



Blending project goals and performance goals in ecological planning: Ian McHarg's contributions to landscape performance evaluation

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Abstract

Ian McHarg's ecological planning method has been influential since the publication of *Design with Nature* in 1969. However, less is known about McHarg's pioneering contributions to landscape performance evaluation, which are critical in today's practice. After a review of McHarg's theoretical foundation and interdisciplinary design process, we suggest that McHarg's method facilitates the function of environmental performance, because planning goals, including performance benchmarks, are integral parts of the design process. In addition, we respond to the misconception of McHarg's disinterest in social and economic factors, through a review of three exemplary projects—Interstate 95 in New Jersey, Medford Township, and The Woodlands—all of which illustrated salient, multifaceted benefits. Last, we synthesize the policy and practical implications of landscape performance evaluation (e.g., environmental impact assessment) that enrich McHarg's theory and actionable planning process toward sustainability. We conclude that McHarg is a forerunner in landscape performance evaluation. Through blending project goals and performance goals, McHarg's method improves project performance and increases the validity of ecological planning.

Keywords Socio-ecological practice research · Ecological resilience · Landscape architecture · Landscape performance · Multifunctional landscapes · Design with Nature · Performance zoning · Ecohumanism

1 Introduction

Ian Lennox McHarg (1920–2001), American landscape architect and regional planner, is widely recognized as the father of ecological planning (Hough 1984, p. 5; Spirn 2000; Ndubisi 2002, 2014; Herrington 2010, p. 1; Steiner and Fleming 2018, p. 1). His theoretical framework and methodology are presented in the seminal book *Design with Nature* (McHarg 1969). This book has influenced landscape architecture practices worldwide since its publication, and, as the book title specifies, following nature's lead in planning and design is presented as the core of achieving sustainability. Anthropogenic uses or interventions shall become an integral part of the natural processes (Steiner et al. 1988; Ndubisi 2002; Yang and Li 2016; Xiang 2019a, b).

In 1992, when President George H. W. Bush bestowed the National Medal of Arts to McHarg, he stated that “It is my hope that the art of the twenty-first century will be devoted to restoring the earth” (McHarg and Steiner 2006, p. 129). Indeed, throughout McHarg's career, he endeavored to heal the earth through knowledge that would increase competence and intelligence in planning and design. McHarg emphasized project performance because he believed in the importance of elevating the standards of care in profession practice. Using one of his favorite phrases, designers need to shape the built environment to promote “human health and wellbeing” (Holden 1977, p. 381). McHarg also believed that the better the people understand their environments and resources, the better equipped they are to provide a responsible plan for the future (Palmer 1981, p. 50; McHarg 1996). Largely influenced by his intellectual mentor, Lewis Mumford, McHarg promoted ecological literacy in the design profession and in the society at large, through his theory of the necessity of *Design with Nature* and his multitude of planning and design practices that embraced human systems, or human ecology, as an essential part of the design process (Cohen 2019).

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In addition to taking the responsibility of protecting public health, safety, and welfare, landscape architects in recent decades are increasingly charged to communicate quantifiable performance benefits of their design. *Landscape performance* can be defined as a measure of the effectiveness with which landscape solutions fulfill their intended purpose and contribute to sustainability (Landscape Architecture Foundation 2011). Performance benefits are quantitatively assessed in the environmental, social, and economic aspects. Landscape performance evaluation therefore augments the compelling portfolio of the landscape architecture profession through articulation of project values and their essential contributions to society (Mendenhall 2016; Canfield et al. 2019). In a similar vein, landscape performance evaluation enhances the rigor and validity of the field of ecological planning, further contributing to McHarg's theoretical framework and the practical application of that framework.

Extensive literature touches on McHarg's ecological planning (later human ecological planning) method and how he formulated and enacted Mumford's vision of ecohumanism (Cohen 2019); however, less is known about his legacy and contributions to landscape performance evaluation that have considerable relevance in today's practice. As laid out in *Design with Nature*, ecological science serves as the theoretical core, with interdisciplinary collaboration a unique aspect of McHarg's design process (McHarg 1969; Giliomee 1977; Thompson and Steiner 1997, pp. 1–5; Xiang 2016, pp. 56–57). This design process greatly facilitates the establishment of performance benchmarks and allows the opportunity to forecast performance outcomes before construction (e.g., through modeling of different scenarios) (McHarg 1996, pp. 273–276).

There is a distinction between performance goals and performance evaluation. "Evaluation" encompasses the assessment of design goals and scenarios at the planning stage, as well as that of observed outcomes post-project construction and occupancy. Both are important dimensions of landscape performance evaluation. McHarg's method articulated performance goals at the planning stage. He further proposed to compare project performance before and after development, in order to test the design impact against performance goals (McHarg and Steiner 2006). Additionally, McHarg's process demonstrated how scientific inquiries can become an integral part of the design process and how "design" and "science" complement each other throughout the process (Xiang 2017, pp. 2243–2245).

As an example, Table 1 shows the planning guidelines and performance requirements of the Toronto Central Waterfront Planning Study, a project McHarg suggested for the protection of natural resources (Wallace et al. 1976). It is important to note that simply preserving the

Table 1 Planning guidelines and performance requirements in Toronto Central Waterfront Planning Study. Adapted from Lee (1982, Fig. 2, p. 151)

Performance requirements for the protection of unique resources	Protected wildlife Sensitive breeding colonies Regionally significant wildlife concentrations Unusual plant species Seasonable wildlife interest Aquatic life
Performance requirements for the maintenance of vegetation resources	Shoreline associations Successional associations Woodlands Parkland and other urban-related vegetation
Performance requirements for the maintenance of wildlife values	Maximum ecological benefit Minimum nuisance

existing landscapes is not sufficient to create high-performing landscape systems; McHarg's design process juxtaposes the underlying ecological functions and processes with those of the proposed design.

Although ecological planning made a remarkable debut in *Design with Nature*, the field remains unfinished. It is an evolving field with fertile grounds for exploration (Ndubisi 2002, pp. 6–8; Steiner 2004, pp. 82–84); in particular, more rigorous scholarly works are needed (Ndubisi 2014, p. xviii). This paper responds to "Design with Nature at 50: Retrospect and Prospect Special Issue Call for Papers" (Steiner and Fleming 2018) to specifically summarize McHarg's contributions to landscape performance evaluation through ecological planning. We suggest that McHarg's method creatively blends project goals and performance goals in order to achieve optimal environmental, social, and economic benefits. Three exemplary McHargian projects demonstrate McHarg's vision, process, and strong relevance to contemporary exploration of landscape performance evaluation.

2 Ecological determinism: theoretical basis and landscape performance evaluation

2.1 Theory

As specified in *Design with Nature*, ecological determinism defines a new urban morphology based on ecology, countering the conventional wisdom of economic determinism (McHarg 1969; McHarg and Steiner 1998, p. 7; Xiang 2019c, p. 163). The premise is that using ecology as the basis for planning and design would provide multifaceted performance benefits and ameliorate the potential diverging

(or conflicting) interests among the environmental, social, and economic aspects of the project. Eugene P. Odum, former director of the University of Georgia's Institute of Ecology, stated that "the big obstacles to sensible land planning are social and economic" (Holden 1977, p. 381). Contrary to the current economic paradigm that tends to emphasize short-term economic gains (Simon 1983a, b; Wang et al. 2016), McHarg suggested that ecological planning can go hand in hand with economic planning (McHarg and Steiner 2006). One of the reasons is that sound planning can provide economic savings and avoid unnecessary spending, for example, by minimizing land erosion, flooding hazard, and maintenance costs and preserving clean water supplies. Similarly, preserving social values can be perceived as synonymous with ecological planning. Social benefits can be prominent if unquantifiable human values are included in the equation, as shown by the works of notable "ecological" economists (e.g., E. F. Schumacher, Kenneth Boulding, and Nicholas Georgescu-Roegen) (Holden 1977, p. 381). In other words, McHarg's method is based on solid economic and social grounds.

Ample examples demonstrate the negative outcomes (e.g., losses) of ignoring site ecology. Enormous economic and human losses in past devastating disasters could have been prevented if natural processes were included in land planning to protect human health and safety. For instance, the 1994 flooding of the Mississippi River "was exacerbated by failure to understand the role of river ecologies in mitigating flooding and by years of engineering practices that neutralized much natural protection" (McHarg and Steiner 2006, p. 114).

By proposing ecological determinism, McHarg contends that landscapes cannot be fully understood without grasping their "physical and biological evolution" (McHarg and Steiner 1998, p. 7). Using ecological science as the basis of planning and design allows designers to understand a specific point in time of the landscape development (John-Alder 2014, p. 60). In the following, two principles govern the basis for planning. First, ecology focuses on the role of interactions among organisms, in addition to the influence from the surroundings (McHarg and Steiner 1998, p. 7). All flora and fauna are interdependent and have intricate associations with their environment. Second, planning efforts are grounded on the "understanding, establishing, modifying, or projecting these relationships" in socio-ecological systems (Cohen 2003, p. 44). In short, ecological planning "offers the best hope to achieve the maximum social, economic and environmental benefits" in planning and designing our built environment (Cohen 2003, p. 45; 2019).

2.2 Process

McHarg's process of landscape suitability analysis was explained in *Design with Nature* (e.g., chapter 10, "Processes as Values") and demonstrated in more than ninety projects. He seeks the maximal carrying capacity of land through a design process that respects, integrates, and facilitates multiple ecosystem processes, functions, and services (Yang and Li 2016, p. 22). This process embraces the principle of using ecological science as the basis for planning and design, offering a promising direction in balancing human needs toward a goal of sustainability (McHarg 1969; Spirm 1984; Steiner et al. 1988).

In practice, ecological planners fuse the science of ecology and the art of planning and design. Ecological knowledge guides the action of ecological planners to understand chronologically the interactions between natural phenomena and landscape patterns. This process begins with exhaustive ecological inventories, including biophysical and social factors of the landscape area where design interventions are proposed (McHarg 1969; Holden 1977, p. 381). First, all of the environmental factors are presented chronologically in a "layer-cake" model. These factors include "meteorology, geology, physical oceanography, surficial geology, geomorphology, groundwater and surficial hydrology, soils, vegetation, wildlife (including marine biology), and limnology" (Holden 1977, p. 381).

Second, the social factors are overlaid in the ecological inventories, which include "ethology, ethnography, cultural anthropology, economics, sociology, and geography (particularly computational science)" (McHarg and Steiner 2006, p. 115). A human perspective is imperative because this perspective demonstrates how people relate to their environment in the past, during the present, and projecting into the future. An ethnographic history layer of the layer-cake model would reveal important information such as "populations, structured in constituencies, characteristic values, settlement patterns, resource utilization, and specific issues and attitudes to them" (McHarg and Steiner 2006, p. 116).

More importantly, this process allows a feedback loop to derive and optimize performance goals based on project goals. Different scenarios can be compared and contrasted regarding anticipated performance outcomes at the planning stage. For more than four decades, this process with its underlying principle has been applied in projects of various scales and focuses (Steiner and Osterman 1998; McHarg and Steiner 2006; Ndubisi 2008; Heavers 2019). Many of the projects were completed by McHarg's team at the University of Pennsylvania (Penn), when McHarg served as chair

of the Department of Landscape Architecture and Regional Planning, beginning in 1959, and in McHarg's firm, Wallace McHarg Roberts and Todd (WMRT, now WRT) between 1965 and 1973.

2.3 Landscape performance evaluation

McHarg's principal contribution to landscape performance evaluation is that his method systematically lays out a roadmap that makes data collection and establishment of performance benchmarks part of the design process. Some strengths of his method are gathering baseline data and making qualitative judgments based on empirically gathered information. With clearly stated performance goals, McHarg's method provides a robust analysis of existing conditions as a starting point for design. Relating to project goals, McHarg and colleagues (Johnson et al. 1979) highlighted the fact that the "viability of deriving performance measures from suitability analysis, [which] is extremely useful in ascertaining how well a design of plan has performed in reaching its targeted goals" (Ndubisi 2014, p. 433) and how the adaptive design cycle can contribute to resilience and stability of landscapes (Ndubisi 2016, pp. 194–199).

Specifically, ecological determinism requires the identification of performance criteria, and the design process seeks indicators (or metrics) that evaluate project performance (McHarg and Steiner 2006, p. 38). McHarg went on to provide several examples from environmental sciences. For instance, entropy would be an indicator of the stability (or instability) of a pond ecosystem. Ruth Patrick's histograms can demonstrate the "state of health" of Pennsylvania streams, and Luna Leopold's "duration curve" can discern the stability of stream processes. McHarg further specified that once the technique of indicators was established, it should not only be applied to natural environments but also be expanded to landscapes dominated by humans (e.g., metropolitan) (McHarg and Steiner 2006, p. 38).

Through numerous studies undertaken by faculty and students in landscape architecture and regional planning at Penn, McHarg's team identified the baseline natural resource data that are necessary for the layer-cake ecological inventory model (McHarg and Steiner 2006, p. 116). Chronology was suggested as "the unifying rubric" in the process of collecting long-term baseline data. Furthermore, chronology was also recommended as the device for integration to understand all environmental problems. In other words, all studies should contain a summary of the site's environmental history to allow meaningful integration and design synthesis (McHarg and Steiner 2006, p. xix). A common thread with today's endeavors of landscape performance evaluation is that the evaluation process includes a chronological observation of the designed landscape to identify patterns, trends, and sometimes

pitfalls in performance outcomes. The ability to (better) integrate and interpret chronological data is key to this evaluation. In essence, McHarg's method proposed 50 years ago facilitated today's landscape performance evaluation to understand how the "[site] came to be, what it is, how it works, and where it tends to go" (McHarg and Steiner 2006, p. 116). The following sections provide three well-regarded ecological planning projects to demonstrate how McHarg's method contributes to performance benefits, especially in the social and economic categories.

3 Human ecological planning: social values and economic benefits

Although McHarg's method is comprehensive and a common practice today, his contributions are frequently misunderstood and/or misrepresented, especially in the social and economic aspects of project performance. Critics of McHarg's method remarked on his lack of interest in social issues and the fundamental difference between McHarg's scheme and the economists' scheme in assessing economic benefits (Gold 1974, pp. 284–285; Herrington 2010, p. 8). In fact, a number of case studies examined in *Design with Nature* (e.g., Delaware River Basin Study, Interstate 95 in New Jersey, Staten Island Project, and Plan for the Valleys) incorporated natural processes (biophysical attributes) and social and cultural issues (McHarg 1996; Toth, R., personal communication, July 20, 2014; Yang and Li 2016, p. 22). McHarg emphasized that post-occupancy evaluations of built projects would increase the collective knowledge of the profession (McHarg and Sutton 1975, pp. 89–90). Beyond the realm of survival (e.g., Darwin's "survival of the fittest"), McHarg's human ecological planning method has led to numerous successful socio-ecological practices (Xiang 2019a, p. 3; b). Many practices emphasized social and economic issues, such as highway alignment and town planning. Figures 1 and 2 show the location of three celebrated ecological planning projects, and Table 2 demonstrates the significance of these projects.

3.1 Interstate 95, New Jersey

After the Interstate Highway Act of 1956, McHarg and his firm WMRT's work focused on rural areas in metropolitan regions impacted by federal highways (Spirn 2000; Steiner 2011). With a million acres of rural lands transforming into urban land uses each year, McHarg criticized the prevailing values of short-term economic determinism—that nature was credited with virtually no value by highway engineers (McHarg and Steiner 2006, p. 15). McHarg argued that form must follow more than just function; it must also respect the



Fig. 1 Location key map of the three case study projects (Interstate 95, New Jersey; Medford Township, New Jersey; and The Woodlands, Texas)

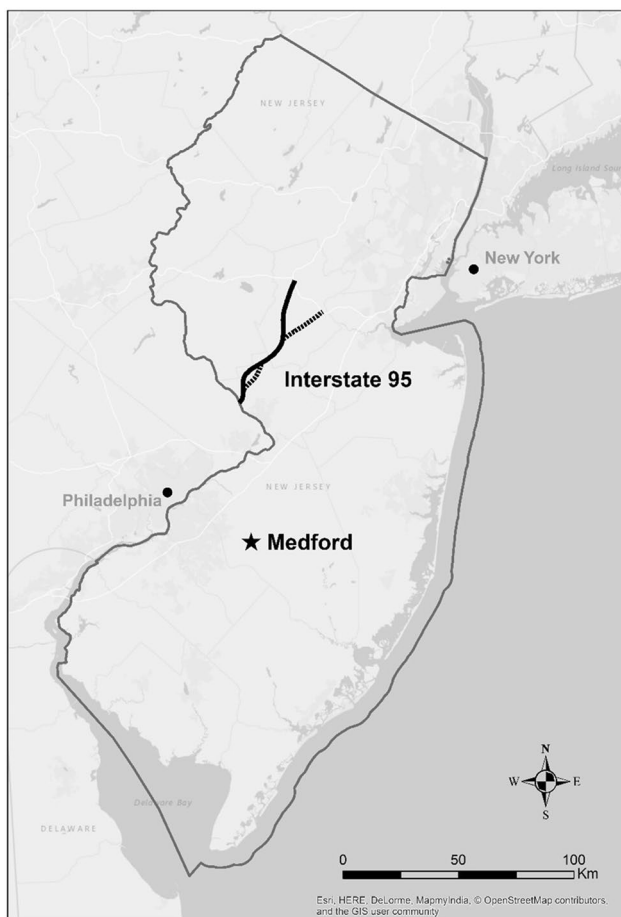


Fig. 2 Location of Medford Township and Interstate 95 in New Jersey

natural environment in which it is placed. The conventional highway planning method was based on the least cost criteria that mainly focused on geology and slope. Although natural resources and esthetic values were among the criteria used in the dominant highway route selection method, a major deficiency was the method's inability to include social values (WMRT 1965; McHarg 1968, pp. 1–2). Social values can include a wide spectrum of factors, such as “historic, water, forest, wildlife, scenic, recreation, residential, institutional, and land values” (McHarg 1969, pp. 31–33; Corbett 2001, p. 2).

For the Interstate 95 project in New Jersey (Fig. 3), McHarg's team articulated that providing an excellent scenic experience (a social value) was a major performance criterion (McHarg 1967, 1968; Evans 2015, p. 11). Social value was emphasized in McHarg's alternative highway alignment method, with criteria expanding from economic to social dimensions (McHarg 1967, 1968; Evans 2015, p. 119).

Compared with the conventional method, McHarg's alternative method presented a holistic cost–benefit analysis that showed the costs and benefits. The benefit side included economic benefits derived from highway projects, including benefits accrued from land-use change (typically in the conversion of agricultural to industrial, commercial, or residential uses). The cost side comprised the measurable plus perceived reduction in economic values resulting from highways, such as constituting a health hazard and potential danger, damaging community integrity, and ruining residential quality, scenic, historic, and recreational values (McHarg 1968, p. 3).

Table 2 Selected Ian McHarg (WMRT) projects that embrace ecohumanism. Adapted from Cohen (2019, p. 231)

McHarg (WMRT) project	Year	Location	Significance (the “first” in the field)
Interstate 95, Comprehensive Highway Route Selection Method	1965	Princeton, New Jersey	Use environmental and social information to decide on a highway route: genesis of environmental impact statement (EIS)
Medford Township	1974	New Jersey	Use ecologically based performance standards for new development; the ultimate goal is to formulate ordinances
The Woodlands New Community	1974	Houston, Texas	Use geohydrological properties to determine land-use patterns and densities for a major development

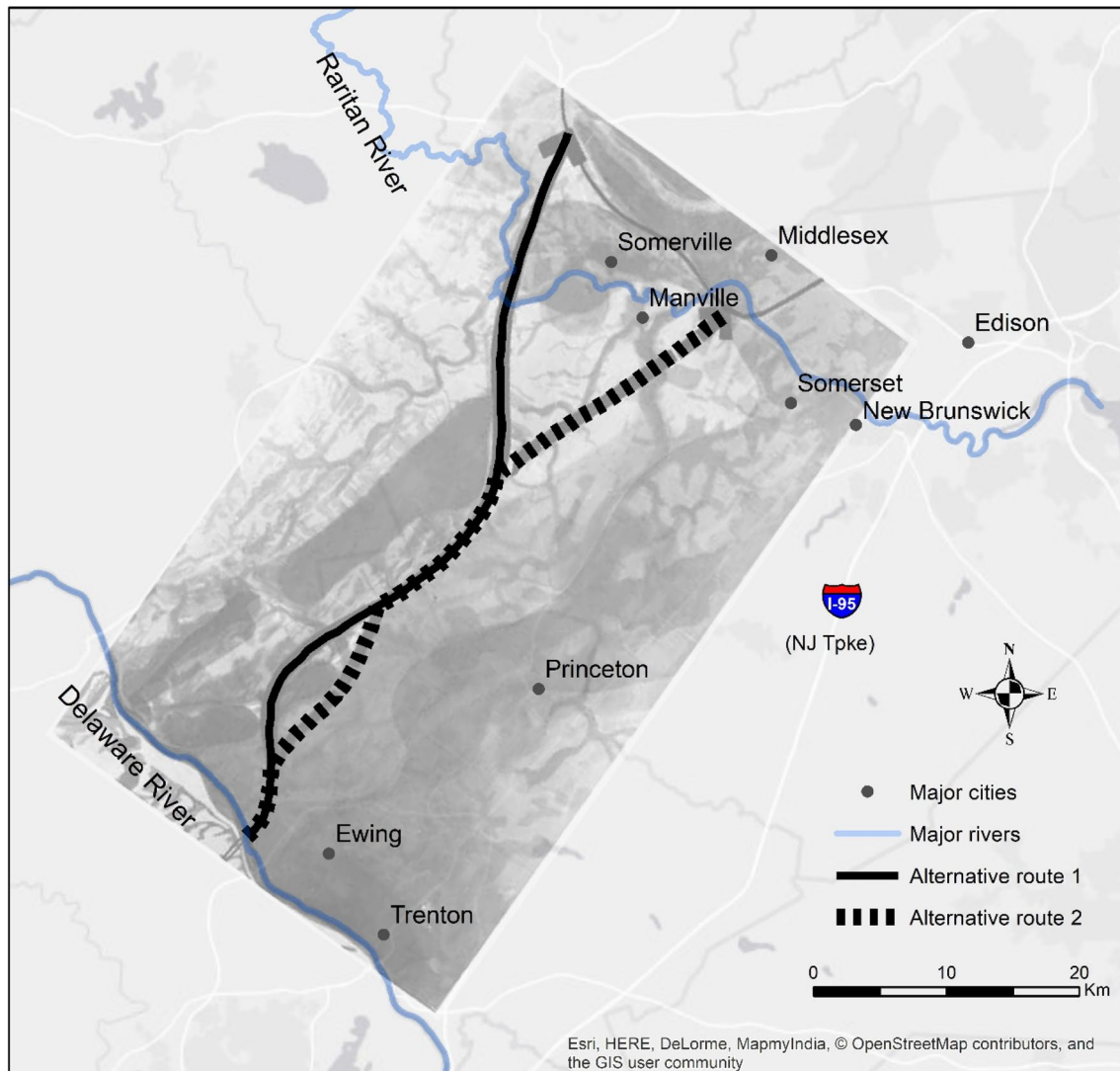
**Fig. 3** Interstate 95 alternative route alignment proposal (as presented in Fig. 12, McHarg 1968, p. 13). Note: The gray background image was georeferenced to match the geographic context. The two alternative routes were digitized based on McHarg’s proposal

Table 3 shows a comprehensive list of components of the costs and benefits attributable to the proposed Interstate 95 alignment. The alternative alignment focused on social value, scenic quality, and natural resources and located these factors geographically. The assumption was that areas with

the lowest social value would experience the least social cost when bisected by the highway (McHarg 1968, p. 4; McHarg 1969, pp. 32–34). In addition, this method not only involved the typical determinants of highway route selection (topography, soils) but also included other environmental variables

Table 3 A comprehensive analysis of benefits and costs attributable to Interstate 95 alignment in New Jersey. Adapted from McHarg (1968, p. 4, Table 1)

Price benefits	Price costs
<i>Operating economies</i>	<i>Costs</i>
Function of distance \times volume \times constant for operating economies and safety	Function of distance \times engineering, land and building acquisition, construction, financing administration, operation, and maintenance
<i>Economic values created</i>	<i>Economic values lost</i>
Increment of increased land and building values attributable to the highway within its sphere of influence	Increment of reduced land and building values due to the same cause
Nonprice benefits	Nonprice costs
<i>Values added</i>	<i>Values lost</i>
Increased convenience, safety, and pleasure provided to drivers on the facility	Decreased convenience, safety, and pleasure to populations and institutions within the sphere of influence; health hazard, nuisance, and danger
Price savings	Price costs
<i>Construction economies</i>	<i>Construction costs</i>
Propitious conditions of topography, geology, drainage foundations, and minimum structures	Inordinate costs due to difficult topography, geology, drainage, foundations, and the necessity for many and/or expensive structures
Nonprice savings	Nonprice costs
<i>Social values saved</i>	<i>Social costs</i>
Community	Community values lost
Institutional	Institutional values lost
Residential	Residential values lost
Scenic	Scenic values lost
Historic	Historic values lost
Surface water	Surface water resources impaired
Ground water	Ground water resources impaired
Forest water	Forest water resources impaired
Wildlife	Wildlife values resources impaired

for better management of groundwater and surface water resources and further reduced vulnerability to erosion—all of which lead to economic savings (McHarg 1968, p. 3). Subsequently, after the minimum social cost and minimum physiographic obstruction scenarios were identified, the highway alignment proposals were assessed based on their effect on scenic values.

Therefore, under the auspices of environmental impact assessment, the outcome of alternative highway alignment considered social values, while embracing economic and environmental benefits (McHarg 1967, 1968, p. 3). As a result, the sum of the least social cost and the highest benefit option of the alignment was identified. It protected social ties and scenic values of communities adjacent to the highway, and it was a low-cost proposal in construction and maintenance. Ultimately, McHarg's assessment framework considered the long-term values and services to the community (e.g., future land values) or, in the contemporary term, ecosystem services.

3.2 Medford Township, New Jersey

The Medford study was another bold step in land-use planning. It was “perhaps the single most important product of the Center for Ecological Research in Planning and Design” that McHarg established at Penn (Cohen 2019, pp. 149–150) (Fig. 4). Residents in Medford resorted to McHarg's team to develop legal tools that would prevent the community from being encroached upon by urban and industrial developments (Holden 1977, p. 381). The goal of the Medford study was not to create a master plan but rather to develop innovative ordinances that can control the Township's growth in order to preserve the quality of its environment. This landmark work, known as “The Medford Development Ordinance (1979)” (Palmer 1981, pp. 373–383), remains in use as a basis to guide planning decisions today (Weller and Talarowski 2014, p. 91).

The Medford study was released in 1974; Narendra Juneja served as deputy principal investigator, and Arthur Palmer



Medford Village - 1980

Fig. 4 Medford Township, New Jersey, in 1980 (Palmer 1981, p. 56). Image courtesy: Creative Resource Systems, Winterville, NC

was specifically responsible for drafting environmental ordinances (Juneja 1974; Palmer 1981). After the analysis of constraints and opportunities, McHarg, Juneja, and Palmer established a framework for performance requisites, which were further proposed to be integrated into the Medford Township plan and zoning ordinances (Juneja, 1974; Palmer 1981; Steiner 2008, pp. 219–220; Cohen 2019).

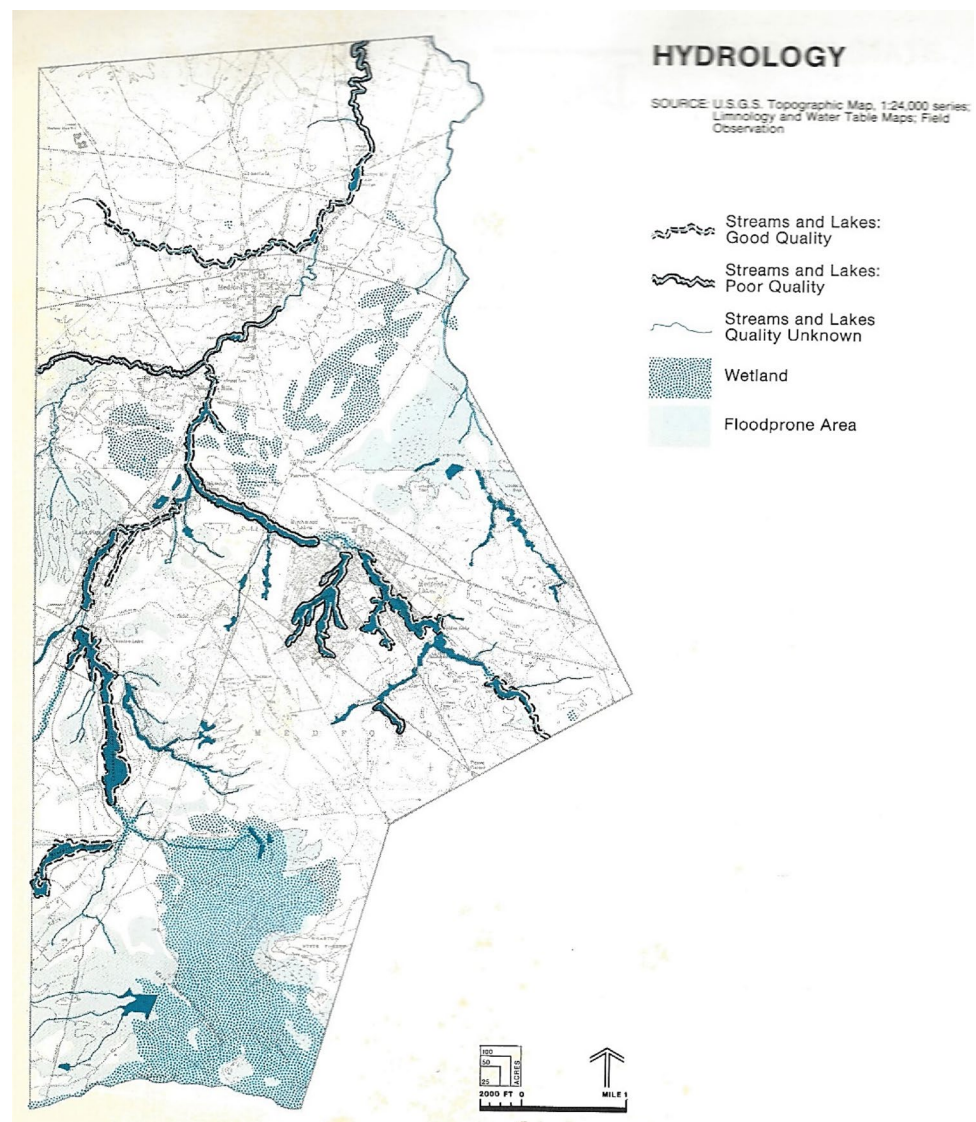
The study specified that “[Medford] development could not adversely affect water quality or quantity, vegetation, or wildlife habitat” (McHarg 1996, pp. 273–285) (Fig. 5). Social values, in addition to the natural environment, were overlaid to develop landscape performance requirements (Ndubisi 2002, p. 78; Steiner 2008, p. 220). McHarg’s team managed to incorporate “social values” into the study “through an extensive public participation program and a concerned citizenry” (Cohen 2019, p. 149). This marked the human ecological planning approach characterized in the later cadre of McHarg’s projects. This new approach used the natural environment as a model for maintaining social values and presented innovations in the landscape suitability approach (Ndubisi 2002, pp. 77–79). In addition, the Medford study put an emphasis on performance, which

“is different from other McHarg’s previous writings, and showed a shift in his projects” (Spirn 1985, p. 48).

Robert Nicholls, a former student of McHarg at Penn and a professor (now faculty emeritus) in the School of Landscape Design at the University of Georgia, noted that “[Medford] is the very first study towards the end of producing ordinances ... to regulate growth in response to the carrying capacity of the natural system.” Additionally, according to Nicholls, the neatly developed compact plan and every proposed ordinance were convincing and defensible. The rationales presented in the study would be nearly invulnerable to legal attacks in court (Holden 1977, p. 381; Palmer 1981; Cohen 2019).

Echoing Robert Nicholls, Carter van Dyke, president of CVDA—Planners/Landscape Architects, another former student who had worked extensively with McHarg and Juneja on this study, also considered Medford a breakthrough because it achieved outstanding policy and land-use recommendations based on project goals. In addition, based on ecological determinants, the Medford study became a critical foundational work of *performance zoning* (Kendig 1980), later developed by Lane Kendig, Carter van Dyke,

Fig. 5 Hydrology analysis of Medford, New Jersey (Juneja 1974, p. 50). Metrics were further developed to protect water quality and to demonstrate hydrology values to society and individual values



and others (particularly with McHarg) (van Dyke, C., January 20, 2019, personal communication).

Based on the successful implementation of zoning ordinances in Medford, Kendig and others expanded the practice of performance zoning in Bucks County, Pennsylvania, Lake County, Illinois, and other municipalities. To its credit, performance zoning is authorized in Section 605(2) of the Pennsylvania Municipalities Planning Code. Kendig also founded Lane Kendig Inc. (now Kendig Keast Collaborative [KKC]). KKC has been applying its expertise in zoning ordinance development in more than 100 jurisdictions across the nation (Kendig and Keast 2010, p. xi).

3.3 The Woodlands, Texas

Tangible economic outcomes have persuaded big developers to accept McHarg's method. McHarg's prize project was

The Woodlands, Texas, considered by many as one of the best examples of ecological planning in the 1970s (McHarg and Steiner 1998, p. 325; Yang 2018; Cohen 2019; Daniels 2019). McHarg stated that he saved the developer George Mitchell \$68 million, broken down into two main components. The first was a \$18 million saving in avoiding the expensive underground stormwater drainage infrastructure, because McHarg's (WMRT's) ecological plan used a series of integrated green infrastructure (GI) strategies (e.g., swale, wetland and forest preservation, infiltration basins) to manage runoff onsite (Fig. 6).

The second component was a \$50 million loan obtained from the US Housing and Urban Development (HUD) (Holden 1977, p. 381). The development has been a financial success in Houston's real estate market (Morgan and King 1987; Galatas and Barlow 2004). More importantly, McHarg's method emphasized long-term economic savings,

Fig. 6 The Woodlands, Texas. Community streetscapes in the subdivision village of Grogan's Mill (e.g., open drainage swales, forest protection along streets, and individual parcels)



looking into future resilience of the community, which was fundamentally different from the conventional approach that focused mostly on short-term economic achievements. When nature ravages (e.g., devastating urban flood), immediate financial losses dwarf short-term economic gains.

As a case in point, The Woodlands performed well in historical storms in the Houston area; in particular, residential villages developed in the early phases that strictly followed McHarg's (WMRT's) plan endured several major storms (e.g., 1979, 1994 Hurricane Rosa, 2001 Tropical Storm Allison, 2008 Hurricane Ike, 2015 Memorial Day flood, 2016 Tax Day flood, 2016 Memorial Day flood, and 2017 Hurricane Harvey). Several of these flood events surpassed 100-year levels (i.e., 1979, 1994, and 2017). Houston and the suburbs of Oak Ridge North and Timber Ridge, which are adjacent to The Woodlands, were awash during these events, whereas The Woodlands, 43 km north of Houston, sustained minimal flooding during most of these events, with relatively minor impact during Harvey (Yang 2018, pp. 212–214). The sharp contrast of flood resilience is because of McHarg's ecological plan as applied in The Woodlands, which Houston lacks (Lyle 1999, pp. 236–237; Fleming 2017; Yang 2018). The total damage of Hurricane Harvey in 2017 was estimated at \$125 billion, even higher than that caused by Hurricane Katrina in New Orleans in 2005. These facts showed that

exorbitant costs can be avoided using ecological planning, which can lead to a higher level of flood resilience as well as sound economic performance.

Furthermore, social dimension was, in fact, explored in The Woodlands (Fig. 7). McHarg had strived vigorously in the planning stage to encompass *human ecology* into the ecological model (McHarg 1996). He invited a group of distinguished social scientists in a conference to suggest ideas about future residents' profiles and their preferences of environment (McHarg 1996, p. 345). Despite the wealth of knowledge generated from this conference, McHarg's proposal for the human ecology piece was unfortunately suppressed by an economist in the team, among other reasons for its failure (McHarg 1996, p. 345).

Despite this disappointment, during the past four decades, empirical studies have consistently shown that The Woodlands' landscape performance supports planning goals. Table 4 presents the planning and design strategies in the environmental, social, and economic benefit categories, detailed by 11 metrics. It is evident that there are close similarities between landscape performance outcomes forecast by McHarg (WMRT) and empirical examinations since the 1980s. In general, landscape performance outcomes are in accord with forecasted scenarios (Yang and Li 2016, p. 26; Yang 2018).

Fig. 7 A typical trail in The Woodlands, which usually goes parallel with the adjacent community/collector street. The extensive trail system makes good connections with subdivision villages and parks and open space, facilitating social interactions



4 McHarg's contributions to landscape performance evaluation

4.1 Interdisciplinary curriculum to enhance landscape performance

McHarg and his followers, including a legion of landscape architects and regional planners, considered themselves “ecological planners.” Many deemed McHarg to be the single most prominent figure who dragged the landscape architecture profession out of restricted boundaries to embrace a broad multidisciplinary collaboration, particularly in the areas of resource management and land-use planning (Holden 1977, p. 379). McHarg’s best legacy at Penn, according to him, was the ecological planning (later human ecological planning) curriculum that he established (Cohen 2003, p. 9; 2019). Because of the interdisciplinary nature of the new curriculum, the associated planning/design process had significantly contributed to landscape performance evaluation, in that performance goals are well in line with project goals. The three aforementioned projects demonstrate this key aspect (Table 5).

The integrated, ecology-based curriculum at Penn was supported by the Ford Foundation in the 1970s. Enrollment preference was given to candidates with natural science backgrounds (McHarg and Steiner 2006, pp. 115–116). As McHarg popularized in *Design with Nature*, the aim was to produce “applied human ecologists.” The curriculum required students to obtain talking knowledge as well as

a certain level of working familiarity in physical sciences, biological sciences, ethnography, and anthropology (Holden 1977, p. 380). In the following decades, Penn’s program and curriculum produced 15 deans, 38 chairmen and directors, and 150 professors; trained 1500 graduate students; and founded 20 new programs worldwide emphasizing ecological planning and design (McHarg and Steiner 2006; Margulis et al. 2007).

In a similar vein, leading texts on landscape performance evaluation have indicated that a true evaluation of the project performance is an interdisciplinary endeavor that requires seamless collaboration throughout the design process and further to the post-construction period and over time to assess how the project endures (e.g., Canfield et al. 2019; McCoy et al. 2018; Yang 2018). Landscape performance draws upon research and knowledge generated from a wide range of disciplines, such as landscape architecture, horticulture, ecology, civil engineering, transportation planning, urban economics, social sciences, and public health. In today’s practice, the ability to assemble a transdisciplinary design and research team has become increasingly important, because landscape architects are tackling more complex, large-scale projects (Domlesky 2018, p. 125).

In addition, McHarg’s concept to enhance project performance was operationalized in a “simple working method for open space” that he proposed in 1964 and applied in his both teaching and practice (WMRT). Essentially, this method delineates environmentally sensitive areas to be preserved as open space, because these areas usually offer

Table 4 Landscape performance is in accord with WMRT's projections (Yang and Li 2016, Table 4, p. 26). Integrated planning and design in The Woodlands: metrics, strategies, and performance fore-

casts in Ian McHarg's (WMRT's) original plan and empirical examinations decades later

Metric	WMRT strategies, performance forecast	References	Empirical analysis decades later	References
1. Stormwater runoff	Link soil permeability with housing density; would generate lower runoff than conventional development	WMRT (1973c), McHarg and Sutton (1975), Juneja and Veltman (1980)	The Woodlands land-use plan minimizes the hydrologic impacts; lower runoff than conventional Houston communities	Juneja and Veltman (1980), Bedient et al. (1985), Yang and Li (2010, 2011), Doubleday et al. (2013), Yang et al. (2013)
2. Flood control	Predicted peak flows increase by 55%, versus 180% in Houston's conventional development	WMRT (1973a, b, c, 1974), Juneja and Veltman (1980), Spirn (1984, 2000)	Peak flows 2–3 times lower than conventional development; peak flows similar to forest conditions during 100-year storms and would be 50% lower if strictly followed McHarg's approach	Doubleday et al. (2013), Yang and Li (2010, 2011), Yang et al. (2013)
3. Water quality	Open drainage, wetland, permeable pavement, building construction BMPs ^a ; lower pollutant levels than Houston's conventional communities	WMRT (1974), Juneja and Veltman (1980)	Pollutant loadings (NO ₃ -N, NH ₃ -N, and TP) are substantially lower than Houston communities ^b	Yang and Li (2013)
4. Water conservation	Minimize irrigation water use through limiting lawn areas and irrigated public space	Spirn (1984, 1985), Kutchin (1998)	n/a	n/a
5. Forest protection	Large, permanent forest preserve; tree protection at street right-of-way and individual parcels	WMRT (1973a, b, c, 1974), Spirn (1984)	Lower levels of forest fragmentation than North Houston communities; 25% land preserve as open space in perpetual	Morgan and King (1987), Galatas and Barlow (2004), Kim and Ellis (2009)
6. Wildlife	Preserve continuous wildlife corridors at wetlands and floodplains	WMRT (1973b, 1974)	Wildlife corridor and forest connectivity well preserved	Spirn (1984), Forman (2002), Kim and Ellis (2009)
7. Urban heat island	Not a focus area in WMRT plan	n/a	On average 2 °C lower land surface temperature than Houston communities	Sung (2013), Yang and Li (2013)
8. Energy conservation	Solar panel application; planting design and housing orientation strategies	Kutchin (1998), Galatas and Barlow (2004)	n/a	n/a
9. Social value	Integrate ecological and social goals; use of floodplains and drainage channels as open space	WMRT (1973b), Spirn (1984)	Good ethnical diversity and integration; rich social events and community employment opportunities; good stand of resident's satisfaction and well-being	Morgan and King (1987), Galatas and Barlow (2004), Forsyth (2002, 2003, 2005), The Woodlands Township (2011)
10. Transportation	Not a focus area in WMRT plan	n/a	Better interconnectedness, higher walkability than conventional Houston communities	Zhang and Yi (2006)
11. Cost-benefit	Would save \$14 million for Phase I alone; low-maintenance parkland and residential yards	McHarg and Sutton (1975)	Potential avoided costs include flooding damage and salvation, personnel injuries, erosion and sediments control, and water quality pollutants treatment; increased housing value due to park and open space	Yang and Li (2010, 2011), Yang et al. (2013), The Woodlands Township (2011)

^aBMP best management practice. Construction fencing is usually only a few feet away from the building footprint to ensure minimum site disturbance

^bNO₃-N nitrate nitrogen, NH₃-N ammonia nitrogen, TP total phosphorous

multiple performance benefits (e.g., wetlands mitigate floods and safeguard drinking water supplies) (McHarg and Steiner 2006, p. 15). More importantly, the benefits typically go

beyond environmental dimension to enhance social capital and economic gains. The method has been applied in the Philadelphia metropolitan region and in other areas of

Table 5 Ian McHarg's ecological planning method aligns performance goals with project goals in selected projects

McHarg (WMRT) project ^a	Principal performance goal	Key project goal
Interstate 95	Preserve excellent scenic quality, minimize physiographic obstruction	Combine least social cost and highest economic benefit in route selection
Medford Township (103 km ²)	Performance requirements on environmental indicators and social values	Regulate growth based on carrying capacity, produce development ordinances
The Woodlands New Community (114 km ²)	Zero runoff from most sub watersheds, reduce peak flow and total runoff	Protect pine forest, maintain groundwater level

^aProject areas are reported in 2019 figures

smaller populations, such as The Woodlands. In addition, the method has influenced numerous other open space studies. McHarg's partner and colleague, David Wallace, illustrated the method in *Metropolitan Open Space and Natural Process* (Wallace 1970).

4.2 Leading firms' practice in landscape performance evaluation

Design with Nature has influenced numerous firms that carry forward McHarg's concept of sustainability. Many of them have progressively integrated an evaluation framework in assessing environmental, social, and economic outcomes. For the empiricist planner, indicator is an important tool to guide planning and policy actions. It is clear that criteria are needed to establish landscape performance benchmarks (McHarg and Steiner 2006, p. 39). In McHarg's concept, indicators (or metrics) would be transferrable to different disciplines and easily comprehended by the public. Indicators can be quantitative or qualitative in nature; they are supported by values, can measure impacts of change, and can produce meaningful information for land planning and/or resource management.

Two examples of practices, Andropogon Associates and Design Workshop, are worth mentioning. Both creatively blend science, especially ecological science in design, and both have established themselves among the vanguard of conducting landscape performance evaluation. Carol and Colin Franklin, Leslie Jones, and Rolf Sauer, former members of McHarg's firm WMRT, founded the prominent firm Andropogon in 1974 (Spirn 1985). Today, the firm enjoys an international reputation and continues to be an influence in how practitioners approach their designs. In particular, the firm uses "designing with nature" as its creed, and many of its projects feature creative stormwater management techniques (Yang et al. 2015, p. 791). In addition, Emily McCoy, principal and director of Integrative Research at Andropogon, led the recent publication *A Landscape Performance + Metrics Primer for Landscape Architects: Measuring Landscape Performance on the Ground* (McCoy et al. 2018). As part of the American Society of Landscape Architects (ASLA) Landscape Architecture Technical Information

Series, the book offers rich information on methods and equipment for data collection and analysis that are most pertinent to landscape field work, such as site preparations and survey of environmental conditions (e.g., soil infiltration rate).

The other example is the landscape architecture and planning firm Design Workshop. The firm has been using Legacy Design[®], the firm's philosophy and methodological framework for landscape performance evaluation, for the past five decades (Design Workshop 2007, p. 10; Jost 2012, pp. 97–99; Mendenhall 2016). Allyson Mendenhall, director of Legacy Design[®] and principal at Design Workshop, believes that Legacy Design offers a comprehensive approach toward sustainability and specifies landscape performance metrics in the four categories of "environment, community, economics, and art" to guide the design process and, ultimately, as a framework to evaluate project outcomes and level of success. This process strives to balance environmental sensitivity, community connections, artistic beauty, and economic viability (Culbertson 2011, p. 235; Leonard 2013, pp. 92–94). Interestingly, 2019 also marks the 50th anniversary of Legacy Design.

Other practitioners and scholars build on McHarg's environmental focus and strengthen social, economic, esthetic, and public health dimensions of sustainability, while advancing theoretical frameworks and actionable agendas (Thompson and Steiner 1997; Steiner 2017, 2018). In particular, the Sustainable Sites Initiative (SITES), co-developed by the ASLA, the Lady Bird Johnson Wildflower Center at the University of Texas at Austin, and the US Botanic Garden, starts to navigate through a collaborative and interdisciplinary pathway toward landscape performance evaluation (Calkins 2012; Steiner 2019, pp. 3–4; Whitlow et al. 2019).

4.3 Policy implications at national and municipal levels

In addition to performance zoning spearheaded by McHarg and Juneja's Medford study, McHarg's method also shaped the direction of sustainability policies at the national level. McHarg's contributions to landscape performance evaluation can be found in the emergence of "environment" in

public policies and programs. Since the 1970s, the health of the environment has emerged as a significant subject (McHarg and Steiner 2006, pp. xix, 40). To the credit of *Design with Nature* and McHarg's influential practice, the Clean Air Act, the Clean Water Act, and several other laws have established standards for environmental quality and have placed limits on pollution (McHarg and Steiner 2006, p. 40).

Particularly after 1962, McHarg played an increasingly important role in developing the intellectual basis and methodological framework for the National Environmental Policy Act (NEPA) (McHarg and Steiner 1998). McHarg's interdisciplinary approach to ecological planning and his systematic evaluation of the plan formed a standard practice in NEPA, and this is particularly reflected in the Environmental Impact Statement (Bass et al. 2001). The Interstate 95 study, according to McHarg, "was the genesis of environmental impact assessments," and the study was "probably its earliest exercise" (Cohen 2019, p. 150). In addition, the 1969 NEPA Section 102(a) requires that for "every federal action," an environmental impact statement ... be prepared that will "utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and environmental design arts in planning and decision making which may have an impact on man's environment" (McHarg 1996, p. 187; Cohen 2019, p. 152). Furthermore, McHarg's human ecological planning (ecohumanism) curriculum at Penn trained copious leaders in public agencies, cultivating environmental policies toward sustainability (Cohen 2003, 2019). These included prominent leaders of the heritage areas movement within the National Park Service (Eugster 2003, p. 53).

Another policy example at the national level was the US Environmental Protection Agency's low-impact development and GI design initiatives substantially promoted by McHarg's theory and exemplary projects (e.g., The Woodlands) (Yang et al. 2015; Yang 2018). A number of municipalities across the USA have adopted GI in their general plan and planning guidelines, and some of them further provided technical manuals that emphasize performance outcomes.

Staten Island in New York is a good example of contemporary policy endeavors at the municipality level. After Staten Island was hard hit by Superstorm Sandy in 2012, the City of New York has been seeking an alternative, ecology-based approach for flood control and community development (Feuer 2014; Gumb et al. 2007). The Staten Island Bluebelt Plan is one of these programs at the city level. The Bluebelt Plan integrated GI strategies (e.g., wetlands, waterways, underground sand filters, and other sponge landscapes) for stormwater management, flood control, and water quality improvement. McHarg's proposal for Staten Island in *Design with Nature* inspired the development of the

Bluebelt Plan (Eisenman 2005; Gumb et al. 2008; Appleton 2012). Partial implementation of the Bluebelt Plan showed encouraging performance outcomes (Gumb et al. 2009). The above examples demonstrate McHarg's contributions to sustainability policy development that aims to create high-performing landscape designs.

5 Conclusions

McHarg's ecological planning method presented in *Design with Nature* and three exemplary projects were reviewed with respect to landscape performance evaluation. We have highlighted McHarg as a pioneer in this enterprise, providing evidence that supports his comprehensive approach toward quantifiable environmental, social, and economic benefits. In addition, we have summarized McHarg's contributions to landscape performance evaluation regarding the interdisciplinary curriculum that he established at Penn, leading landscape architecture and planning firms' practice in landscape performance evaluation emanated from *Design with Nature*, and McHarg's influence in the policy realm that necessitates sustainable development, particularly in the area of environmental impact assessment.

To conclude, McHarg's method anticipates the incorporation of landscape performance evaluation in design. His method establishes a framework and road map beginning with gathering baseline data and establishing performance goals, all of which help guide decision making. Rigorous scholarly works on landscape performance evaluation would also increase the validity of the ecological planning field. McHarg's holistic thinking and demonstration of landscape performance evaluation, social and economic benefits in particular, offer a promising direction to building resilience in our communities, towns, and regions.

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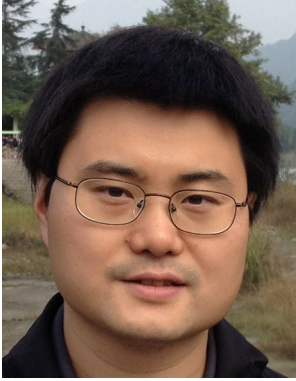
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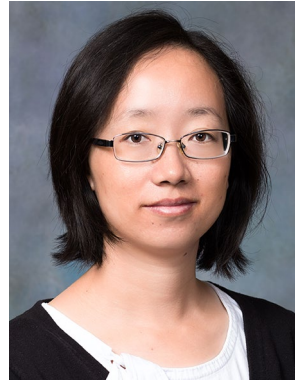
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