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Benefits and Challenges of Linking Green Infrastructure and Highway Planning in the United States

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Abstract Landscape-level green infrastructure creates a network of natural and semi-natural areas that protects and enhances ecosystem services, regenerative capacities, and ecological dynamism over long timeframes. It can also enhance quality of life and certain economic activity. Highways create a network for moving goods and services efficiently, enabling commerce, and improving mobility. A fundamentally profound conflict exists between transportation planning and green infrastructure planning because they both seek to create connected, functioning networks across the same landscapes and regions, but transportation networks, especially in the form of highways, fragment and disconnect green infrastructure networks. A key opportunity has emerged in the United States during the last ten years with the promotion of measures to link transportation and environmental concerns. In this article we examined the potential benefits and challenges of linking landscape-level green infrastructure planning and implementation with integrated transportation planning and highway project development in the United States policy context. This was done by establishing a conceptual model that identified logical flow lines from planning to implementation as well as the potential interconnectors between green infrastructure and highway infrastructure. We analyzed the relationship of these activities through literature review, policy analysis, and a case study of a suburban Maryland, USA landscape. We found that regionally developed and adopted green infrastructure plans can be instrumental in creating more responsive regional transportation plans and streamlining the project environmental review process while enabling better outcomes by enabling more targeted mitigation. In order for benefits to occur, however, landscape-scale green infrastructure assessments and plans must be in place before integrated transportation planning and highway project development occurs. It is in the transportation community's interests to actively facilitate green infrastructure planning because it creates a more predictable environmental review context. On the other hand, for landscape-level green infrastructure, transportation planning and development is much more established and better funded and can provide a means of supporting green infrastructure planning and implementation, thereby enhancing conservation of ecological function.

Keywords Green infrastructure · Integrated transportation planning · Executive Order 13274 · Eco-logical · Planning and environmental linkages (PEL)

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Introduction

Calls for planning the landscape as a whole have been made for more than forty years (McHarg 1969; Odum 1969). The term "landscape" embodies a multi-scalar concept that incorporates structure, function, and change; principles of sustainability; and coupled human and natural systems (Musacchio 2009). The motivation for landscape planning is to undertake a holistic, multi-temporal, multi-spatial approach to developing and sustaining the environments that humans rely upon and organize (Steiner 2008). With its focus on landscapes and ecoregions as complex systems, landscape planning is a core integrative

concept (Selman 2006). In the United States, however, landscape planning is rarely deployed as such (Steiner 2002). Rather, sectoral or special interest, planning is the norm.

Two potentially significant sectoral activities are green infrastructure planning and highway infrastructure planning. Both green infrastructure and highway infrastructure seek to create a network enabling a form of connectivity across a landscape. They both are important, especially in growing metropolitan regions, where demand for transportation capacity continues to increase and green infrastructure faces cumulative threats to a connected, functioning ecological network. Furthermore, the two have important interactions as networks occurring across the same territories. Historically, highway networks have had the upper hand. Transportation planning and highway development are well established in practice and have better funding, having been on the national agenda since the 1950s. Tens of billions of dollars are spent on highway projects per year. Green infrastructure planning is new and remains sporadic, largely occurring in selective states, counties, and cities. Implementation of landscape-scale green infrastructure plans is even rarer (The Conservation Fund 2012).

"Green infrastructure" is a term applied to a continuum of conservation-related features from the site scale to the landscape level to large ecoregions. The development of green infrastructure planning, sometimes under varying names, is increasingly espoused by landscape, conservation, and metropolitan planners as an effective way to create a network of ecological functionality in regions that are otherwise highly impacted by anthropogenic changes (Ahern 2010; Benedict and McMahon 2006; Cheng and Daniels 2003; Benedict and McMahon 2002; Ryan et al. 2002). From this literature a common goal of green infrastructure can be defined to conserve or create a network of ecosystems in order to optimize their functioning and resilience. It relies heavily on concepts from landscape ecology, including structure, function, connectivity, and dynamism.

In the United States, as elsewhere, one of the most impactful forms of planning and intervention on landscapes is highway infrastructure planning. Highways create a network driven towards connectivity with the objective being the efficient movement of people and goods. Highway infrastructure causes direct effects, including landscape fragmentation, ecosystem impairment, and loss of habitat connectivity. At the same time, highway projects are seen as having important indirect impacts on land use and ecosystems, particularly through localized induced land development (Ewing 2008) as well as impacts on adjacent ecosystems (Forman Sperling and others 2003). Multi-year funding and authorization of new federal highway projects occurred in 1991, 1998, and 2005. The 2005 act has been extended into 2014.

Recently, there have been calls from transportation literature and federal transportation policy supporting "planning and environmental linkages" as a way of enabling integrated transportation planning (Barberio and others 2008; ICF Consulting 2005a). The calls are for connections with natural resource agencies generally, which are often simply referred to in transportation literature simply as "resource agencies." At the same time there are calls from green infrastructure literature to undertake its planning not only as a way of saving and restoring conservation networks, but also as a way of broadly influencing "grey infrastructure" planning and development (The Conservation Fund 2009; Benedict and McMahon 2006; Benedict and McMahon 2002). Examination of simultaneous consideration of these two networks from a landscape perspective has not been done before.

Our premise is the emerging theory and practice of landscape-scale green infrastructure enhancement have potential impacts on the practice of integrated transportation planning and highway infrastructure development. This leads to the important question, how could linking landscape-scale green infrastructure planning and implementation with transportation planning and highway project development in the United States enhance both networks and lead to better landscape and environmental outcomes?

The broad question of linking landscape-scale green infrastructure planning and implementation with transportation planning and highway project development leads to a more systematic set of research questions as shown in Fig. 1. In this conceptual framework the first two questions follow generalized flow lines from landscape-scale planning to project-level implementation for each network. Then, six detailed questions cross the centerline of the conceptual model and connect the realms of green infrastructure and regional highway planning and development.

In order to address these questions, we reviewed definitions and goals in the emerging area of green infrastructure planning; analyzed trends in integrated transportation planning, highway project development, and environmental impact assessment; and examined the state of practice of project development by presenting a recent case study of a suburban Maryland landscape. The case study methodology used during this study aligns with similar methods presented in Yin (1984). Maryland has been at the forefront of green infrastructure planning, and we examined Maryland's statewide green infrastructure assessment and the work done to date by Prince George's and Montgomery Counties. We analyzed the final environmental impact statement (FEIS) for the Intercounty Connector, a 2.566 billion dollar (US) highway project

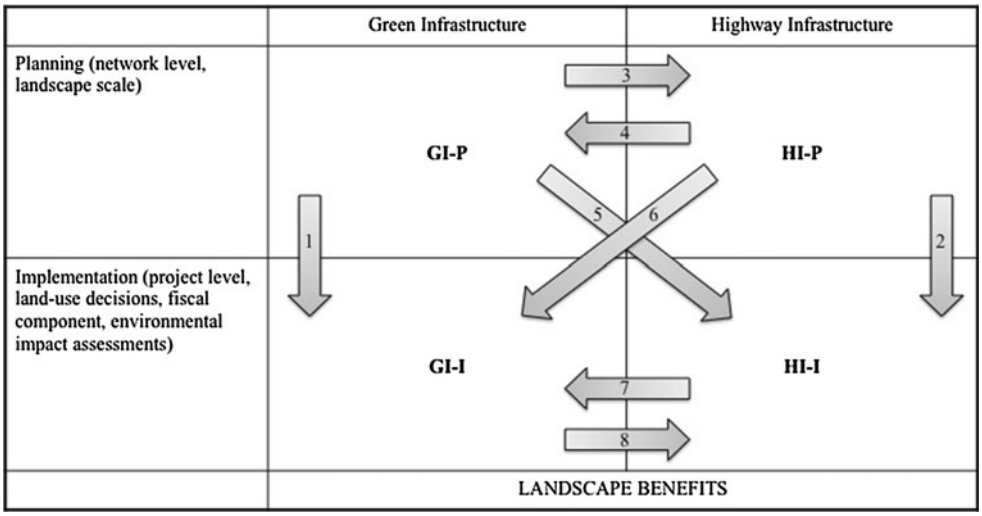

Fig. 1 Conceptual framework for linking green infrastructure with highway planning, *Arrow 1* GI-P GI-I: How can green infrastructure planning be improved for better project implementation and better outcomes?, *Arrow 2* HI-P → HI-P: How can transportation planning at the network level be improved for better highway project planning and implementation and better outcomes?, *Arrow 3* GI-P → HI-P: How can green infrastructure planning affect transportation planning at the network level?, *Arrow 4* HI-P → GI-P: How can transportation planning at the network level affect green infrastructure planning?, *Arrow 5* GI-P → HI-I: How can green infrastructure planning affect highway project planning and implementation?, *Arrow 6* HI-P → GI-I: How can transportation planning at the network level affect green infrastructure project implementation?, *Arrow 7* HI-I → GI-I: How can highway project planning and implementation affect green infrastructure project implementation?, *Arrow 8* GI-I → HI-I: How can green infrastructure project implementation affect highway project planning and implementation?

crossing these counties for evidence of green infrastructure plans influencing project planning and development. The Intercounty Connector was specifically called out in the Priority Project Transition List, which resulted from presidential Executive Order 13274, Environmental Stewardship and Transportation Infrastructure Project Reviews. Part of the FEIS is the Record of Decision, which includes a summary of significant findings, the Record of Responses to Public Comments, and the Mitigation Package. We also analyzed the Intercounty Connector Secondary and Cumulative Effects Analysis Technical Memorandum.

Green Infrastructure as Landscape-Scale Conservation Planning

For this analysis, we defined landscape-level green infrastructure as a network of natural and semi-natural areas occurring at the landscape or ecoregional scale that protects and enhances ecosystem services, regenerative capacities, and ecological dynamism over long timeframes. Green infrastructure consists of natural lands, working landscapes, and various forms of open space that create a network and function together to sustain ecological value and processes (Benedict and McMahon 2006).

Our interest here is in green infrastructure at the landscape and ecoregional scales, where issues of species protection, habitat connectivity, and network integrity dominate conservation objectives. This varies somewhat from the use of "green infrastructure" at the site, street, and neighborhood scales, where the term usually involves greenways as well as stormwater management and groundwater recharge and involves structures such as rain gardens (U.S. Environmental Protection Agency 2010; New York City Department of Environmental Protection 2010; Philadelphia Water Department 2009; Portland Bureau of Environmental Services 2012; San Francisco Public Utilities Commission 2011; Seattle Public Utilities 2011). Green infrastructure is also applied at the national scale (Wickham and others 2010).

Network connectivity is a core concept in landscape-scale green infrastructure planning. Theoretical and empirical studies in landscape ecology indicate that conservation plans—although potentially effective at protecting significant natural areas—require a structural network to optimize long-term functioning and viability (Opdam and others 1995; Groves and others 2002). The design of a green infrastructure network is based upon principles of landscape ecology and conservation biology whereby hubs and corridors are identified through a set of parameters often determined by the agency responsible for overseeing the green infrastructure plan. Identification of these components is essential to the planning process. This includes the concepts of island biogeographic theory and metapopulation dynamics. The identification of hubs, corridors, and gaps recognizes the areas that possess the greatest

ecological importance as well as those most threatened by development pressures (Weber and others 2006). Hubs tend to be large contiguous, unfragmented areas of ecologically significant space, while corridors are linear remnants that are generally smaller in size and provide connectivity between various hubs and other linkages (Maryland Department of Natural Resources 2003a).

A SWOT (strengths-weaknesses-opportunities-threats) analysis for creating landscape-level green infrastructure networks is given in Table 1. It was developed by the authors as a summary of literature and case studies on the topic. Green infrastructure is a critical component of planning for landscape sustainability because it considers landscape structure and ecological services, as well as long-term adaptation. Landscape ecology and the metrics associated with it are essential in designing green infrastructure alternatives (Leitão and others 2006). As a professional activity, planning for green infrastructure relies on a high level of technical expertise expressed through GIS analysis, specifically with respect to spatial configuration, connectivity and adjacency metrics.

Green infrastructure is a form of "soft" infrastructure in that it relies less on built interventions and more on natural landscape elements. There is a high reliance on existing conditions; although as a component of landscape planning, past conditions are important indicators of historic landscape integrity and provide guidance for possible restoration (Marcucci 2000). Green infrastructure scenarios have a particularly long-term perspective because a central objective of the network is to enable ecological sustainability. The long-term view is even more important given the issue of landscape adaptations to accelerated climate change (Lawler 2009).

The green infrastructure planning process follows a framework consisting of setting goals through input from various stakeholders, analysis of areas of environmental significance to delineate a network that maximizes ecosystem functionality and maintains connectivity, synthesis

Table 1 Landscape-level green infrastructure SWOT analysis

Strengths	Weaknesses
Leads to a landscape ecological network that is functioning and resilient	Insufficient funding for planning
Based on empirically tested concepts within the fields of landscape ecology and conservation biology	Data inconsistency between areas
Landscape-level GI connects to GI at local and large scales	Insufficient funding for implementation
Implementation can be achieved through the development review process	Insufficient planning capacity
Enables environmental management and development to be planned concurrently rather than in opposition	Lack of planners with expertise working at the right scale
Long temporal perspective includes sustainability and climate change	Lack of planning agencies at the right scale
	May require regional (multi-jurisdictional) cooperation
	Relatively small set of implemented examples
	Lack of consistency in defining GI
	Lack of public knowledge on the concept of GI and its benefits
	Long temporal perspective needed to appreciate full benefits
Opportunities	**Threats**
Partnerships with organizations such as The Conservation Fund	Can be viewed as less important than other planning activities under budgetary constraints
Work with "Eco-logical" initiative of the Federal Highway Administration	Local political culture opposed to GI
Growing strategy for conserving valuable ecosystem services	Competing interests for shared resources
Chance to include climate change adaptation strategies into development scenarios	Market uncertainty and outside funding sources
Can be part of a functional land use masterplan	Lack of federal support for GI
	Lack of integration with other sectors (i.e. transportation)
	Development threats often precede conservation and GI planning

of the network analysis to identify gaps and guide planners to secure areas that are critical to restoration efforts, and finally implementation of a decision support tool that helps to prioritize protection, restoration, and preservation opportunities (Jordan 2012; McDonald and others 2005). This framework allows for a general process that neighboring jurisdictions can follow thereby enabling collaboration between planning agencies to preserve and increase connectivity within the landscape.

Concepts of green infrastructure are being used as a framework for conservation planning throughout the United States and Europe (The Conservation Fund 2009; Mell 2008; Gill and others 2007). It is gaining increasing attention: the first National Green Infrastructure Conference was held in Shephardstown, West Virginia, USA in February, 2011 (The Conservation Fund 2011). It is important to note the term "green infrastructure" is not used universally throughout the US, although the processes, concepts, and components of green infrastructure planning are common in many greenway, conservation, stormwater management, and urban forestry plans that consider landscape networks. The general process of green infrastructure planning has been used by some states primarily in the form of greenway plans such as in Oregon, Minnesota, and Washington (Oregon Metro 2011; Minnesota Department of Natural Resources 2011; Mountains to Sound Greenway 2011). Sometimes, such as in Virginia, aquatic resources are planned out separately as "blue infrastructure" (Virginia Coastal Resources Program 2011). Green infrastructure planning is often connected to outdoor recreation plans and especially greenway plans (e.g., Anne Arundel County Office of Planning and Zoning 2002).

Integrated Transportation Planning

In order to achieve better transportation outcomes with better environmental outcomes, the trend in the United States has been towards "integrated transportation planning," which integrates actions of various transportation agencies and links with objectives and plans of environmental resource agencies. The seeds of this were planted with the enactment of the National Environmental Policy Act of 1969 (NEPA). This law required, among other things, environmental assessment of transportation projects that use federal revenues. During the last forty years, the legally sufficient methods of assessing individual project proposals have evolved and become more articulated. Environmental impact statements must consider the direct, indirect, and cumulative impacts of project alternatives on notable natural features and socioeconomic features. Mitigation of those impacts is considered in three types of responses—in order of preference: avoid, minimize, and compensate. Still, critics of the process argued that environmental assessments occurred primarily for specific projects and rarely for regional conditions (ICF Consulting 2005b).

Both avoidance and minimization rely on regional transportation plans and also on project alternative design. Regional transportation plans are the responsibility of metropolitan planning organizations (MPOs), which have been mandatory, multi-jurisdictional, metropolitan-centric bodies in the United States since the 1960s. In many states, rural areas not covered by an MPO are organized into regional planning organizations (RPOs) for the purposes of transportation planning. The Intermodal Surface Transportation and Efficiency Act (ISTEA), signed into law in 1991, strengthened the role of MPOs and provided greater federal funding for their work. Importantly, it gave MPOs a stronger voice with state officials with respect to regional priorities and transportation improvement plans.

In 2002, President George W. Bush signed Executive Order 13274, Environmental Stewardship and Transportation Infrastructure Project Reviews to streamline environmental impact reviews required by NEPA and thereby speed development of transportation infrastructure projects. Among other things, Executive Order 13274 established the Interagency Task Force, which was charged with numerous items including identifying and promoting policies to promote environmental stewardship and streamline the approval process. The task force created three work groups: the Purpose and Need Work Group (ICF Consulting 2005c), the Indirect and Cumulative Impacts Work Group (ICF Consulting 2005a), and, the Integrated Planning Work Group (ICF Consulting 2005b).

The Integrated Planning Work Group in particular examined linking short and long-term goals; federal and state agencies; and transportation, environmental resource, and land use issues from system planning through project-specific environmental reviews. The Integrated Planning Work Group produced a deliberative draft of a baseline report in 2005 (ICF Consulting 2005a). The findings of the report called for a much stronger integration with landscape-scale environmental analysis throughout the transportation planning process, especially for highways and surface transportation. Importantly, however, it found that such an effort is hindered by the lack of landscape-level environmental analysis.

Specifically, the report called for three "needed progressions in resource planning" (ICF Consulting 2005b, p. 28). The first need addressed strategic ecosystem protection: "landscape-scale analysis would help to inform the areas of most critical concern for natural and cultural resources, informing a prioritization of resources to the most critical issues, locations, and transportation projects" (ICF Consulting 2005b, p. 28). The second need exists

because landscape-scale resource plans and inventories do not exist for many regions. This deficiency effectively prevents a development review process from looking at landscape conservation issues. Third, the report noted that local land planning itself needs greater consideration of environmental conditions but is hindered by overemphasis on economic development and jurisdictional fragmentation. The report indicated that some states have begun collecting site specific and project specific environmental data into central GIS databases, enabling landscape-level analyses.

The Integrated Planning Work Group created a subgroup that supported a program called Eco-logical, an interagency team working towards a vision of integrated infrastructure development and ecosystem conservation. Eco-logical was published in April 2006 by the U.S. Department of Transportation. It was itself a collaborative effort among various agencies including the Bureau of Land Management, Environmental Protection Agency, Federal Highway Administration, National Ocean and Atmospheric Administration Fisheries Service, National Park Service, U.S. Forest Service, and several state Departments of Transportation, aiming to follow the principles of NEPA and Executive Order 13352 on Facilitation of Cooperative Conservation (Brown 2006). One upshot of Eco-logical was to fund a series of pilot assessments of landscape-scale environmental resources. One example was the Thomas Jefferson Planning District Commission, which used a Federal Highway Administration Eco-logical Grant and a Virginia Department of Forestry Urban and Community Forestry Grant to conduct a six-county GIS analysis that looked at current conditions and opportunities for protecting existing green infrastructure resources (Thomas Jefferson Planning District Commission 2009; Thomas Jefferson Planning District Commission 2011). It was created as a resource guide for the member jurisdictions to conduct further conservation planning work.

The principle of integrated transportation planning was reinforced in 2005 with the passage of The Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users (better known as SAFETEA-LU). In particular the concept of Planning and Environmental Linkages was promoted as a way to improve environmental decision-making (Barberio and others 2008). Greater integrated transportation planning involves connecting environmental, resource, and ecosystem knowledge early in the transportation planning process and facilitating high-priority mitigation of environmental impacts in the project level development.

Case Study: Suburban Maryland

With the clear policy trend towards integrated transportation planning, we turn to the prospects for linking green infrastructure planning with highway planning by examining a particular case study. Integrated transportation planning (incorporating multiple issues and agencies into a process directed by state and regional transportation plans) and linked planning (linking existing well developed green infrastructure plans with transportation plans) are both protocols that are too new to have been used in a completed major project. We examined a case study from suburban Maryland, chosen because it is the most recent case of new highway siting and development in a state that has taken a leading role in the development of green infrastructure plans. Figure 2 shows the study area. The case study involves the Intercounty Connector, a major highway project for which the Final Environmental Impact Statement was signed in 2006. The Intercounty Connector is one of 15 high priority projects monitored by the Task Force created by Executive Order 13274 (Maryland State Highway Administration and others 2006, I-3). Because green infrastructure planning, integrated transportation planning, and the Intercounty Connector environmental impact assessment were all being developed at the same time, we did not anticipate finding an example of a highly linked process. Rather, we used the case study to see where, if anywhere, green infrastructure concepts and data were used, and more importantly to analyze how linkages could be accomplished and what the potential benefits and challenges are. In the subsequent discussion section, the case study was used to illuminate the questions in the conceptual model of analysis.

The Washington-Baltimore metropolitan region is the fourth largest combined statistical area in the United States, and it continues to grow. In Maryland, the State Data Center projects that metropolitan populations are expected to increase by 26 percent between 2000 and 2030, increasing the probability of natural lands succumbing to the pressures of development (Maryland Department of Planning 2009b). State Data Center projections also assert that between 1997 and 2020 urban land uses will increase by over 25 percent while forest and agriculture are expected to decrease approximately 9 percent (Maryland Department of Planning 2009a).

At this increasing rate of development, many of the state's wildlife and migration corridors are lost; ecosystem functionality is increasingly disturbed or destroyed; and water quality degrades throughout many of the state's streams and rivers as well as the highly valued Chesapeake Bay (Weber and others 2006).

Maryland's Green Infrastructure

Green infrastructure in Maryland protects valuable ecosystem services that are necessary for the continued functioning of connected ecosystems as well as promoting

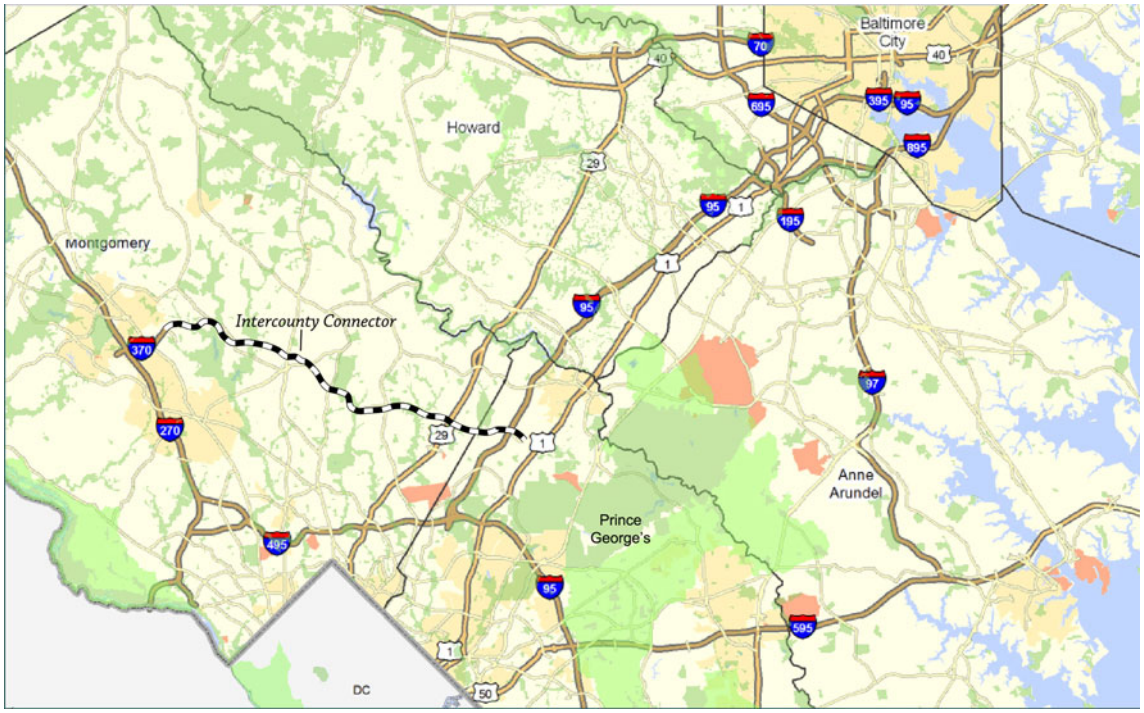

Fig. 2 Route of the Intercounty Connector overlaid on a Maryland GreenPrint map

overall wellbeing for its residents (Weber and others 2006). In 2003, Maryland conducted its first assessment of statewide green infrastructure to provide consistency in the evaluation of land conservation, restoration, and protection efforts (Maryland Department of Natural Resources 2003a).

The Florida Greenways Network (Florida Department of Environmental Protection 1998; Ahern, et al. 2006) provided a model for Maryland to develop a statewide assessment of green infrastructure as well as its potential connectivity to neighboring states (Wickham and others 2010). The Maryland Green Infrastructure Assessment (Maryland Department of Natural Resources 2003b) is a statewide effort aimed at identifying the state's most important natural lands. The Maryland Department of Natural Resources conducted the assessment, which heavily utilized geographic information science (GIS) technology coupled with the theories present in landscape ecology and conservation biology to help identify an ecological network. In 2000, the Department of Natural Resource's Chesapeake and Coastal Watershed Service spearheaded a GIS analysis through the use of satellite and aerial imagery, land use cover maps, and environmental and biological databases developed within the state's Natural Heritage Program, Biological Stream Survey, and Forest Service (Conn 2009). Maryland currently has two million acres of ecologically significant land that is not affected in some way by development. It is estimated that approximately 70 percent of this green infrastructure is unprotected (Maryland Department of Natural Resources 2003a). The minimum size of hubs consisting of expansive unfragmented areas considered at the state level was 40 hectares (100 acres). The average size of all hubs was approximately 890 hectares (2,200 acres) (Maryland Department of Natural Resources 2003b). Then corridors where determined that were linear remnants of natural lands, which connect similar hubs.

The state government was involved in making a case for green infrastructure conservation. By 2003, Governor Erlich institutionalized green infrastructure in state land conservation planning efforts and added a set of comprehensive ecological indicators that were to be used to expand the state's land preservation purchases. This initiative allowed for the state Rural Legacy and Open Space conservation programs to prioritize conservation activities based upon the state's designated green infrastructure (GreenPrint 2009). Additionally, the Maryland GreenPrint Program was created to identify areas where acquisitions and easements could be leveraged to protect green infrastructure. As Maryland continued to embrace green infrastructure as a valuable form of long range conservation planning, the scope of GreenPrint changed and became the first web-based map showing the ecological importance of every parcel of land within the state (GreenPrint 2009).

In Maryland, land use planning and permitting occur at the county level. The adoption of a green infrastructure approach by the state of Maryland was coupled with the

creation of various countywide plans throughout the state. The countywide plans followed similar methodologies for network design but were conducted at a finer spatial scale and involved numerous local stakeholders throughout the planning process. The plans are an extension of the statewide Green Infrastructure Assessment and commonly provide goals, objectives, policies, and recommendations for successful implementation. The plans are often intended to align with other county or state plans and aim to maintain consistency with other planning efforts. Prince George's and Montgomery, the two counties that make up the area located along the Intercounty Connector, initiated their own countywide green infrastructure planning in 2002 and 2001 respectively.

In Prince George's County, the Planning Department prepared the general plan to serve as a comprehensive plan for the entire county. The most recent general plan was adopted in October 2002 and set forth recommended goals for the environmental areas suggesting the creation of a green infrastructure plan. The process used to develop the green infrastructure plan included extensive participation by citizen stakeholder groups as well as other government agencies (Jordan 2012). In 2005, Prince George's County formally adopted as county policy the Countywide Green Infrastructure Functional Master Plan. This plan is an extension of the statewide Green Infrastructure Assessment but was constructed at a finer scale and accounted for all countywide areas of environmental significance (Prince George's County Planning Department 2010). Prince George's County adopted this plan as a functional plan that is a formal part of the development review process. Being an adopted functional plan also gives it more teeth in the environmental impact assessment process.

Montgomery County actually initiated green infrastructure planning in the 1940s when it began buying land along identified stream corridors and planned a stream valley park system that was established prior to the rapid growth experienced by the county. All of the major stream corridors located within the county are now classified as public parks (Benedict and McMahon 2003). In 2001, Montgomery County began a ten-year $100 million initiative to complete a countywide network comprised primarily of areas of open space, protected farmland, ecological reserves, and green space preserves (Maryland Office of the Governor 2008). The current green infrastructure plan is a part of this initiative and will be implemented as a functional master plan that will bear equal weight as other county plans including transportation plans. In 2006, the Montgomery County Planning Board approved the publication of the Purpose and Outreach Strategy Report (The Maryland—National Capital Park and Planning Commission 2006), which initiated the formal planning process. This collaborative process allowed for the creation of maps, which resulted in conceptual maps of the county's desired green infrastructure network. An extensive public participation component has been included in this planning process and the plan has yet to undergo approval by the county planning board and county council. The Montgomery County green infrastructure plan has not been completed, but draft maps of the proposed network have been created. Implementation was placed on hiatus due to county fiscal concerns.

The Intercounty Connector

Changes to the area's transportation infrastructure have become critical to managing the growth seen in the metropolitan region. The Intercounty Connector, also known as Maryland Route 200, is a multi-modal east–west highway that connects northwestern Prince George's County with eastern and central portions of Montgomery County (Maryland State Highway Administration 2003). The aim of the project is to link existing and proposed development areas between I-95/US 1 and I-270 corridors. Figure 2 shows the study area.

The regional transportation planning that led to the proposal for the Intercounty Connector occurred long before integrated transportation planning was advocated. The Intercounty Connector has been planned and studied for more than 50 years as part of the creation of an outer freeway known as the Washington Outer Beltway, but it was not until 1979 that the Maryland State Highway Administration initiated the first planning studies for the Intercounty Connector. In 1983 and 1997 the State Highway Administration issued draft environmental impact statements (DEIS) and began holding public hearings for the project. In both instances no decision was reached and a third DEIS was issued in 2004. The Secondary and Cumulative Effects Analysis Technical Memorandum (Technical Memorandum) was also published in 2004. The final environmental impact statement (FEIS) including the Record of Decision, the Record of Responses to Public Comments, and the Mitigation Package, was signed in 2006. As planned, the Intercounty Connector is 29 km (18 miles) and contains eight interchanges. The project consists of five contracts and contains 25.7 km (16 miles) in Montgomery County and the remainder in Prince George's County. Construction on the Intercounty Connector began in late 2007. Total costs for the project are estimated at US$2.566 billion, including a US$370 million mitigation package. It will be funded by various entities using bonds, general funds, and tolling revenues (Maryland Department of Transportation State Highway Administration 2009).

As a way of understanding the potential links to green infrastructure in the planning and development process, we analyzed the NEPA-required environmental impact

assessment documents with the question: how did the Intercounty Connector project planning approach landscape-scale conservation? More specifically, we examined five relevant phases in the assessment process: purpose and need, study area definition; analysis of impacts, mitigation schedule, and public and agency comments.

For starters, the Purpose and Need statement for this project was unusual in that it went beyond current transportation needs to look at past actions:

> Although not traditionally addressed as part of the purpose of a transportation improvement, a goal of the Intercounty Connector project is to enhance and restore the natural, community, and cultural environments that have been negatively affected by *past* development in the study area. This environmental stewardship goal is in addition to the traditional avoidance, minimization, and mitigation of impacts to environmental resources potentially resulting from the proposed transportation improvement (Maryland State Highway Administration and others 2006, I-27, *emphasis original*).

The damage caused by past development referred to local phenomena that have landscape-scale importance. Deteriorated environmental conditions included streams, riparian buffers, wetlands, forests, and water quality. A significant inadequacy concerning community and cultural environmental needs was a lack of pedestrian and bicycle trails. Building trails and protecting greenways that contain them became a part of the multimodal project design in the scoping phase of the Intercounty Connector. These advanced environmental stewardship designs enhanced green infrastructure implementation, although not necessarily by directly responding to a broader green infrastructure plan.

Three types of impact are required to be analyzed: direct, indirect, and cumulative. Direct impacts are those that result because of the immediate action of the development. Loss of a forest parcel to a highway interchange is one example of this. Indirect impacts (called secondary impacts in Maryland) are removed in time or distance from the project development. Induced development or loss of connectivity in a green infrastructure network would be examples of this. Cumulative impacts are the effects of the direct and indirect actions combined with other reasonably foreseeable actions in study area. Water quality impacts across a watershed could be an example of this.

For the Intercounty Connector, the FEIS presented the comprehensive analysis of direct, indirect, and cumulative impacts for the three project alternatives under consideration: No-Build, Corridor 1, and Corridor 2.

The study area for analysis for direct impacts was the immediate project site. As is typical for indirect (secondary) and cumulative effects, the study area was much broader. The Intercounty Connector did take a landscape-level approach to defining this study area, called in the assessment the Secondary and Cumulative Effects Analysis Boundary. This went beyond the standard perspective of identifying induced development. Also factored in were natural resources through a combination of watersheds and green infrastructure where the data existed. Network connectivity was not, however, a significant factor in determining study area, probably due to a lack of completed assessments and adopted plans. As part of the Technical Memorandum analysis, 41 master plans were referenced from six counties including, Montgomery, Prince George's, Anne Arundel, Carroll, Frederick, Howard, as well as the District of Columbia. Within the referenced master plans was the Prince George's Countywide Green Infrastructure Plan (2003) (Maryland-National Capital Park and Planning Commission 2010).

The green infrastructure within the Secondary and Cumulative Effect Analysis Boundary was calculated by subwatershed. Within the areas identified, the Patuxent River upper subwatershed contained the greatest percentage of green infrastructure hubs at 45 percent, while the subwatershed containing the greatest amount of green infrastructure corridors was the Lower Monocacy River subwatershed accounting for six percent (U.S. Department of Transportation and others 2004, p. 176).

To analyze potential direct and secondary impacts of the Intercounty Connector, the Technical Memorandum took the green infrastructure hubs and corridors identified in the statewide Green Infrastructure Assessment and overlaid them with near future, future, and secondary development. This was summarized in the FEIS. On this project, impacts on green infrastructure were considered as secondary rather than cumulative impacts. Secondary impacts were quantified separately for hubs and corridors within the Secondary Impacts to Natural Resources section of the report (Maryland State Highway Administration and others 2006, VII-70).

While the analysis did take advantage of the green infrastructure assessment data available at the time, it was limited by the lack of more complete green infrastructure planning. Potential impacts on individual hubs and corridors from highway alignment and projected induced development were studied. However, there was no consideration of the relative significance of individual hubs and corridors, nor was there any consideration of the overall effects on the network.

The established purpose of environmental assessment is to mitigate environmental impacts first by avoiding them, next by minimizing them, and finally by providing compensatory actions. A mitigation table was part of the Record of Decision and played a large role in the Intercounty Connector; a $370 million package of mitigation and stewardship activities were listed as part of the chosen

alternative. The mitigation package designated site descriptors for mitigation activities; mitigation benefits such as areas, corridor length, or wildlife passages; a brief description of the mitigation effort; and an identification number so that the area may be readily identified on a project map.

Comments were received from state and federal natural resource agencies, non-governmental organizations, and interested individuals. The comments and responses were included as part of the FEIS. The Maryland Department of Natural Resources commented that the Intercounty Connector "may fragment many of the existing hubs including the loss of north–south connectivity between hubs" (Maryland State Highway Administration and others 2006, IV-254). The response drew attention to proposed mitigations. It noted that reforestation efforts associated with the Intercounty Connector are complementary to the green infrastructure goals. It drew attention to many of the reforestation sites, which were consistent with the green infrastructure planning including promoting buffer enhancement, forest connectivity (forest interior dwelling species habitat development), and reforestation near or adjacent to existing hubs and corridors. According to the Response to Comments, identified Intercounty Connector reforestation sites would increase existing forest interior, buffer streams, wetlands and other aquatic habitats, as well as protect other sensitive natural resources and habitats (Maryland State Highway Administration and others 2006, IV-255).

Also within the comments section, the Maryland Department of Natural Resources raised a concern that the broader ecosystem-scale functioning of the areas may not have been considered properly. The response by the authoring agencies reiterated that the Intercounty Connector's mitigation and environmental stewardship efforts were consistent with the goals of the Green Infrastructure Assessment. As an example, reforestation sites were focused on properties that were adjacent to existing protected forest habitat (Maryland State Highway Administration and others 2006, Appendix R-4).

The Response to Comments and the Mitigation Schedule contained the most direct and specific references to green infrastructure plans and implementation at the parcel level. This is logical give the chronology of the project; response to Public Comments and the Mitigation Schedule would have been among the last items written, at which point Maryland's Green Infrastructure Assessment and the county plans were coming into greater focus.

In summary, the Record of Decision for the Intercounty Connector was formally signed on May 29, 2006 (U.S. Department of Transportation and Federal Highway Administration Maryland Division 2006). The term "green infrastructure" did not appear in the main body of the document, and landscape-scale impacts were not specifically identified or noted throughout the document. There was recognition, however, of landscape-scale environmental issues in the supporting technical memoranda. Moreover, in the later parts of the environmental assessment that were produced for this highway project, green infrastructure assessments were recognized.

Discussion

Our overarching question has been how could linking landscape-scale green infrastructure planning and implementation with transportation planning and highway project development in the United States enhance both networks and lead to better landscape and environmental outcomes? By synthesizing current knowledge on green infrastructure, policy trends in integrated transportation planning, and the Maryland case study, we discuss the potential benefits and challenges for planners wishing to link landscape-level conservation and transportation.

Returning to Fig. 1, we note that the parallel arrows (1 and 2) running from planning to implementation represent the parallel planning processes associated with green infrastructure and highway infrastructure; each of which is aimed at creating a landscape-scale network. Each of these endeavors is challenged to plan for networks that are implemented incrementally through an accumulation of projects. Meanwhile, the arrows (3 through 8) crossing the centerline represent important questions linking green infrastructure planning with highway planning.

Arrow 1: GI-P → GI-I: How can green infrastructure planning be improved for better implementation and better outcomes?

The strength and weaknesses for green infrastructure planning and implementation were discussed earlier and depicted in Table 1. The proposed benefits of green infrastructure include providing habitat, supporting air and water quality, and enabling ecoregional adaption to climate change. The Maryland case study offered additional lessons.

The green infrastructure plans as they were executed in Prince George's and Montgomery Counties can serve as integrated conservation plans combining stormwater, habitat, recreation, and floodplain issues. Properly done, effective green infrastructure planning includes citizen participation and has popular support. With an extensive public input process, Prince George's County developed and adopted a functional master plan that combined green infrastructure and land use. By adopting these as functional plans, counties in Maryland made green infrastructure part of the development review process. Maryland exemplified how a green infrastructure planning approach can be used to guide conservation planning and promote healthy ecosystems at a landscape scale.

The challenge for environmental planning at any scale is to turn plans into actions that enhance ecological sustainability (Steelman and Hess 2009, pp. 93–104). Landscape-scale green infrastructure planning will be more likely in states that have statewide data and technical assistance. Nonetheless, we see from the case study that individual counties can begin conducting their own assessments, at a finer scale, to develop countywide plans.

Another challenge for green infrastructure planning is that it is a recent arrival on the landscape. Although Maryland is in the vanguard of states that are enabling landscape-scale green infrastructure networks, the fact remains that resources for planning and implementation are limited even here.

The landscape and eco-regional scales are critical for effective green infrastructure planning that enhances connectivity, sustainability, adaptability, and resilience. However, this scale could be completely unrelated to the scale of land use planning and zoning. In our case study it is important to note that counties in Maryland have land use planning and zoning authority. They are an effective and functional size for landscape-scale green infrastructure planning, and they are backed up by a state assessment. When other states are highly fragmented in local governance, such as Pennsylvania or Illinois, challenges compound for creating and implementing strong green infrastructure networks in growing regions.

Because there are few adopted green infrastructure plans and the objectives and outcomes are in part long term, there are no outcome assessments. The benefits from green infrastructure planning, although well-articulated are still hypothetical benefits.

Arrow 2: HI-P → HI-P: How can transportation planning at the network level be improved for better highway project planning and implementation and better outcomes?

The trend for over ten years has been for integrated transportation planning. The purpose of integrated transportation planning is to develop improved systems by considering a wide range of variables and streamlining the process for individual projects. Highway planning and construction must consider physical, fiscal, social, environmental, legal, and regulatory concerns. The strengths and weaknesses of integrated transportation planning were laid out in the work of the Interim Task Force of presidential Executive Order 13274 as well as literature on planning and environmental linkages.

The trend towards integrated transportation planning is beneficial and is likely to continue at both the agency level and through new funding and authorization legislation, which at the time of this writing is stalled in Congress. Integrated transportation planning can lead to a more predictable process for planning and development while adhering to environmental protection requirements.

Going beyond this policy analysis, the case study looked at a particular highway project that was targeted on the Executive Order 13274 Interagency Task Force's list of priority projects. This project has since completed the environmental review process, and four of the five phases of the project have been built. One cannot draw generalized conclusions from a single case study, but this example does suggest benefits from an integrated transportation approach. The environmental review was legally sufficient for the project to proceed in a streamlined fashion. Also, the purposes and needs included remedy of past environmental damage in central Maryland.

Next, Fig. 1 shows the six questions linking green infrastructure and highway infrastructure from planning activities to implementation. The questions in the form of "how can one activity affect another" are discussed in the terms of benefits and challenges to facilitate application to practice.

Arrow 3: GI-P → HI-P: How can green infrastructure planning affect transportation planning at the network level?

One benefit to transportation planning at the network level is to enable regional transportation plans to consider the ecological network in evaluating alternative regional scenarios, not just for the highway network but also for the entire multi-modal network. A green infrastructure plan's contribution to integrated transportation planning can thereby enable selection of modes and routes that avoid or minimize destruction of high-value landscape ecological elements. Linking to a green infrastructure assessment or, better yet, an adopted plan will yield better analysis of the true impact of a regional transportation plan on the sustainability, adaptability, and resilience of a landscape. This benefit can be proactive, but we see that it can also be retroactive. Green infrastructure plans are one way of identifying past environmental damage from transportation and highway networks. This enables including correcting past damage as part of the objectives, purposes, and needs through out the planning and development process. It is important to note: not all past environmental damage will be revealed by a regional green infrastructure plan.

Beyond the scientific knowledge of the ecological landscape, a green infrastructure plan also contains an expression of the goals and values of a landscape's communities. Including an adopted green infrastructure plan in integrated transportation planning theoretically can lead to greater public acceptance of the regional transportation plan.

Important challenges exist. In order to realize these benefits, green infrastructure assessments and plans must be in place before regional transportation planning is undertaken. The potential for county and state green infrastructure assessment and plans to influence integrated transportation planning only occurs if the plans exist. Existing green infrastructure plans would enable Executive

Order 13274's specific call for integration with landscape-level resource plans. Moreover, it is important to note, that stronger green infrastructure plans, especially if they are part of a functional comprehensive plan, will have greater impact on land use and growth management as well as transportation development.

Arrow 4: HI-P → GI-P: How can transportation planning at the network level affect green infrastructure planning?

An important way that we see transportation planning at the network level affecting green infrastructure planning is through direct funding of natural resource assessments at the landscape level by transportation agencies. This we saw in the form of Eco-logical pilot studies such as the one undertaken by the Thomas Jefferson Planning District Commission. The assessments, and potentially subsequent adopted plans that arise from them, are critical for transportation plans to move forward. Fortuitously, more and better landscape-level resource analysis and planning and better local environmental planning are consistent with, if not synonymous with, green infrastructure planning.

A weakness for green infrastructure planning noted earlier is the potential lack of appropriate jurisdiction to undertake assessments and planning at the landscape-scale. Often there are jurisdictional challenges with regional conservation planning where no one agency has the landscape scope or authority for planning. Transportation agencies are already required to work at regional scales and to that end have developed MPOs and RPOs as multijurisdictional planning entities. These are well positioned to provide a structure for landscape-level green infrastructure planning as well, especially if they are backed up with statewide efforts.

A word of caution is warranted, however: a challenge lies in the way that green infrastructure planning might be facilitated. "Integrated" planning could imply that the regional transportation planning organizations will conduct transportation and environmental planning, setting up a possible conflict of interest on environmental and conservation measures. This would also diminish the apparent validity of the green infrastructure planning. We see in order for green infrastructure planning to be accepted and implemented, it needs to have substantial local and community control and be based on accepted scientific knowledge. Eco-logical or green infrastructure assessment studies should be funded as part of long-range transportation planning but led by local planning authorities in collaboration with environmental resource and transportation agencies. This has the potential to create landscape-level resource data that are called for in integrated transportation planning as well as enabling counties or regions to further green infrastructure planning by using the technical studies in a public planning and decision process.

Arrow 5: GI-P → HI-I: How can green infrastructure planning affect highway project planning and implementation?

Green infrastructure planning and plans can be particularly beneficial to the development of highway projects.

A landscape-level environmental resources assessment, or even better an adopted green infrastructure plan, will enable highway project planners assessing alternative routes to consider landscape ecological conservation. From the highway project development perspective, existing, community-driven green infrastructure plans enable more comprehensive conservation plans and ultimately, therefore, a more streamlined and defensible environmental review process for projects.

When it comes to developing a specific new highway project, impact assessment that integrates a green infrastructure plan will yield better analysis of the true impacts of project alternatives on the ecological network. This will occur because there will be better data and established high-priority conservation and restoration areas. The case study indicates that green infrastructure considerations occurred during the environmental assessment process. However, only the Maryland statewide assessment had noticeable influence in this case because it was complete, whereas the county plans were still in process during the development of the FEIS.

An established regional green infrastructure assessment will also justify a more accurate and often broader study area for environmental assessment in the indirect and cumulative impacts analysis phase of environmental impact assessment. If impacts from a highway project are seen as affecting ecological network connectivity as opposed to a site, then looking at the wider network in terms of impacts and potential mitigation is warranted. This can also justify increased compensatory mitigation during project development. Compensatory mitigation is designed to offset negative impacts rather that to create a net benefit for conservation, but with an adopted green infrastructure plan, the negative impacts can be leveraged to optimize the protection of the green infrastructure network.

However, this also presents a potential challenge. A regional green infrastructure plan may indicate compensatory mitigation in a different jurisdiction than where the impact occurs. This could create difficult local politics and environmental justice issues. An analysis of regional green infrastructure may indicate a high priority to protect landscape elements in less dense areas, even though the fragmentation and loss of greenspace are occurring closer to the metropolitan center. Issues of regional cooperation, local politics, and environmental justice will have to be addressed specifically.

Arrow 6: HI-P → GI-I: How can transportation planning at the network level affect green infrastructure project implementation?

Interestingly, the theories and empirical evidence suggest only limited direct effects of regional transportation planning on the actually implementation of individual green infrastructure projects. This is logical given it is not in the mission of these agencies to implement green infrastructure projects. One place where there is evidence of some impact is in the planning of multimodal corridors and the alignment of bicycle and pedestrian trails in greenways.

Transportation planning at the network level does have two important indirect pathways affecting green infrastructure project implementation. Looking at the conceptual model one is through green infrastructure planning (Arrow 4 to Arrow 1: HI-P → GI-P → GI-I). The other is through highway project planning (Arrow 2 to Arrow 7: HI-P → HI-I → GI-I).

Arrow 7: HI-I → GI-I: How can highway project planning and implementation affect green infrastructure project implementation?

Highway infrastructure development poses a significant challenge to green infrastructure implementation negatively through destruction of ecological resources. There are also benefits through positive mitigation actions. This is a direct upshot from the impacts in Arrow 5. When compensatory mitigation is required as a result of highway development, green infrastructure priorities can be accomplished through strategic protection or restoration. It is important to note that the compensatory nature of the mitigation implies that there is a trade off with environmental damage elsewhere. Nonetheless, properly done, a green infrastructure plan can identify elements that are strategically important in the ecological network. For the Intercounty Connector, the FEIS aimed to ensure consistency between restoration sites identified in the statewide assessment with possible mitigation sites associated with the project (Maryland State Highway Administration and others 2006, p. 615).

Another intriguing positive effect is inclusion in the purpose and needs to correct past actions. We see this in the Maryland case study with the inclusion in the Purpose and Need for the Intercounty Connector to remedy past environmental damage. This goes beyond mere mitigation. It is the upshot of green infrastructure planning affecting transportation planning at the network level, which in turn affects highway project planning (Arrow 3 to Arrow 2 to Arrow 7: GI-P → HI-P → HI-I → GI-I).

Arrow 8: GI-I → HI-I: How can green infrastructure project implementation affect highway project planning and implementation?

Protected or restored green infrastructure elements and networks are an asset to a region with tangible benefits to the community and ecosystems. Because a protected element has recognizable value, it can influence the selection of project alternatives in the environmental review process. The challenge is that the value of green infrastructure, often in the form of passive parkland, may have to compete with other values for neighborhoods and businesses in siting alternatives. In any case, being able to recognize the value of ecosystem services from a linked green infrastructure network increases leverage for increased mitigation in highway project implementation.

Also, an existing green infrastructure corridor can advance the purpose of a multimodal highway project by providing opportunities for effective bicycle-pedestrian routes. This occurred in the Maryland case study.

Conclusion

Green infrastructure and highway infrastructure have inherent competing connectivity goals on landscapes in that they represent dramatically different sectors. It is not surprising that these two networks affect each other. Nonetheless, there are compelling reasons why linking highway infrastructure planning and green infrastructure planning can produce improved outcomes for both. There are four major reasons. First, green infrastructure planning improves integrated transportation planning by providing clear data on valuable ecological resources and clear expression of the local community's objectives for landscape sustainability. Second, because these benefits are significant for integrated transportation planning, transportation authorities have sufficient reason to fund landscape-scale green infrastructure assessments in growing metropolitan areas, and metropolitan planning organizations can provide an institutional framework to conduct green infrastructure assessment where none might exist. Third, green infrastructure assessments and plans also help in the development of specific highway projects by providing solid data for environmental review and streamlining the review process. Finally, pre-existing green infrastructure plans benefit from highway project development plans by leveraging mitigation money for strategic environmental resource protection. These findings are based on extending general theory, applying policy, and analyzing a major case study.

Integrated transportation planning is a developing policy trend, and green infrastructure planning is still in its early phase. Empirical cases of linked green infrastructure and highway infrastructure are very limited. There are no regional transportation plans yet that include strong green infrastructure plans. Therefore we did not analyze important scenarios such as the potential impacts on multimodal regional transportation planning from a fully adopted green infrastructure plan. Even in the case study we examined, county plans were not fully developed while the FEIS was

being finalized. More research is warranted as these cases occur.

Another challenge in creating a collaborative dialogue between these two sectors is structural. As a matter of planning dynamic landscapes, there is an important temporal scale difference between green infrastructure and transportation infrastructure as keystone processes. Because green infrastructure is at its base an ecological conservation plan, it has both short-term and long-term (100 years or more) objectives and outcomes. Long-term ecological outcomes can be hard to sell to decision makers. Therefore transportation issues can seem more compelling than landscape ecological issues. While some benefits of green infrastructure, such as water quality or recreation improvements, occur over years and decades, other environmental phenomena take much longer. Climate change adaptation of ecoregions requires green infrastructure planning to manifest over centuries. If it is to facilitate sustainability, green infrastructure planning must have a long view that includes adaptation to climate change. Transportation systems, on the other hand, are planned over the scale of decades. Furthermore, we discuss the linking as though both activities are equals in the political and funding world. The simple truth is highways are massively funded for relatively near-term public benefits as compared to green infrastructure. Just the mitigation package for the Intercounty Connector was over three times greater than the ten-year budget for green infrastructure implementation for Montgomery County.

A great challenge in creating sustainable landscapes in growing regions is safeguarding ecological function and resilience in the face of increased hard infrastructure and developed land uses. Linking green infrastructure planning and highway infrastructure planning is not likely to solve everything. Because green infrastructure and highway infrastructure planning and implementation are each driven by sectoral objectives, it is entirely possible that there are goals which are mutually exclusive and can not be balanced by linking the planning processes. The landscape ecology science behind green infrastructure data and studies could contradict a vision for growth that a county might have. It may also be at odds with other economic or homeland security plans. Hard choices would have to be made. Nonetheless the mutual benefits from linking green infrastructure planning and implementation with highway infrastructure planning and development are promising enough to warrant ongoing collaboration.

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