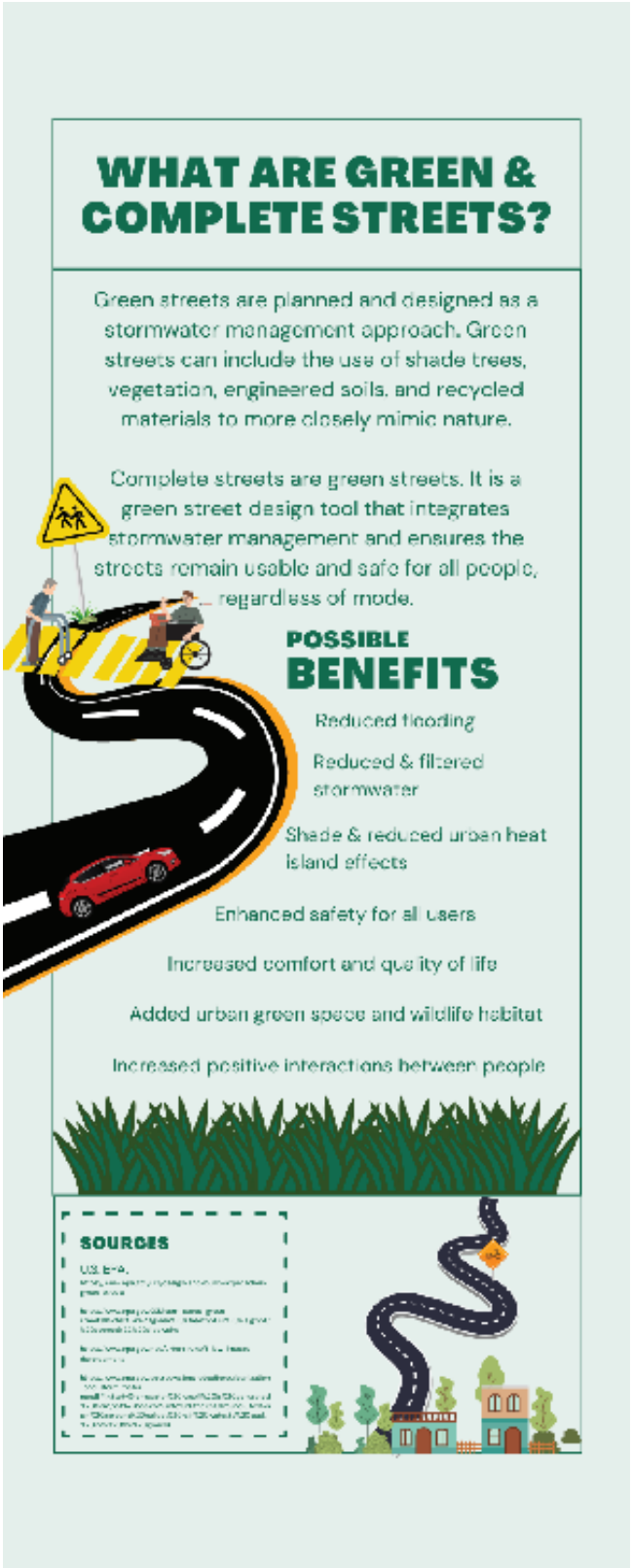
the first movers in implementing this new street typology. But, green and complete streets can and should expand beyond Devens. Using Goddard Street as an example, other communities can apply the design best practices learned in Devens to streets in their own neighborhoods, both existing and soon-to-be-built.

This report aims to provide guidance on how to inform and work with key stakeholder groups such as developers and their engineers, public works directors, and the general public about the implementation of best practices and the benefits of constructing green and complete streets. We hope these materials inspire readers to ask if their town or city has a plan to meet the safety and environmental needs of all users of their roadways.

Together, we can reimagine our roadways to be safe, accessible, equitable, and sustainable places to be, one bioswale and one chicane at a time.

Appendix

Appendix A: Example Stakeholder Handouts




THE THREE PRINCIPLES OF GREEN STREETS
Complete Streets
Designed and operated to enable safe use and support mobility for all users, creating comfortable access. Common characteristics include bike lanes, pedestrian crossings, and traffic calming elements.
Benefits can include decreased car dependence, increased safety, improved traffic flow, increased physical activity and improved health.
Green Infrastructure
Natural systems that are installed in a community or city that help treat stormwater runoff. It often uses vegetation, engineered soil, and permeable surfaces to capture and clean stormwater before infiltrating into the ground or discharging to other watercourses
Benefits can include reduced flooding, reduced waste water pumping and treatment costs, and added urban green space.
Placemaking
Generating a strong sense of place is known as placemaking. It is about strengthening the connection between people and the places they share.
Benefits can include increased positive interactions between people, increased sense of inclusion and belonging, and increased comfort and quality of life.

Appendix B: MassDOT Complete Streets Funding Program: Devens

Introduction

The goal of the Complete Streets funding program is to provide information and construction funding to municipalities in the Commonwealth of Massachusetts to encourage a policy-based approach to building safe, reliable, and interconnected transportation systems at the neighborhood level. Through a well-connected, and well-thought-out planning and policy cities and towns can slow traffic speeds, increase demand for multi-modal forms of transportation, and create human-friendly, desirable places to live. The program considers all community types – urban, suburban, rural – for eligibility and an in need of complete streets treatments. To be considered for program funding the municipality must pass a Complete Streets policy at the highest level of its government.

Start & Access Application

All application materials are to be submitted through the Massachusetts Complete Streets Program Portal, and the most current versions can be found on the portal: https://gis.massdot.state.ma.us/CompleteStreets/Account/Login. Only one account is allowed per municipality.

- We know Devens is already registered, since information in MassDOT map indicates that DEC had its Prioritization Plan approved in 2018. If you have any issues logging in, you can contact completestreetsprogram@state.ma.us.

This is a good starting place: https://gis.massdot.state.ma.us/completestreets. Skim the page and click around. Under Resources, find and click the link for Program Forms and Resources. The list of links to follow will give good sense of what steps will be needed, and what templates you will use to move forward with the application.

Summary of actions needed

There are three (3) Tiers of the Complete Streets Funding Program application process. Devens is on Tier 3, ready to proceed with an application for approval of one of the projects from your prioritization plan (Tier 2).

Below are the step required to proceed through each tier with actions needed, funding available, DEC status and timelines. It will be followed by brief recommendations for DEC to apply for funding in FY23.

- Tier 1 – Training & Complete Streets Policy Development
    - Actions: Attend Complete Streets 201; Passing of Complete Streets policy; Submit Complete Streets Policy; Submit letter of intent to become a complete streets eligible municipality to MassDOT.
    - Program Funding: No funding available; intent letter qualifies municipality for Tier 2 funding.
    - Status: DEC completed this step in May 2017. You can move onto Tier 2. However, since passage of the green and complete streets policy in 2021, you might consider resubmitting as a commitment beyond the complete streets policy MassDOT has on record. Although it is not required to proceed to Tier 2, since your complete streets application has already been accepted.
    - Timeline: Rolling
- Tier 2 – Complete Streets Prioritization & Plan Development
    - Actions: Submit Complete Streets Prioritization plan to MassDOT
    - Program Funding: up to $38,000 for technical assistance and creation of policy; granted only one time per municipality.
    - Status: DEC completed this step in September 2018 but will want to update the Tier 2 Prioritization Plan to reflect current project plans. **Devens 2018 Prioritization Plan for editing**
    - Timeline: due April 1 or September 1

- Tier 3 – Project approval & Notice to Proceed
  - Actions: Submit Tier 3 Application for FY2023: **Tier 3 Application Forms**
    - Application form (Excel)
    - Project narrative, scope of project (Word)
    - Project estimate (Excel)
    - Environmental Punchlist (PDF)
  - Program Funding: Up to $400,000 every four fiscal years, rolling.
  - Status: Devens is currently on the list as Eligible for FY 2023 funding ($400,000).
    - https://gis.massdot.state.ma.us/CompleteStreets/Content/Docs/FY23R1%20Tier%203%20Funding%20Eligibility.pdf
  - Timeline: May 1 – Notice to proceed August; October 1 – Notice to proceed February

After receiving a notice to proceed the project construction can begin. All funding is received through reimbursement after construction has begun (reimbursement forms: https://www.mass.gov/lists/chapter-90-forms). Reimbursement requests can be made before construction is complete, at half-way points for example in order to pay of expenses that have already accrued.

Once construction is complete a Post Construction Report is required: https://forms.office.com/Pages/ResponsePage.aspx?id=Fh2GPrdIDkqYBowE2Bt7Km3N_VvsUZpArYQEkNZsFdJUQzJVS1k0MjIxSUdSTVQ0QVBFNDBQUkdJOS4u

Before and After photos are encouraged.

Recommendations

We recommend submitting the August 2021 Devens Green & Complete Streets policy to MassDOT to complement or replace the 2017 Complete Streets policy they have on record (Tier 1). The next step will be to update the Tier 2, Prioritization Plan. The facilitator of the training suggested that a good way to help ensure approval to fund Tier 3 construction projects is to update and indicate progress on your prioritization plan. Finally, since we are past the April 1 timeline for prioritization plan and the May 1 deadline for the Tier 3 funding application, we recommend focusing on the October 1 deadline or Round 2 of FY2023 funding.

Resources

Design Guides: https://nacto.org/; https://ruraldesignguide.com/

CSFP Guide: https://www.mass.gov/files/documents/2018/08/13/FundingProgramGuidance.pdf

MassDOT Map: https://gis.massdot.state.ma.us/completestreets/Map/

Complete Streets Training folder: https://tufts.box.com/s/p2cy4zegydadhtm7pkbg7wkg6lozubng

Appendix C: List of Resources

List of Resources

Design and Build Approaches for Green Streets

Green Infrastructure Design and Implementation

Design and Implementation Documents

The Real Cost of Green Infrastructure and Cost Reduction Strategies

Streetmix Tool

Urban, Rural and Suburban Complete Streets Design Manual

NACTO Urban Street Design Guide

Health Impact Assessment & EnviroAtlas

Street Design Guide: City of Minneapolis

Imagining Livability Design Collection: Short-Term, Mid-Range & Long-Range Projects, Planning & Policies

Triple Bottom-Line Benefits of Street Trees in Devens

Stormwater Maintenance

Guidebooks / Toolkits / Case studies

Green Infrastructure Toolkit

Green Streets Guidebook: Holyoke, MA

Green Infrastructure Guidelines for Devens Projects

Complete & Green Streets For All

Low-Impact Development Techniques for Stormwater Management at Devens

Protected Bike Lanes in NYC

Regional Workbook for Complete Streets

Rural Complete Streets: Toronto Centre for Active Transportation

Quick Fact Sheet: How Much Are Incomplete Streets Costing Your Community?

U.S. Traffic Calming Manual by Reid Ewing and Steven J. Brown. 2009, American Planning Association Planners Press

Appendix D: Green & Complete Streets Guidebook for General Public

PREPARED BY

Devens Field Project Team
Tufts University 2022

ACKNOWLEDGEMENTS

The Devens Field Project Team would like to thank the many people who contributed their time, effort, and resources to this project.

First, we would like to thank our project partners, the Devens Enterprise Commission, who brought this project to life. We are extremely grateful for the vision, guidance, and feedback that Peter Lowitt and Neil Angus provided us with throughout the process.

We would also like to extend our thanks to Nitsch Engineering, Devens Department of Public Works, and the Tufts UEP Teaching team.

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Policy and Planning

DEVENS
ENTERPRISE • COMMISSION

How to Use the Guidebook

- This Green and Complete Streets (GCS) Guidebook was made for the **general public**.
- It is a one-stop resource for a quick explanation of green and complete streets and their benefits.
- It includes **frequently asked questions** and addresses common concerns of street users.
- **Examples** are provided to visually demonstrate common components of GCS and successful implementation.
- A **Tools & Resources** section lists information where help can be found on a wide range of topics related to GCS.

TABLE OF CONTENTS

INTRODUCTION

What are Green and Complete Streets?

By design and function, roads and sidewalks are important infrastructure elements. The Federal Highway Administration estimates that more than 20% of U.S. roads are in urban areas, and that roads, sidewalks, and parking lots are estimated to make up almost two-thirds of the total impervious cover, contributing a similar ratio of runoff (Lukes & Kloss 2008). Effective road drainage and stormwater management systems have been overlooked, which is why green infrastructure is being utilized to mitigate stormwater runoff. Effective road design and drainage makes communities more resilient to climate change.

Stormwater management is an important management technique as it reduces the amount of runoff and runoff pollution. Stormwater runoff is generated from rain and snowmelt and often contains harmful pollutants. Green infrastructure has technologies and approaches to best manage runoff, through infiltration, evapotranspiration, and by capturing and reusing stormwater to maintain or restore natural hydrologies (US EPA OMS 2015). Stormwater management is an opportunity to prevent pollution at its source and an element to tackle in building sustainable, resilient municipalities and communities.

Roads present many opportunities for green infrastructure application. One principle of green infrastructure is green streets. Green streets are planned and designed to manage stormwater onsite, whereas traditional street design practices manage stormwater through sewer and pipe systems (R. 03 US EPA 2015). **Green streets** incorporate green infrastructure (GI) which are natural systems that are installed in a community or city to help treat stormwater runoff ("What is green infrastructure?" 2022). GI often uses vegetation, engineered soil, and permeable surfaces to capture and clean stormwater before infiltrating into the ground or discharging to other watercourses. Benefits can include reduced flooding, reduced waste water pumping and treatment costs, and added urban green space. GI also improves air quality through the reduction in particulate matter and other smog pollutants- an important factor for all, especially people with respiratory illnesses. The design and appearance of green streets will vary, but the goals are the same: manage stormwater and provide environmentally enhanced roads.

Complete streets seek to shift the focus of a traditional auto-centric street design to one that designs the street for the safety and accessibility of all roadway users, regardless of their mode of travel, age, or ability (Active Transportation Alliance 2014). Complete streets provide the benefit of enhanced safety, along with the improvement of public health by providing safe and accessible places for more active modes of transportation and recreation, increasing physical activity (Zaccaro & Atherton 2018). Complete streets can also improve equity and be an economic driver (Prytherch 2021), can increase local connectivity (Marcus 2019), and can encourage mode shift, which can reduce congestion and reduce fuel usage, decreasing carbon emissions (Glazener & Khreis 2019).

Green and complete streets can generate a strong sense of place, known as placemaking. Placemaking is about strengthening the connection between people and the places they share ("What is placemaking?" 2007). Benefits can include increased positive interactions between people, increased sense of inclusion and belonging, and increased comfort and quality of life.

BENEFITS

Why should you care?

Green streets create aesthetically attractive streetscapes, connecting neighborhoods and creating unique community settings while managing stormwater and reducing erosion. Green streets introduce vegetation in urban environments, providing habitat for wildlife and insects. Complete streets create friendly streets, enhancing safety and inviting all to use the street. Together, green and complete streets are not only a climate resiliency strategy, but rather community enhancing elements providing health, social, economic, and environmental benefits. A community that has green and complete streets is one that can generate a strong sense of place.

Other Public Health Benefits:
Public health benefits are often associated with green spaces and nature as aspects of the living environment can affect the health and wellbeing of people (Van den Berg, Hartig & Staats 2007). Many studies suggest that being near nature is better for mental and physical health. It is shown to increase happiness, improve health, and foster more generous, creative, and compassionate people (Bentley 2016). Research on green spaces has also concluded that they may provide positive influences on social interactions, mitigate mental fatigue and reductions in violent and aggresive behavior. (Wolf 2010; Kuo & Sullivan 2001; Maas et al. 2009).

What are the direct benefits of having green and complete streets in your community?

- Reduced flooding
- Shade and reduced urban heat island effects*
- Increased bike, pedestrian and vehicular safety
- Decreased car dependence
- Increased physical activity and improved health
- Improved traffic flow and connected forms of transit
- Increased positive interactions between people
- Beautification
- Economic growth
- Improved quality of life

*Urban heat islands occur when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat. This effect increases energy costs (e.g., for air conditioning), air pollution levels, and heat-related illness and mortality (US EPA 2021).

FAQ

Are green and complete streets only for non-motorized transportation?

No, a GCS addresses the needs of all users of the transportation systems and balances those needs. Motor vehicles can use green and complete streets while traveling at low speeds.

Does a GCS mean all transportation modes on all roads?

No, it is about considering the people who want to use the transportation system and providing transportation choices that address those needs. It is a network and system approach that ensures the entire transportation system provides accessibility and mobility.

Do green and complete streets cause more traffic congestion?

No, on the contrary, one of the benefits of GCS is improved traffic flow as complete streets can ease congestion by allocating space for each mode of transportation.

What are some examples of complete streets improvements?

- Road diet; adding bicycle lanes, inserting a center turn lane, removing excess travel lanes.
- Increases safety for all users
- Reduces motor vehicle speeding
- Higher bicycle comfort and use
- Traffic calming; narrowing vehicular lanes, shortening curb radii.
- Slows traffic, increasing pedestrian safety
- Decreases crossing distance for pedestrians
- Pedestrian improvements; installation of sidewalks, crosswalks / raised crosswalks, curb ramps, curb extensions.
- Improves accessibility
- Increases visibility at crossings
- Curb extensions shorten crossing distance

FAQ

Why is the green and complete streets approach effective for communities?

Green and complete streets consider and accommodate for all user types. For many years, streets have been designed with the prioritization of speed and volume of movement, but GCS works for communities because it is not a one-size-fits-all approach, it is context sensitive. Green and complete streets are designed as an inclusive system that connects a network, improves safety, and addresses the transportation needs of all street users. Regardless of where you live, who you are, or how you need to travel, you will get to where you need to be in a safe, reliable, and affordable way.

What are some challenges that communities face when adopting a GCS model?

The biggest challenge is changing the system and challenging the status quo. Our built environment is predominantly auto-centric and is not reflective of the current and future demands for alternative and multi-modal transportation. There tends to be pushback as many engineers, architects, and developers are used to doing things one way and have not been given the tools and performance metrics to build something differently. Although pushback can be a common challenge, sometimes these professionals want to design something differently but internal factors that they have no control over limit their choices and decisions. Budget and political will are two challenges that can both be overcome through education, advocacy and training.

Pushback also commonly comes from public safety officials and public works officials who are unfamiliar with these approaches. They often think GCS components will cost more to maintain and are the cause of slow emergency response time, when in fact, the opposite is true. Green and complete streets make streets safer, regulate speed to reduce accidents, and have less buried infrastructure making them easier to maintain. GCS are also adaptable to more frequent and intense storm events, which reduces flooding and further improves road safety.

How can complete streets address communities of disinvestment?

The Complete Streets Coalition created elements of an ideal complete streets policy to set up policies and resolutions that translate into implementation and practice, prioritizing equity. The complete streets approach does not look at one street, but rather at the system to see where multimodal access is most needed and the location of where most disinvestment is occurring. It does this by asking questions such as 'Where are the places with most incomplete streets?' and 'What communities have historically received the least amount of investment?'.

successful

EXAMPLES

1,600+
Complete Streets Policy have been passed in the United States

Village of Great Neck Plaza, New York State: Great Neck Road

Green and Complete Streets Components: Changes to the travel lanes, turning restrictions, and pedestrian safety amenities like bulb-out sidewalks to reduce crossing distances and enhance the visibility of pedestrians, pedestrian countdown timers, higher visibility crosswalk markings and warning signs, wider pedestrian median refuges, and a two-foot safety zone between the travel lane and parked vehicles.

Hauppage to Port Jefferson, New York State: Route 347

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Green and Complete Streets Components: Corridor redesign improved pedestrian and bicycle infrastructure connections to bus routes and light rail, and helped to reconnect the neighborhood landuses.

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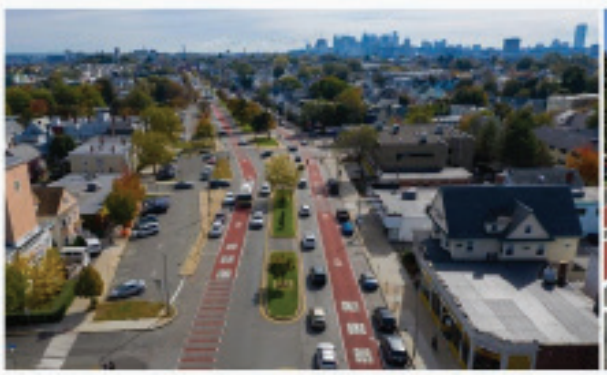

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North Fremont Street, City of Monterey, California

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- It is a one-stop resource for a quick explanation of green and complete streets and their benefits.
- It includes **frequently asked questions** and addresses common concerns of street users.
- **Examples** are provided to visually demonstrate common components of GCS and successful implementation.
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By design and function, roads and sidewalks are important infrastructure elements. The Federal Highway Administration estimates that more than 20% of U.S. roads are in urban areas, and that roads, sidewalks, and parking lots are estimated to make up almost two-thirds of the total impervious cover, contributing a similar ratio of runoff (Lukes & Kloss 2008). Effective road drainage and stormwater management systems have been overlooked, which is why green infrastructure is being utilized to mitigate stormwater runoff. Effective road design and drainage makes communities more resilient to climate change.

Stormwater management is an important management technique as it reduces the amount of runoff and runoff pollution. Stormwater runoff is generated from rain and snowmelt and often contains harmful pollutants. Green infrastructure has technologies and approaches to best manage runoff, through infiltration, evapotranspiration, and by capturing and reusing stormwater to maintain or restore natural hydrologies (US EPA OMS 2015). Stormwater management is an opportunity to prevent pollution at its source and an element to tackle in building sustainable, resilient municipalities and communities.

Roads present many opportunities for green infrastructure application. One principle of green infrastructure is green streets. Green streets are planned and designed to manage stormwater onsite, whereas traditional street design practices manage stormwater through sewer and pipe systems (R. 03 US EPA 2015). **Green streets** incorporate green infrastructure (GI) which are natural systems that are installed in a community or city to help treat stormwater runoff ("What is green infrastructure?" 2022). GI often uses vegetation, engineered soil, and permeable surfaces to capture and clean stormwater before infiltrating into the ground or discharging to other watercourses. Benefits can include reduced flooding, reduced waste water pumping and treatment costs, and added urban green space. GI also improves air quality through the reduction in particulate matter and other smog pollutants- an important factor for all, especially people with respiratory illnesses. The design and appearance of green streets will vary, but the goals are the same: manage stormwater and provide environmentally enhanced roads.

Complete streets seek to shift the focus of a traditional auto-centric street design to one that designs the street for the safety and accessibility of all roadway users, regardless of their mode of travel, age, or ability (Active Transportation Alliance 2014). Complete streets provide the benefit of enhanced safety, along with the improvement of public health by providing safe and accessible places for more active modes of transportation and recreation, increasing physical activity (Zaccaro & Atherton 2018). Complete streets can also improve equity and be an economic driver (Prytherch 2021), can increase local connectivity (Marcus 2019), and can encourage mode shift, which can reduce congestion and reduce fuel usage, decreasing carbon emissions (Glazener & Khreis 2019).

Green and complete streets can generate a strong sense of place, known as placemaking. Placemaking is about strengthening the connection between people and the places they share ("What is placemaking?" 2007). Benefits can include increased positive interactions between people, increased sense of inclusion and belonging, and increased comfort and quality of life.

BENEFITS

Why should developers and planners care?

Increase Home Value
GCS designs are proven to improve residential units' aesthetics and home values. Shared streets designs in the Netherlands and United Kingdom have been received favorably by residents, with 70% to 80% of residents reporting their streets as attractive or highly attractive after redesign (Collarte 2014). In the Netherlands, residential shared streets with GCS elements have 10% to 15% higher home values than residential non-shared streets (Appleyard and Cox 2006).

Mental/Physical Health
Incorporating nature into street designs can have direct health benefits. Being near nature is shown to improve mental and physical health. It increases happiness, improves health, and fosters more generous, creative, and compassionate people (Beatley 2016). Studies have also found higher rates of children engaged in play activities in shared streets compared to conventional streets (Biddulph 2012).

Accessibility
Accessibility increases when GCS elements are implemented, with notable improvements in ease of walking and higher levels of active participation by older residents (Curl, Ward Thompson, and Aspinall 2015). GCS that include even pavements and low or no curbs help improve older residents' activity levels (Ståhl, Horstmann, and Iwarsson 2013).

What are the direct benefits of having GCS in your community?

- Reduced flooding
- Shade and reduced urban heat island effects*
- Increased bike, pedestrian and vehicular safety
- Decreased car dependence
- Increased physical activity and improved health
- Improved traffic flow and connected forms of transit
- Increased positive interactions between people
- Beautification
- Economic growth
- Improved quality of life

*Urban heat islands occur when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat. This effect increases energy costs (e.g., for air conditioning), air pollution levels, and heat-related illness and mortality (US EPA 2022).

FAQ

Are GCS more costly than conventional streets?

While GCS is an emerging concept that currently lacks standardized approaches, some treatments can be implemented inexpensively and have a similar cost to conventional street treatments. Painting a more visible crosswalk and implementing "bump-outs" at intersections with planters can help slow down traffic and improve pedestrian visibility while adding a greening effect to the street. While some GCS treatments may have higher upfront costs than conventional treatments, the lower long-term maintenance cost and improved benefits in health and safety for residents can help offset the initial costs.

Does a GCS mean all transportation modes on all roads?

No, it is about considering the people who want to use the transportation system and providing transportation choices that address those needs. It is a network and system approach that ensures the entire transportation system provides accessibility and mobility.

Do GCS cause more traffic congestion?

No, on the contrary, one of the benefits of GCS is improved traffic flow as complete streets can ease congestion by allocating space for each mode of transportation.

What are some examples of complete streets improvements?

- Road diet; adding bicycle lanes, inserting a center turn lane, removing excess travel lanes.
- Increases safety for all users
- Reduces motor vehicle speeding
- Higher bicycle comfort and use
- Traffic calming; narrowing vehicular lanes, shortening curb radii.
- Slows traffic, increasing pedestrian safety
- Decreases crossing distance for pedestrians
- Pedestrian improvements; installation of sidewalks, crosswalks / raised crosswalks, curb ramps, curb extensions.
- Improves accessibility
- Increases visibility at crossings
- Curb extensions shorten crossing distance

FAQ

Why is the GCS approach effective for communities?

GCS considers and accommodates all user types. For many years, streets have been designed with the prioritization of speed and volume of movement, but GCS works for communities because it is not a one-size-fits-all approach, it is context sensitive. GCS are designed as an inclusive system that connects a network, improves safety, and addresses the transportation needs of all street users. Regardless of where you live, who you are, or how you need to travel, you will get to where you need to be in a safe, reliable, and affordable way.

What are some challenges that communities face when adopting a GCS model?

The biggest challenge is changing the system and challenging the status quo. Our built environment is predominantly auto-centric and is not reflective of the current and future demands for alternative and multi-modal transportation. There tends to be pushback as many engineers, architects, and developers are used to doing things one way and have not been given the tools and performance metrics to build something differently. Although pushback can be a common challenge, sometimes these professionals want to design something differently but internal factors that they have no control over limit their choices and decisions. Budget and political will are two challenges that can both be overcome through education, advocacy and training.

Pushback also commonly comes from public safety officials and public works officials who are unfamiliar with these approaches. They often think GCS components will cost more to maintain and are the cause of slow emergency response time, when in fact, the opposite is true. GCS make streets safer, regulate speed to reduce accidents, and have less buried infrastructure making them easier to maintain. GCS are also adaptable to more frequent and intense storm events, which reduces flooding and further improves road safety.

How can complete streets address communities of disinvestment?

The Complete Streets Coalition created elements of an ideal complete streets policy to set up policies and resolutions that translate into implementation and practice, prioritizing equity. The complete streets approach does not look at one street, but rather at the system to see where multimodal access is needed and the location of where most disinvestment is occurring. It does this by asking questions such as 'Where are the places with most incomplete streets?' and 'What communities have historically received the least amount of investment?'.

successful

EXAMPLES

1,600+
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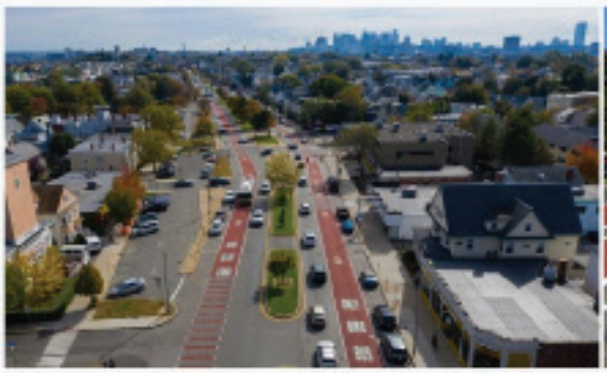

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Appendix F: Green & Complete Streets Guidebook for Public Works

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BENEFITS

Why should you care?

Improved Stormwater Management: Green streets create aesthetically attractive streetscapes, connecting neighborhoods and creating unique community settings while managing stormwater and reducing erosion. One of the greatest benefits of maintaining green spaces in developments and introducing porous spaces is their effectiveness for stormwater management. Green infrastructure reduces stormwater runoff, improves water runoff quality, and restores groundwater supplies (USDOT 2015). Porous asphalts offer particular advantages in colder climates by reducing the need for deicing salts, chemicals, and sand.

Other Maintenance Benefits: Porous pavements rarely require deicing chemicals. Though they may be used be used the amount of deicing chemicals will be significantly less than for impervious pavements (Palmer 2012). Municipal and public works staff may partner with residents and encourage them to adopt green spaces. The community stewards help maintain the adopted space, observe and help monitor water flows, and can attend to planters, community gardens, even adding perennials and native plants. This gives community members opportunity to relate to their natural environments and public works departments a chance to engage with residents about about community maintenance (Green Street Stewards n.d).

What are the Direct Operational Benefits of Having Green and Complete Streets?

- Reduced flooding
- Porous surfaces reduce labor needs for snow clearance
- Reduce or eliminate chemical or sand treatment for snow
- Extended life-cycle of porous paved roads, less frequent replacement and repair.*
- Lower impact construction and lower cost than gray infrastructure.
- Improve wet weather visibility
- Beautification, healthier work environment
- Opportunity to positively engage with residents, potential for Resident Community Stewards.

* Mainting long-term performance of porous asphalt pavements' stormwater management capabilities, surface infiltration rates should be inspected annually during rain events to observe any changes in effectiveness of infiltrating stormwater. University of New Hampshire has created a regular inspection and maintenance guide for porous pavements (UNHSC 2011).

FAQ

Do GCS require special equipment or specialized practices for snow removal and maintenance?

Some modification of snow removal and clean practices may be necessary, though they are neither specialized nor cost prohibitive. Plow as needed after storm events. Special plow blades should be used whenever possible to avoid scarifying the porous asphalt surface. Raised blade is not recommended. Sand should not be used on porous surfaces because it will eventually seep into the system causing it to clog. A clogged system will not work properly. In order to remove any solids and debris that could lead to more permanent clogging of the pavement, it is recommended that porous asphalt pavements be vacuumed at least two times a year or power-washed (UNHSC 2012; Palmer 2012).

How might GCS infrastructure affect maintenance access?

Using roads and right-of-ways as locations for green infrastructure alleviates access and maintenance concerns by using public space. GCS are built to be seen, easy to access and easy to maintain, since they can work with natural hydrology and consider movements of people throughout.

Do GCS cause more traffic congestion?

No, on the contrary, one of the benefits of GCS is improved traffic flow as complete streets can ease congestion by allocating space for each mode of transportation.

What are Some Examples of Complete Streets Improvements?

- Road diets: Add bicycle lanes, inserting a center turn lane, removing excess travel lanes.
- Reduce motor vehicle speeding
- Higher bicycle comfort and use
- Traffic calming: Narrow vehicular lanes, shortening curb radii.
- Decrease crossing distance for pedestrians.
- Improve accessibility
- Raised intersections increase visibility

FAQ

Why is the GCS approach effective for communities?

Green and complete streets consider and accommodate for all user types. For many years, streets have been designed with the prioritization of speed and volume of movement, but GCS works for communities because it is not a one-size-fits-all approach, it is context sensitive. Green and complete streets are designed as an inclusive system that connects a network, improves safety, and addresses the transportation needs of all street users. Regardless of where you live, who you are, or how you need to travel, you will get to where you need to be in a safe, reliable, and affordable way.

What are some challenges that communities face when adopting a GCS model?

The biggest challenge is changing the system and challenging the status quo. Our built environment is predominantly auto-centric and is not reflective of the current and future demands for alternative and multi-modal transportation. There tends to be pushback as many engineers, architects, and developers are used to doing things one way and have not been given the tools and performance metrics to build something differently. Although pushback can be a common challenge, sometimes these professionals want to design something differently but internal factors that they have no control over limit their choices and decisions. Budget and political will are two challenges that can both be overcome through education, advocacy and training.

Pushback also commonly comes from public safety officials and public works officials who are unfamiliar with these approaches. They often think GCS components will cost more to maintain and are the cause of slow emergency response time, when in fact, the opposite is true. Green and complete streets make streets safer, regulate speed to reduce accidents, and have less buried infrastructure making them easier to maintain. GCS are also adaptable to more frequent and intense storm events, which reduces flooding and further improves road safety.

How can complete streets address communities of disinvestment?

The Complete Streets Coalition created elements of an ideal complete streets policy to set up policies and resolutions that translate into implementation and practice, prioritizing equity. The complete streets approach does not look at one street, but rather at the system to see where multimodal access is most needed and the location of where most disinvestment is occurring. It does this by asking questions such as 'Where are the places with most incomplete streets?' and 'What communities have historically received the least amount of investment?'.

successful

EXAMPLES

1,600+
Complete Streets Policy have been passed in the United States

Village of Great Neck Plaza, New York State: Great Neck Road

Green and Complete Streets Components: Changes to the travel lanes, turning restrictions, and pedestrian safety amenities like bulb-out sidewalks to reduce crossing distances and enhance the visibility of pedestrians, pedestrian countdown timers, higher visibility crosswalk markings and warning signs, wider pedestrian median refuges, and a two-foot safety zone between the travel lane and parked vehicles.

Hauppage to Port Jefferson, New York State: Route 347

Green and Complete Streets Components: Traffic calming measures, such as narrower lane widths and lower speed limits, a continuous, 15-mile separate bicycle and shared-use pedestrian path, pedestrian refuge areas, a raised, planted median, high-visibility crosswalks, and pedestrian countdown timers. Transit facility improvements, such as bus stops and solar lighting at new bus shelters

successful

EXAMPLES

Charlotte, North Carolina: East Boulevard

Green and Complete Streets Components: Corridor redesign improved pedestrian and bicycle infrastructure connections to bus routes and light rail, and helped to reconnect the neighborhood landuses.

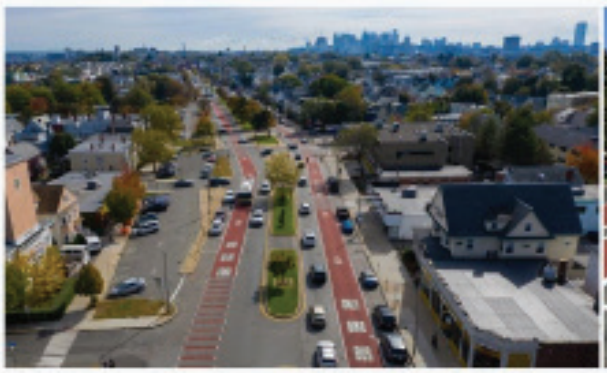
New York City, New York: 9th Avenue

Green and Complete Streets Components: Reduced travel lanes (lane removal and narrowing), protected bike bath, crosswalks, traffic lights / turn signals, and street trees.

successful

EXAMPLES: URBAN AREAS

Broadway Street in Somerville, MA



Green and Complete Streets Components: Bus/bike only lane, safety zone between bus lane & bike lane, crosswalks, signage, green corridor and street trees.

North Fremont Street, City of Monterey, California

Green and Complete Streets Components: Protected bike lanes, bicycle signals are coordinated with traffic signals, crossbikes/crosswalks, and higher curb between street and bike facility.

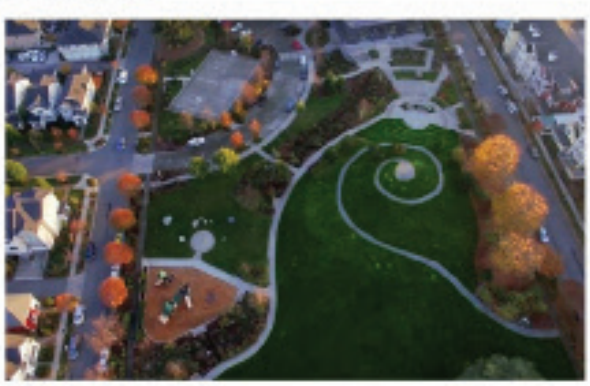
successful

EXAMPLES: SUBURBAN AREAS

North Avenue in Wauwatosa, just outside Milwaukee, MN

Green and Complete Streets Components: Dedicated painted bike lanes, crosswalks and curb cuts.

High Point Neighborhood, Seattle, Washington



Green and Complete Streets Components: Rain gardens, pervious pavement cement, street trees, interconnected pathways for all forms of mobility, curbcuts, large central green space.

successful

EXAMPLES: RURAL AREAS

Trinity Highway in Willow Creek, a community nestled in California's Six Rivers National Forest

Green and Complete Streets Components:
Dedicated painted bike lanes on either side.

Hudson Avenue in Thunder Bay, Ontario, Canada

Green and Complete Streets Components:
Dedicated active living corridor for pedestrians/bikes and painted buffers.

CASE STUDY: DEVENS, MA

Grant Road in Devens, Massachussetts

Green and Complete Streets Components:

- Reduced travel lane widths
- Raised crosswalks
- Dedicated bike lanes
- Street trees
- Street lights
- Signage

Why did Devens implement a Green and Complete Streets Policy?

The intent of the Devens Green and Complete Streets Policy is to facilitate the development of safe, universally accessible, convenient and comfortable routes for a wide range of road users by creating a road network that meets the needs of individuals utilizing a variety of transportation modes while using trees, landscaping and related low impact site design features to capture and filter stormwater runoff within the right of way to the maximum extent practicable, in a manner appropriate to the function and context of the facility This policy will be considered as part of the decision-making process related to all infrastructure planning, design and construction. Learn more here.

How was Devens able to establish the GCS Policy?

Devens gained community support through education, awareness, incentives, and regulations. The GCS Policy linked above demonstrates how a community can memorialize their commitment to Green and Complete Streets. An example of the educational resources provided by Devens is their LID case study showing cost comparisons, and the economic, social, and environmental benefits of street trees. The Devens Green Infrastructure Guidelines is another resourceful tool that recognizes the principles of sustainable development and brings everything together.

TOOLS & RESOURCES

Overview of Complete Streets:
Smart Growth America

Overview of Green Streets:
EPA- Learn About Green Streets

Complete Streets are Green Streets

A more in-depth guide:
Complete and Green Streets for All

For more **public health benefits** and **research** on the impacts of green streets, Dr. Kathy Wolf at the University of Washington has conducted many studies. Find more at Green Cities: Good Health

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IMAGE REFERENCES

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Hauppage to Port Jefferson, New York State: Route 347

Charlotte, NC

NYC 9th Avenue

Broadway Street in Somerville, MA

City of Monterey, California

North Avenue

Vancouver, Canada

Trinity Highway in Willow Creek, California

High Point Neighborhood, Seattle, Washington

https://hpigreen.com/tag/green-infrastructure-planning/

Other Images

Page 1 image
Cover photo, page 2 & 4 background pictures
Page 2 bottom image
Page 3 image
Page 4 bottom image
High Point Commons Park facing south page 8
31st Ave SW page 8
Page 10: photo received from Neil Angus, DEC
All five images on page 11

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