ENHANCING QUANTIFICATION OF A LANDSCAPE PROJECT'S ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS: A STUDY OF LANDSCAPE ARCHITECTURE FOUNDATION'S LANDSCAPE PERFORMANCE SERIES

A Dissertation

by

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ABSTRACT

Landscape performance is a newly initiated effort to evaluate the outcomes of landscape solutions in constructed projects. Built upon the sustainability triad, the outcomes landscape performance attempts to measure consists of environmental, economic and social aspects. These outcomes are collected and used to guide future design.

The primary purpose of this study is to enhance landscape performance measurement to better inform future decision making. To achieve this goal, I took a four step approach: 1) reviewing performance measurement in four design disciplines to learn experiences from other disciplines and provide recommendations for landscape performance measurement, 2) studying current published case studies to identify gaps in the current landscape performance quantification practices, 3) analyzing the currently used landscape metrics and methods to identify gaps, and providing recommendations for future improvement, and 4) integrating costs into the framework of landscape performance quantification and exploring economic evaluation methods to valuing non-market landscape performance benefits to facilitate cost-benefit analysis of sustainable solutions.

The results show that compared to previous performance measurements and rating systems, landscape performance is the only one with a framework that addresses the three aspects of sustainability. Its framework uses practices to guide research and simultaneously uses research results to inform practices. It has a good potential of

collecting evidence for sustainable solutions and promoting measureable sustainable landscape practices. However, since landscape performance research is still new, it has a number of gaps, such as insufficient social and economic benefit quantification, insufficient cost consideration, and a lack of core prototype measuring methods and explicitly defined performance benchmarks. These gaps undermine credibility of landscape performance results and restrict its contribution to future decision making. This study helps fill these gaps by providing a number of recommendations, such as developing performance benchmarks for typical landscape solutions, developing robust core measuring systems to facilitate efficient data collection and quantification, and developing sample questionnaires to help with social benefits quantification.

The significance of this study is that it will enhance the framework of landscape performance quantification, clarify cost embedded benefits of sustainable solutions, and promote sustainable landscape design practices.

DEDICATION

I dedicate this dissertation to my daughter and my parents.

ACKNOWLEDGEMENTS

My deepest thanks go to my committee chair, Dr. Ming-Han Li, for his constant guidance, support and encouragement throughout my Ph.D. study at Texas A&M University. My special thanks also go to Dr. Forster Ndubisi for his guidance and support during my research. Their insights and passion for research will benefit my future academic pursuit.

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CHAPTER I

INTRODUCTION

Background

Sustainable development was first put forward by the World Commission on Environment and Development (1987) in the Brundtland Report. It emphasizes pursuing a balance among environmental preservation, economic development and social equity. Sustainable development stimulates the development of planning ideologies such as new urbanism, smart growth, transit oriented development, and traditional neighborhood development. Furthermore, it inspires creative design practices such as low impact development techniques, material recycling/reusing, and brownfield reclamation. These ideologies and design practices are usually considered sustainable development practices and have been widely applied in the past thirty years.

Landscape architecture is an evidence-based discipline, which requires using creditable evidence to guide design. Therefore, evaluating the outcomes of the currently applied planning ideologies and design practices is crucial. Up to now, various studies have shown that the above-mentioned planning ideologies and design practices create numerous benefits, such as promoting walkability, reducing autotrips, improving water quality, and increasing residents' satisfaction. However, these studies rarely examine sustainability's three aspects together, choosing instead to focus on one or two aspects and ignoring the interaction between the three aspects.

Landscape performance is an effort to fill this gap. It measures the outcomes of sustainable development in the environmental, economic and social aspects, and uses this feedback to inform future designs. It was initiated by a non-profit organization — Landscape Architecture Foundation (LAF) — in 2010. Its framework builds upon the sustainable triad (Li et al., 2013), requiring landscape projects to be examined in the environmental, economic, and social aspects of sustainability. LAF advocates landscape performance quantification through the Case Study Investigation (CSI) program. In this program, researchers team up with practitioners to quantify the performance benefits of high-performing landscape projects.

To date, more than 37 research teams and 68 leading landscape firms have participated in the CSI program, and 82 case studies have been published online, contributing to the formation of an "online interactive set of resources to show value and provide tools for designers, agencies and advocates to evaluate performance and make the case for sustainable landscape solutions" (LAF, 2014).

Landscape performance research is still new. There exist a number of gaps in the benefit measurements, methods, framework, and the ultimate guidance on design. The objective of this study is to examine landscape performance, identify gaps, and provide recommendations on how to improve its framework, metrics, and methods.

Organization of Dissertation

I achieved this objective by taking four main steps: 1) reviewing performance measurement in landscape architecture and three related fields to learn experiences from other disciplines; 2) studying and comparing landscape performance case studies published over a two year period to identify gaps, provide recommendations on improvement, and reveal landscape performance's development; 3) analyzing the currently used metrics to identify gaps, and examining the reliability and validity of the currently used quantification methods, and 4) integrating costs into the framework of landscape performance and discussing the possibility of monetizing non-market landscape performance benefits to facilitate cost-effectiveness studies. Each step has a specific research focus, and therefore, is organized in four different chapters. Each chapter is written as a standalone journal article that includes an introduction, method, results, and conclusion.

Chapter II presents performance measurement in architecture, urban planning, transportation and landscape architecture. I first reviewed performance measurement in these four disciplines regarding its definition, historical origin, framework, and metrics and methods. Then, I compared these items across different disciplines, identified similarities and differences, and borrowed successful experiences from the other three disciplines to guide performance measurement in landscape architecture .

Chapter III includes the investigation of landscape performance case studies published in 2011 and 2012/2013. I studied the published CSI case studies in terms of project type, location (rural/urban), size, completion date, and benefit composition, and identified problems existing in the CSI programs. I compared the results of case studies published in the two periods that had different requirements, that is, 2011 vs. 2012/2013. This chapter reveals the current CSI program's weaknesses in project selection and benefits quantification, provides recommendations on how to mitigate these issues, and illustrates how the CSI program has developed over one year.

Chapter IV includes the studies on metrics and methods of the current CSI program. I first compared landscape performance metrics with ecosystem services, a set of post-occupancy evaluation metrics, and checklists of two sustainable development rating systems, Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND) and Sustainable Sites Initiative (SITES), to identify gaps in landscape performance metrics. Then, I made recommendations on how to borrow the appropriate metrics from the above mentioned evaluation systems to improve landscape performance metrics. As for the currently used quantification methods, I used the reliability and validity defined in the book "Measurement, Design, and Analysis: An Integrated Approach" by Pedhazur and Schmelkin (1991) as standards to examine several typically used methods in current landscape performance quantification.

Chapter V documents a study that integrates cost into the framework of landscape performance measurement. I adopted a life cycle cost framework from the literature and combined it with the framework of landscape performance. Then, I used a constructed wetland in one of the LAF's 2012 case studies to demonstrate how to report benefits' costs and how to conduct a cost-benefit analysis. Considering that the value of many landscape performance benefits is difficult to determine, I reviewed literature for currently accepted economic valuation methods and discussed their possibility of monetizing non-market landscape performance benefits.

Finally, I summarized the findings of my four studies in Chapter VI and recommended improvements to future landscape performance quantification practices.

CHAPTER II

REVIEW AND COMPARISON OF PERFORMANCE MEASUREMENT IN LANDSCAPE ARCHITECTURE, ARCHITECTURE, URBAN PLANNING, AND TRANSPORTATION

Chapter Summary

Landscape architecture is an evidence-based discipline, which requires using credible evidence to guide future design. Thus, collecting evidence is of great importance. Landscape performance is an effort initiated in 2010 to collect evidence for sustainable landscape solutions. It emphasizes quantifying the outcomes of constructed high-performing landscape projects.

The purpose of this chapter is to review performance in architecture, landscape architecture, transportation and urban planning; compare its definition, framework and evaluation metrics and methods; and make recommendations that can help improve landscape performance evaluation.

The results show that compared to other performance measurement systems, landscape performance is the only one with a framework that addresses the environmental, economic, and social aspects of sustainability. It has a good potential of assessing sustainable solutions. However, since landscape performance is still new, it has a number of gaps in its definition, framework, metrics and methods. Experiences of performance measurement from the other three fields can help fill these gaps and improve landscape performance. The recommendations are summarized in the conclusion of this paper.

Introduction

Evidence-based design is defined as “design decisions based on the best available information from credible research and evaluation of existing projects” (Stankos and Schwarz, 2007, p.1). It is a relatively new approach emerged in the late 1990s to improve the design quality and users’ experience in the healthcare industry (Sailer et al., 2008). Later on, evidence-based design was extended to be used in other fields too, such as transportation (Bones et al., 2013) and landscape architecture. To promote evidence-based design, collecting credible evidence is of particular importance. Performance evaluation is such an effort that can contribute to this evidence collection and promote evidence-based design practice.

Performance is defined in the dictionary as “the accomplishment of a given task measured against present known standards of accuracy, completeness, cost and speed” (Business Dictionary, 2014). The origin of performance evaluation dates back to the 1940s, when “Measuring Municipal Activities: A Survey of Suggested Criteria for Appraising Administration” was published to advocate municipal activity assessment (Poister and Strieib, 1999). Since then, performance evaluation has been used extensively to evaluate design solutions in different design fields. Post-occupancy evaluation (POE), building performance evaluation, transportation performance evaluation, planning performance evaluation, and landscape performance evaluation have been increasingly recognized in design-related research.

The purpose of this paper is to review performance in architecture, landscape architecture, transportation and urban planning; compare definitions, framework and evaluation metrics and methods; and make recommendations that can help improve landscape performance evaluation.

Methods

Criteria for Selection of Articles

The selection of research is based on the following criteria: 1) the publication focuses on performance evaluation in architecture, landscape architecture, transportation, and urban planning; 2) the publication addresses definition, historical development, goals, and framework of performance in the above mentioned fields; 3) the paper is published in English; 4) considering that performance is closely related to practice, the format of the publication is not limited to papers and books, and reports are also acceptable.

Article Review and Analysis

Research papers were collected and sorted according to different fields (architecture, transportation, landscape architecture and urban planning); each article was scanned and reviewed for information such as definition, purpose, theoretical framework, historical development, metrics and methods, and main points of the publication. This information was summarized in a table and compared across different fields to identify similarities and differences.

Results and Discussion

Definition and Historical Origin of Performance

Performance in Architecture

Building performance evaluation is defined as “the process of systematically comparing the actual performance of buildings, places, and systems to explicitly documented criteria for their expected performance” (Preiser and Vischer, 2005). Building performance evaluation evolves from post-occupancy evaluation (POE), which emerged in the 1960s in the US and Europe.

In the beginning, POEs were centered on evaluation of residential buildings or disenfranchised groups after World War II to ensure the quality of the design and living environment fulfill resident’s demand (Preiser and Vischer, 2005). Later on, they were developed to a mechanism to collect feedback and inform design for building industry and the building types were also expanded to public buildings such as hospitals, prisons, commercial buildings and offices (Preiser and Vischer, 2005).

Building performance evaluation is more comprehensive than POEs. It addresses performance of a building throughout its whole life cycle, while POE constitutes only one step of building performance evaluation (Preiser and Vischer, 2005).

The purpose of conducting POEs is to provide transparent feedback regarding successful experiences in design, construction, operation and use of buildings, and at the same time reveal pitfalls and disappointments (Cohen et al., 2001). Developed from POEs, the goal of building evaluation performance is to improve the design quality through providing sufficient information and opportunities for communication among building professionals and stakeholders at every phase of a building's life cycle, beginning with strategic planning, and moving on to programming, design, construction, facility management, and adaptive reuse.

Performance in Transportation

There is no widely accepted definition for transportation performance measurement. The Federal Highway Administration defines performance measurement as "a qualitative or quantitative measure of outcomes, outputs, efficiency, or cost-effectiveness" (Braceras et al., 2010, p.3). The U.S. Government Accountability Office defines performance measurement as "the ongoing monitoring and reporting of program accomplishments, particularly progress toward pre-established goals" (Braceras et al., 2010, p.3). Generally speaking, transportation performance measures should relate to the goals and objectives of the program and should be ongoing long-term activities (Braceras et al., 2010).

Transportation performance reviews started to be mandated in the early 1980s by legislation due to declined transit performance in the country (Fielding, 1992). Transit ridership had been experiencing a downward trend ever since 1965. In order to remain ridership, federal, state and local governments had spent a great deal of money which resulted in a very high cost per passenger (Fielding, 1992). Considering the inefficiency of transit investment, legislators required transportation agencies to measure public transit performance to ensure they fulfilled earlier expectations (Fielding, 1992).

Reasons for measuring transportation performance are multifold. From a planning and engineering point of view, transportation performance evaluates and analyzes needs and facilitates communication and decision making regarding resource allocation (Baird and Stammer, 2000). From a business management point of view, it improves performance, contributes to knowledge, motivates behavior and ensures control. From a public administration point of view, it improves accountability for public funds and motivates employees and managers (Baird and Stammer, 2000). Overall, performance measures provide convincing and credible evidence for transit planning, inform decision making regarding resource allocation and setting priorities, and reveal problems for future improvement (Dahlgren, 1998; Baird and Stammer, 2000; Falcocchio, 2004).

Performance in Urban Planning

Performance measurement has a number of meanings in the urban planning field. Harry Hatry (1999) defines performance measurement as "measurement on a regular basis of the results (outcomes) and efficiency of service or programs." Efficiency here refers to outcome-focused efficiency, which measures to what extent the desired outcome is accomplished (Hatry, 1999). It is normally used to improve accountability of the agencies and inform decisions regarding budgeting allocation (Hatry, 1999).

Performance measurement in planning dates back to 1943 with the publication of "Measuring Municipal Activities: A Survey of Suggested Criteria for Appraising Administration" (Ridley and Simmons, 1943). Later on, quite a few studies were published to instruct the use of performance measurement, incorporate them in larger management process, and emphasize their important role in the budgeting process (Poister and Strieib, 1999).

Interests in performance measurement slowed down in the 1980s. One common complaint was that performance measurement failed to make sufficient meaningful contributions to decision making, which was also known as DRIP – Data Rich but Information Poor (Poister and Strieb, 1999). This down trend of performance measurement was not improved until the1990s when efforts were made to stimulate application of performance measurement. These efforts include public's demands to hold government agencies accountable for efficiency of budget they spent, the reinventing government movement, and a series of government resolutions such as Government Accounting Standards Board, the National Academy of Public Administration, and the American Society for Public Administration (Poister and Strieb, 1999). By the end of the 1990s, the majority of the states (47 out of 50) required agencies to report performance measures, and result-oriented budgeting was widely employed (Melkers and Willoughby, 1998).

Performance in Landscape Architecture

Landscape performance is defined by the Landscape Architecture Foundation (LAF) as "the measure of efficiency, with which landscape solutions fulfill their intended purpose and contribute toward achieving sustainability." According to Luo and Li (2014), landscape performance includes two levels of meanings: first, it quantifies performance benefits in the three environmental, economic and social aspects; and second, it examines whether the created benefits are always converging and contribute toward achieving sustainability.

Landscape performance was initiated by LAF in 2010. The demand for landscape performance arose from an inquiry LAF made among high profile design firms on landscape performance of their previous constructed landscape projects. The results showed that few firms were confident in describing what landscape performance is, and most did not know how to measure it. These results led to a serious concern that more scientific evidence is needed in the field of landscape architecture.

Since 2011, LAF started to support a Case Study Investigation program to quantify performance benefits of built high-performing landscape projects. The case studies are included in the Landscape Performance Series to form "an on line interactive set of resources to show value and provide tools for designers, agencies and advocates to evaluate performance and make the case for sustainable landscape solutions" (LAF, 2014).

The purpose of landscape performance is threefold. First, it collects evidence for sustainable landscape solutions and reduces uncertainties during decision making.

Second, because it emphasizes quantifying benefits in the three environmental, economic and social aspects, it promotes ecologically and culturally sustainable design practice. Lastly, it clarifies landscape architects' contribution to sustainability.

The comparison of performance definition and origin in architecture, transportation, urban planning and landscape architecture is summarized in Table 2.1. Looking back into time, performance evaluation was initiated in urban planning and architecture first, and became mandated in transportation and landscape architecture later. Different from some rating systems such as Leadership in Energy and Environmental Design (LEED) and Sustainable Sites Initiative (SITES), performance evaluation is a backward analysis rather than a prospective analysis. That is, it evaluates outcomes of a project after it is built and occupied, rather than predicting proposed outcomes based on design documents. From the definition, landscape performance is the only one that addresses sustainability.

The reasons for evaluating performance are not identical across the four fields. However, one common purpose is to collect feedback and inform future designs. The definitions indicate that building, transportation and urban planning performance evaluation is a more long-term approach, focusing on an on-going monitoring. Performance measurement in building, transportation and urban planning is expected to reveal problems at various phases of a project and provide opportunities for immediate revision. On the other hand, landscape performance is a cross-sectional snapshot, which only evidences the existence of performance benefits at a certain time after a project is built.

Comparison is mentioned in the definitions of performance in the four fields. Performance needs to be compared with something to make sense. In architecture and landscape architecture, performance is compared against certain standards to determine whether expected outcomes are achieved. However, in urban planning and transportation, performance is compared with input to determine whether the applied solutions are efficient.

In architecture and landscape architecture, the standards that measured performance is compared against are not completely the same. For architecture, they refer to “explicitly documented criteria”, while for landscape architecture, they refer to designers’ “intended purpose”. As Preiser and Vischer (2005) claim, the criteria in building performance come from four resources: published literature, analogues and precedents, building performance evaluation and post-occupancy evaluation database, and resident experts. These criteria function as performance benchmarks for design solutions.

Standards in landscape performance are not defined as precisely as in building performance. The intended purpose of designers is vague and not clearly stated in landscape performance case studies. Although each case study briefly introduces goals and objectives in the overview, they are quite general and do not provide detailed performance criteria for landscape solutions. Consequently, most case study reports merely list the performance quantification outcomes without conducting the comparison. For example, many case studies report that trees on the project sites sequester carbon dioxide; however, they did not specify whether this result fulfills the earlier anticipation.

Moreover, there is no benchmark to help one determine whether the amount of carbon sequestered is considered as a good performance. These uncertainties prevent landscape performance from making meaningful contribution to future decision making. I suggest future landscape performance case studies to clarify the intended purpose for applied landscape solutions. In addition, LAF could borrow the benchmarking idea from architecture performance and develop a set of performance benchmarks for frequently used landscape solutions against which measured performance can be compared.

Performance evaluation in urban planning and transportation compares input and output/outcome to determine the efficiency of particular solutions. The input often includes items such as money and time, while the output/outcome generally refers to results of the input. Urban planning and transportation projects are normally of larger scales ─ city, region and even nation, involving vigorous competition for limited resources among various parties. How to allocate the resource and budget is of particular importance. Performance evaluation in urban and transportation planning compares output/outcome against input, clarifies cost-effectiveness of design solutions, and provides guidelines for future decision making regarding resource and budget allocation. Plus, performance evaluation helps improve accountability of government and agencies (Falcocchio, 2004; Poister &Strieib, 1999).

It is worth noting that efficiency in the definition of landscape performance is not accurate. In dictionaries, efficiency is defined as comparison between products and costs (Merriam-Webster Online, 2014; Cambridge Dictionary Online, 2014). However, in landscape performance, it is not the inputs and outputs that are compared; instead, measured performances are compared with the expected performances. For this matter, I think landscape performance would be better defined as the measure of the extent to which landscape solutions fulfill their intended performance criteria and contribute toward sustainability.

Table 2.1. Comparison of performance definition and origin in architecture, transportation, urban planning and landscape architecture

	Definition	**Reason for measuring**	**Performance comparison base**	**Year started**
Architecture	"the process of systematically comparing the actual performance of buildings, places, and systems to explicitly documented criteria for their expected performance"	• Provide feedback regarding successful experience and reveal problems • Improve design quality	Performance criteria (benchmarks)	1960s
Transportation	"the ongoing monitoring and reporting of program accomplishments, particularly progress toward pre-established goals"	• Improve performance, contribute to knowledge, motivate behavior and ensure control • Improve accountability • Evaluate needs and facilitate communication and decision making regarding resource allocation	Costs	1980s
Urban planning	"measurement on a regular basis of the results (outcomes) and efficiency of service or programs"	• Improve accountability • Inform decision regarding budgeting	Costs & Benchmarks	1940s
Landscape architecture	"the measure of efficiency, with which landscape solutions fulfill their intended purpose and contribute toward achieving sustainability"	• Collect evidence for sustainable solutions and reduce uncertainties during design • Promote ecologically and culturally sustainable design practice	Intended purpose of designers	2010

Framework of Performance Measurement

Architecture

Performance measurement in architecture focuses on the integral measurement of life-cycle performance of architecture. Its process-oriented framework comprises six major phases throughout the life cycle of a building, including planning, programming, design, construction, occupancy and adaptive reuse/recycle (Preiser and Vischer, 2005).

The review process starts upon completion of the first phase, strategic planning, and continues until the end of a building's life cycle as shown in Figure 2.1. This framework allows evaluation to start relatively early in the design process, detecting problems and providing immediate adjustment opportunities before going to the next phase. The duration of the reviews vary: effectiveness, program, design and commission reviews happen in the first few months or years along with design and construction. But POE is different. Since the life cycle of a building is normally 30-50 years, phase 5 - occupancy is a quite long period. As a result, POE is a long-term on-going monitoring. It is recommended to be conducted every 2-5 years. Because the reviews happen at the end of each phase of a building's life cycle, a wide range of stakeholders are involved, such as the client, programmers, architects, user representatives, and inspection specialists (Preiser and Vischer, 2005). This framework improves communication efficiency between various parties that are interested in the building.

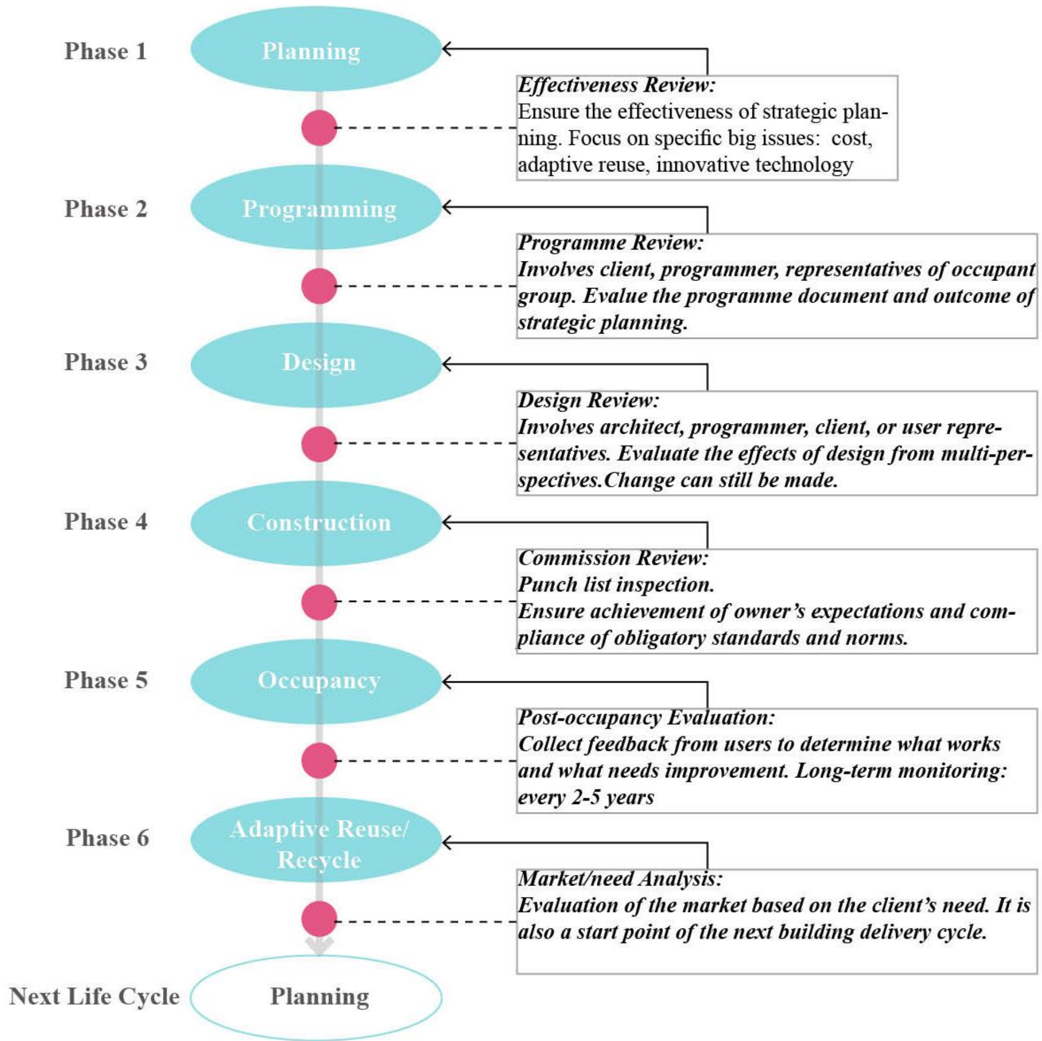

Figure 2.1. Framework of Building Performance Measurement.

There are two types of performance measures: quantitative and qualitative. The quantitative measures evaluate the physical and technique performance of buildings; qualitative measures evaluate how a building is used and perceived by its occupants (Preiser and Vischer, 2005).

Building evaluation performance has three types of function: short-term, midterm and long-term. The short-term function provides immediate feedback to building clients for problem solving; the midterm function provides directions for next building cycle; and the long-term function enhances database for design criteria improvement stage (Preiser and Vischer, 2005).

Building performance measurement consists of three priority levels: technical (e.g., health, safety and security), functional (e.g., functionality and efficiency), and behavioral (e.g., psychological, social and cultural) (Preiser and Vischer, 2005). These performance levels interact and sometimes conflict with each other; in order to increase performance effectiveness, resolution is needed to balance the conflicts (Preiser and Vischer, 2005).

Transportation

Transportation evaluation focuses on a comparable cost-effective analysis of transportation systems. Transportation provides benefits to travelers, such as access to activities and markets, but meanwhile, it costs them for time, money, and environmental degradation (Dahlgren, 1998). Transportation performance measures should relate benefits and costs, revealing problems and facilitating decision making regarding resource allocation (Dahlgren, 1998). The overall benefits and costs of transportation system are summarized by Dahlgren (1998) as shown in Table 2.2.

Table 2.2. Benefits and costs of a transportation system. (Source: Dahlgren, 1998.)

Benefits	Costs
Activities enabled by transportation	Time
Markets enabled by transportation	Money (public and private monetary costs)
Economic and social development	Property loss and injury
Entertainment	Discomfort
Other	Environmental degradation

Generally, there are three types of transportation performance measures, including input, output and outcome (Falcocchio, 2004). Input performance measures refer to the resources invested in a transportation system, such as money spent; output performance measures refer to the products produced by a transportation system, such as number of roads constructed; and outcome performance measures refer to the indirect results of a transportation system caused by output, such as ridership increase (Falcocchio, 2004).

Outputs are easier to quantify compared to outcomes; however, they do not provide sufficient meaningful information to design decision making. For example, the number of increased buses (output) is not as useful as the number of increased riders (outcome) for future designs. Therefore, transportation performance evaluation emphasizes cost-effectiveness, a mix of input and outcome (consumption of output) (Fielding, 1992) (Figure 2.2). Input performance measures are listed in the costs column (Table 2.2), and outcome performance measures are listed in the benefits column (Table 2.2). Output performance measures act as a mediator between transportation system and outcome performance measures.

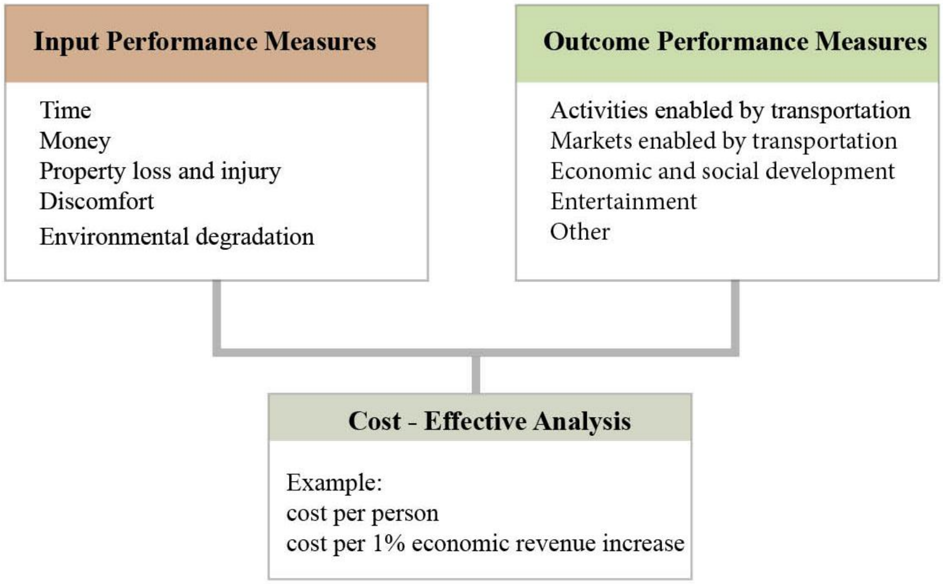

Figure 2.2. Framework of Transportation Performance Measurement

Urban Planning

Performance measurement in urban planning, also known as agency performance monitoring, attempts to evaluate the cost-effectiveness of specific programs and services of government agencies (Hatry, 1999). This evaluation is often customer oriented, focusing on providing good services to customers.

Generally, performance measures can be classified into the following categories inputs, process (workload, activities), workload and activity's basic information, outputs, outcomes, and efficiency and productivity (Hatry, 1999).

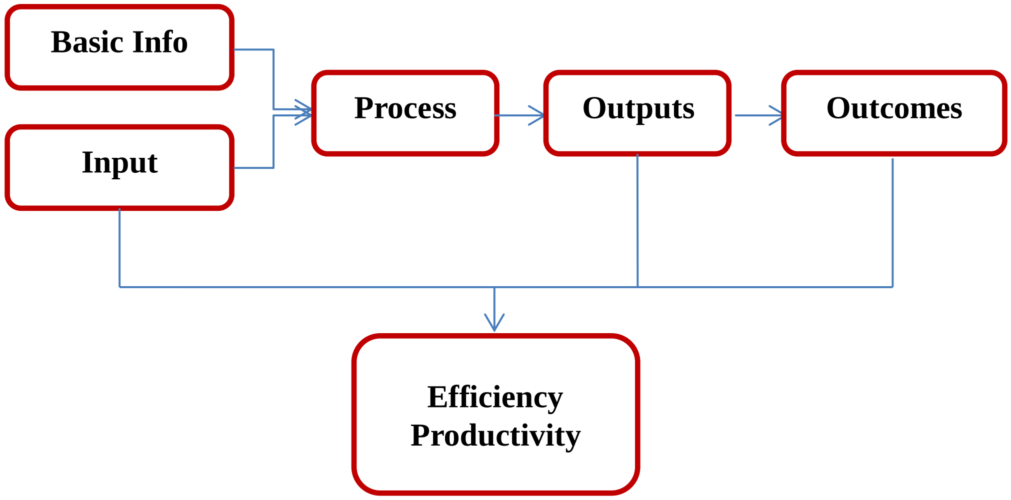

Figure 2.3. Framework of Urban Planning Performance Measurement

According to Hatry (1999), inputs in urban planning are the resources (costs) used to generate outputs and outcomes, such as money and time. This is different from transportation performance, in which tradeoffs is also considered as a part of costs. It is worth noting that outputs are different from outcomes. Outputs are products and services delivered, while outcomes are the consequences of outputs (how the outputs are consumed) (Hatry, 1999). Because outputs do not demonstrate what results are achieved, outcomes are increasingly used as indicators for performance measurement. Efficiency and productivity are similar. They evaluate the cost-effectiveness of input and output/outcome (Figure 2.3). Efficiency is the ratio of input to output (outcome), while productivity is the ratio of output (outcome) to input (Hatry, 1999).

Figure 2.4 shows the process of conducting performance measurement. First, a working group should form to focus on performance measurement. Generally, the working group begins with identifying overall scope, mission, and customers; then, it decides what to be measured, breakouts, data sources and benchmarks that the performance will be compared with. Later, it develops a plan to analyze performance information and a schedule for the steps mentioned above; next, a pilot test will be planned, undertook and reviewed to examine new and modified data collection procedure; after then, the working group implements performance measures, analyzes data and reports the final results (Hatry, 1999). The approximate time of the steps is shown in Figure 2.4.

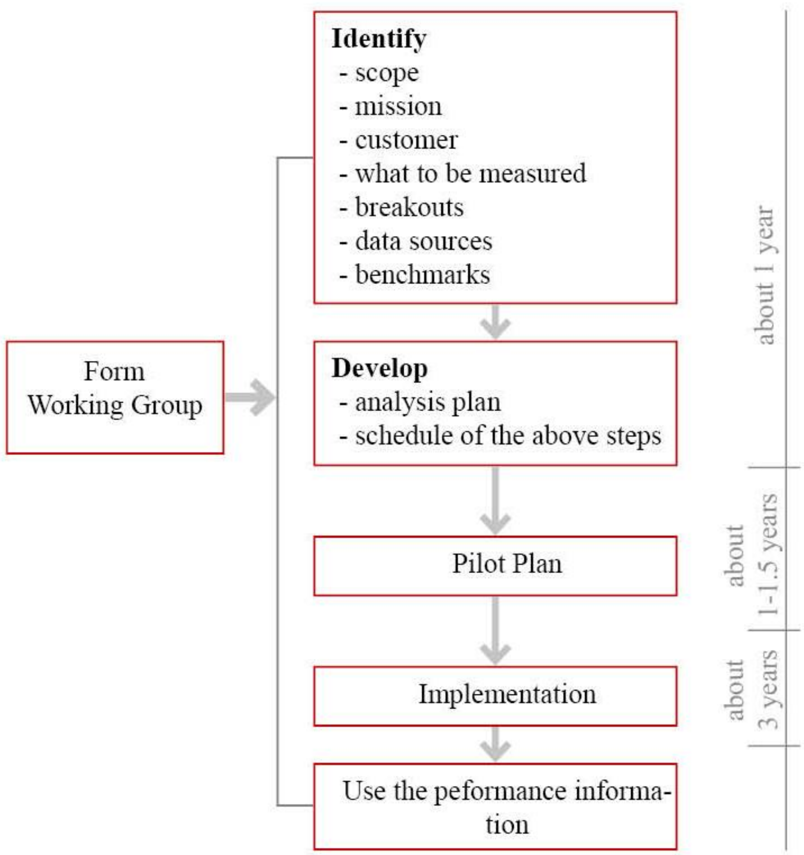

Figure 2.4. Procedure of Urban Planning Performance Measurement

In addition to comparing input with output, urban planning performance measurement also compares performance with benchmarks. The benchmarks come from several sources (Hatry, 1999, p. 119):

1. Performance in the previous period
2. Performance of similar organizational units or geographical areas
3. Outcomes for different workload or customer groups
4. A recognized general standard
5. Performance of other jurisdictions or the private sector
6. Different service delivery practices
7. Targets established at the beginning of the performance period

Landscape Architecture

Landscape evaluation is not new. Various studies have been conducted over the past decades to assess outcomes of landscape projects. For example, Shafer et al. (2000) by surveying users of three greenway trails in Texas, found that greenway trails can improve quality of life and residents satisfaction through resident health/fitness. For another example, Tilman et al. (2006) found that grassland with diverse species sequester more carbon in comparison to traditional lawn. However these studies were only interested in one or two aspects of sustainability and did not recognize the balance and interaction among the environmental, economic and social aspects of sustainability. For the examples above, a trail system might exacerbate the influence of human activities on the natural environment, impact vegetation growth, and damage wildlife habitats. Similarly, grassland with diverse species might cause residents dissatisfaction by creating a messy and wild landscape with the risk of small animals invading into their homes. These piecemeal evaluation approaches did not consider the interaction among the environmental, economic and social aspects of sustainability and could not determine whether a landscape project contributes toward sustainability.

Different from previous research, landscape performance's theoretical framework is built upon the sustainability triad: environment, economy and society (Figure 2.5). This framework allows landscape projects to be investigated in the three aspects of sustainability. According to the requirements of LAF, each case study should report a minimum of five performance benefits and there should be at least one for each type.

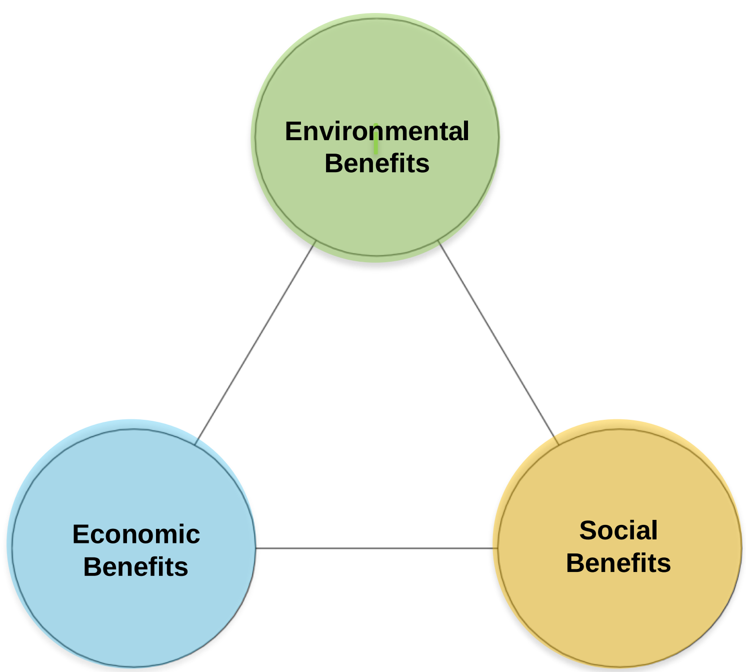

Figure 2.5. Framework of Landscape Performance Measurement

The landscape performance is conducted through a Case Study Investigation (CSI) program. It is a collaboration of faculty, students and leading practitioners, in which practitioners provide baseline information of their constructed landscape projects, faculty as team leaders select quantification metrics and methods, and students quantify and document performance benefits (Figure 2.6). The CSI currently runs from May to August every year, taking advantage of the summer break, when faculty and students can concentrate on research. However, this tight timeframe together with the limited budget only allow research teams to conduct cross-sectional research.

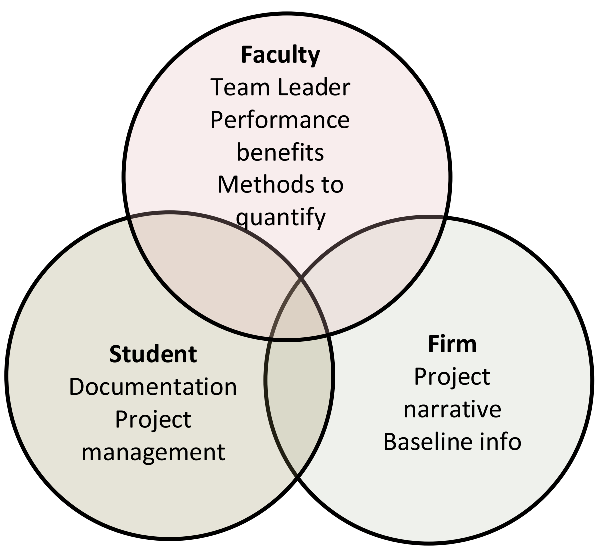

Figure 2.6. Framework of the CSI Program

Unlike building performance, most metrics reported in landscape performance case studies are quantitative. This results from LAF's requirement of reporting benefits with numbers. Research teams need to figure out the answers to questions such as "how much water is saved by using native species?", "how many visitors are attracted because of the plaza?", and "what is the percentage of property value increase due to the park?" For the performance that cannot be reported with numbers, research teams often include them in other sections of landscape performance benefit reports, such as "sustainable features" and "lessons learned."

The comparison of performance framework in architecture, transportation, urban planning and landscape architecture is summarized in Table 2.3. The frameworks of performance measurement in the four fields are quite different. Performance measurement in architecture follows a step-by-step approach along with different phases of a building's life cycle. It aims at revealing problems and providing opportunities for immediate revision before proceeding to the next phase. The framework of building performance measurement involves different sets of performance criteria in every review.

The framework of landscape performance is the only one that requires performance to be quantified in the environmental, economic and social aspects of sustainability. The other three fields, although more or less try to address sustainability, are not as explicit and comprehensive as landscape performance in sustainability assessment. This primarily results from the different purposes and projects of performance measurement in the four fields. In landscape architecture, performance measurement focuses on high-performing landscape projects, which normally employ a range of sustainable solutions. The purpose of landscape performance measurement is to demonstrate the success of these solutions, and consequently, promote ecologically and culturally sustainable design practices.

In architecture, transportation and urban planning, projects that are selected to be measured are not limited to high-performing projects. Performance measurement in these three fields focuses on the achievement of a project's goals and objectives. Building performance is often person-oriented, so health, safety, and users' satisfaction are particularly important. Transportation and urban planning generally focus on cost-effectiveness of programs and services, thus inputs and outputs are most significant. However, it needs to be noted that interests in promoting sustainability through performance are increasing in transportation (USEPA, 2011; Miler, Witlox and Tribby, 2013; Ramani, Zietsman, Ibarra, and Howell, 2013) and architecture (Gu, Lin, Zhu, Gu, Huang, and Gai, 2008; Twill, Batker, Gowan and Chappell, 2011; Meir, Garb, Jiao and Cicelsky, 2009).

As for the duration and frequency of measurement, building performance measurement lasts through a building's life cycle. Reviews during planning, design and construction phases are one-time measures and are relatively quick, while the POE is an on-going monitoring, happening every 2-5 years. Performance measurement of transportation and urban planning performance measurement is similar. It is an on-going process, happening at a certain frequency as a program goes. Unfortunately, landscape performance measurement is currently taking a cross-sectional snapshot approach. Although it successfully demonstrates existence of performance benefits, projects' long-term performance and contribution to sustainability remain unidentified.

In the CSI program, limited budget is one of the reasons why landscape performance takes a cross-sectional approach. Currently, landscape projects do not have funding for performance evaluation. Landscape performance measurement is supported by LAF, a non-profit organization. Every summer, about 10 research teams can be supported to quantify 30-40 landscape projects. Long-term monitoring can be very costly for this amount of projects. I would suggest selecting one to two best cases from each project type to participate in a long-term monitoring program. The performance of these cases will be evaluated periodically (e.g., every 5 years) to complement the current cross-sectional performance measurement.

In terms of costs, building performance evaluate costs during its effectiveness review right after strategic planning; urban planning and transportation performance collects costs as one of its major inputs for cost-effectiveness analysis; landscape performance does not pay sufficient attention to cost at present. Although cost comparison is reported by each landscape performance case study, it takes a piecemeal approach, failing to take life-cycle cost of landscape solutions into full consideration. Benefits are generated at a price. The price not only includes money and time, but could also include tradeoffs. This price is as crucial as benefits for decision making. I would suggest that landscape performance adopts the cost-effectiveness analysis from urban planning and transportation to further clarify performance of landscape solutions and provide better guidelines for future design.

Table 2.3. Comparison of performance framework in architecture, transportation, urban planning and landscape architecture

	Framework	**Involved parties**	**Frequency**	**Consideration of costs**
Architecture	Step-by-step along six phases of the life cycle of a building 1. Planning 2. Programming 3. Design 4. Construction 5. Occupancy 6. Adaptive reuse/recycle	• Client • Designer • Programmer • User representative • Commission agencies • Users	POE :on-going monitoring, every 2-5 years.	Yes
Transportation	Comparison of costs and benefits. Costs: • Time • Money • Property loss and injury • Discomfort • Environmental degradation Benefits: • Access to activities and entertainment • Enabled markets • Economic and social development	• Community • Traveler • Transportation agency	On-going long term monitoring	Yes
Urban planning	Cost-effectiveness evaluation. Focus on efficiency and productivity of programs and services. Inputs vs. Outputs (outcomes)	• Program agency • Customer • Trained observer	On-going long term monitoring	Yes
Landscape architecture	Assess projects in the three aspects of sustainability: Environmental – Economic – Social	• Designer • Research fellow • Research assistant • User	One time measurement	Not sufficient

Metrics and Methods

Architecture

Building performance evaluation goes through the life cycle of buildings with six reviews. Due to the different purposes of each review, methods used for evaluation vary. In the first three reviews before a building is constructed, the evaluation often involves clients, managers, designers, programmers, user representatives and participants from other professionals, such as marketing and real estate (Preiser and Vischer, 2005). Quite a few tools are frequently used to facilitate the communication between various interest groups, including interviews, focus groups, workshops, questionnaires, diaries, group walkabouts and so on (Preiser and Vischer, 2005). These tools ensure that each participating group has opportunities to express their opinion, the designers have a good understanding of users' perspectives, and their professional knowledge and users' demands and wishes reach a balance (Preiser and Vischer, 2005).

The remaining three reviews are real measurement of constructed buildings. The commission review is often conducted by professional agents who possess intensive knowledge (Preiser and Vischer, 2005). This review reveals and solves problems and ensures the satisfaction of clients and users. The market/need analysis evaluates a building as an asset in the aspects of economic, functional, physical, service and environmental to determine its opportunity to be adapted for future uses (Preiser and Vischer, 2005).

POE is most similar to performance evaluation in the other three fields. As the construction knowledge and technology develop, designers and builders are less likely to have opportunities to receive direct feedback from building users; as a result, "each design decision is a hypothesis awaiting its experimental test" (Presier and Vischer, 2005). POE is such an experiment to examine whether design decisions work or not. The interests in POE have lasted for decades. However, the primary challenge of POE remains unsolved – it is difficult to make it routine without continuous funding support from clients after the buildings are delivered (Presier and Vischer, 2005).

Buildings share many similar elements; however, few of them are exactly the same. Performance metrics and methods can vary largely through different projects. However they should meet certain criteria (Presier and Vischer, 2005, p. 77):

- appeal to a wide spectrum of clients
- be applicable in a range of building types
- be comprehensive in the details that they cover;
- be as simple as possible, but not simplistic;
- be practical, with a real-world emphasis;
- be repaid to administer on site, with speedy turn-round of results;
- be acceptable to building managers so that normal use of a building is not unduly hindered;
- be capable of dealing with subtle change from one building and commissioning client to the next;
- provide unambiguous factual data which are well presented and easy to interpret
- be relatively cheap;

- be based on a robust core methodology which meets stringent criteria from different standpoints;
- have continuity, and not fall by the wayside after the development phase is over;
- have, where possible, capability for application internationally.

In addition, standardized methods are beginning to be used in building evaluation to ensure the reliability and generalizability of the results. In UK, two sets of standard evaluation methods are used in a post-occupancy review of buildings and their engineering (Probe) between 1995 and 2002 (Cohen, Standeven, Bordass, and Leaman, 2001). The methods are the TM 22 energy survey method to address technical issues, and the Building Use Studies' occupant questionnaire to address users' perspective issues (Presier and Vischer, 2005).

Besides, various studies have identified trends and needs for future building evaluation. Schramm (1998) argues that inter-cultural differences need to be recognized in the selection of evaluation methods and techniques. Preiser and Vischer (2005) claim that employing multi-method approach could help improve the credibility of findings. They also express that evaluators need to understand the strengths and weaknesses of methods so as to weigh them in the different political and economic contexts (Preiser and Vischer, 2005).

Transportation

Similar to architecture measurement, there is no one set of performance metrics that will fit the needs of all agencies. Metrics and methods in transportation performance evaluation differ from project to project depending on goals and objectives of the projects (Falcocchio, 2004). These goals not only include transportation agencies goals (e.g. serving the public, minimized costs), but also include travelers goals (e.g., access to activities and entertainment) and communities goals (e.g., development and minimized environmental costs) (Dahlgren, 1998).

The various goals of transportation agencies, travelers and communities determine that they have different concerns regarding transportation systems. Transportation agencies tend to be more concerned with the resourced demands of a transportation system (input) as well as the efficiency and productivity of the system (ratio of input to output); customers tend to be more concerned with the service received and costs they need to spend for the service (outcome); and communities tend to be more concerned with the socioeconomic and environmental impact of a transportation system (Falcocchio, 2004).

Metrics and methods need to be linked to these goals and objectives and provide timely reflection on what works and what does not to guide efficient transportation decision making (Falcocchio, 2004). Figure 2.7 shows an example of the metrics development.

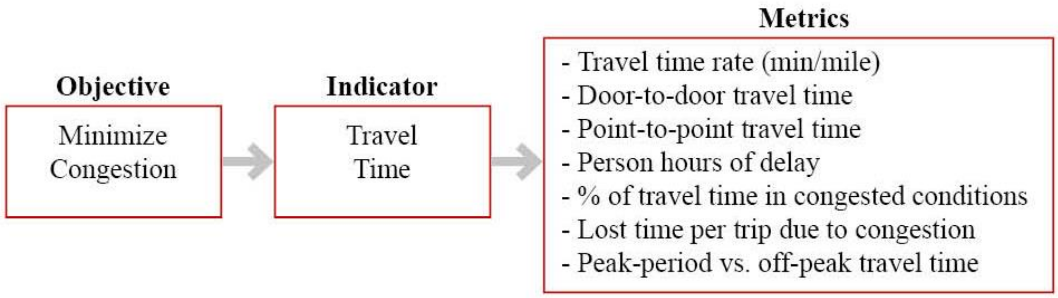

Figure 2.7. Example of Transportation Performance Metrics Development

The example shows that each objective can lead to a number of indicators, each of which can further be measured by various metrics. How to select appropriate metrics and conduct the measurement is crucial for providing timely and regular feedback. Below are some recommendations various studies made on conducting routine performance measurement.

- Limit the number of measures (Fielding, 1992; Dahlgren, 1998; Pickrell and Neuman, 2001)
- Understandable (Pickrell and Neuman, 2001)
- Conside customers perspective (Pickrell and Neuman, 2001)
- Take timeframe into consideration (Pickrell and Neuman, 2001)
- Develop performance standards (Pickrell and Neuman, 2001)
- Consider external factors (Pickrell and Neuman, 2001)
- Continue improving methods (Dahlgren, 1998)
- Develop standardized methods (Dahlgren, 1998)

- Consider different travel situations when creating schedules (Dahlgren, 1998)
- Recognize that different objective have unequal values (Falcocchio, 2004)
- Do not select measures according to data's availability (Transportation Research Board, 2001)

Urban Planning

Performance measurement in urban planning is "results-based" system; therefore, it is important to determine what outcome indicators need to be measured (Hatry, 1999). The outcome indicator selection is limited by available data and measurement resources; generally, it follows certain criteria (Hatry, 1999, p. 58):

- Relevance to the mission and objectives
- Importance to the outcome it is intended to help measure
- Understandability to users
- Program influence or control over the outcome
- Feasibility of collecting reasonably valid data
- Cost of collecting the indicator data
- Uniqueness
- Manipulability
- Comprehensiveness

There are four major methods to collect data and measure performance, including program and agency records, customer surveys, trained observer ratings, and special technical equipment (Hatry, 1999).

Most agencies and programs would collect outcome data as a routine. This data can be used for performance metrics calculation at low costs; however, the disadvantage is that it is normally too basic to comprehensively reflect the quality of service (Hatry, 1999).

Customer surveys are a feasible method to collect data for outcomes. The information that surveys collect can be divided into five categories (Hatry, 1999, pp. 76-77):

1. Questions related to the outcomes of services
   a. Customer condition and attitudes after receiving services, as well as the results of those services
   b. Customer action or behavior after receiving program services
   c. Overall satisfaction with a service
   d. Ratings of specific service quality characteristics
2. Questions seeking information about the type and amount of the service used
   a. Extent of service use
   b. Extent of awareness of services
3. Diagnostic questions
   a. Reasons for dissatisfaction with, or for not using, services
4. Requests for suggestions on improving the service

a. Suggestions for improving services

5. Questions seeking demographic information

    a. Demographic information on customers

Trained observer rating can provide reliable ratings for service and program outcomes. It generally requires systematic rating scales, supervised process with well-trained observers, and periodically checking the rating quality (Hatry, 1999). The formats of the rating systems normally include written descriptions, photographs, and other visual scales (Hatry, 1999). The rating process follows the steps in Figure 2.8.

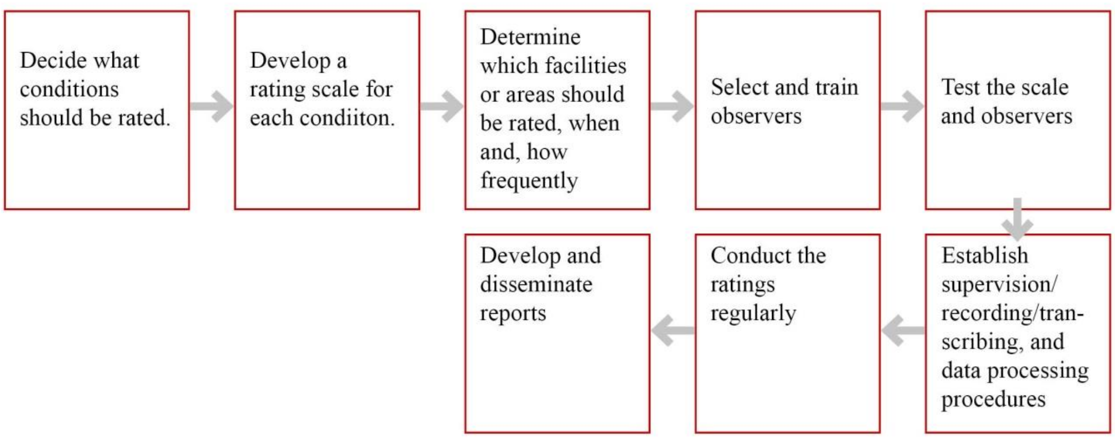

Figure 2.8. Procedure of Trained Observer Rating. (Source: Adapted from Hatry, 1999.)

Special equipment can be used to collect data such as noise level, air pollution, water pollution, and road condition (Hatry, 1999). The advantage of this method is that it provides accurate, reliable data and increases the credibility of the outcome; however, the method can be expensive depending on the equipment and measuring procedure (Hatry, 1999).

Landscape Performance

Attempting to measure sustainability, landscape performance metrics are classified into the three categories: environmental, economic and social (Table 2.4). Each of the groups is further classified into several subgroups.

Table 2.4. Landscape performance metrics

Environmental	Land Water Habitat Carbon, Energy & Air Quality Material & Waste
Economic	Property Value Cost Saving Job Creation Economic Development Other Economics
Social	Recreational and Social Value Public Health & Safety Educational Value Food Production

The selection of metrics often depends on the sustainable solutions that are used in a project. Figure 2.9 shows the approach of landscape performance quantification.

The metrics each landscape performance case study reports differ greatly due to several reasons. First, the landscape strategies each project employed are quite different, determining the diverse metrics that will be used. Second, landscape projects have various goals, size, location, type, and economic and social context. These factors influence the final outcomes of landscape solutions and consequently metrics selection. Lastly, landscape performance research teams typically work separately. Selection of metrics is often affected by the availability of data sources and standard methods and tools that estimate them.

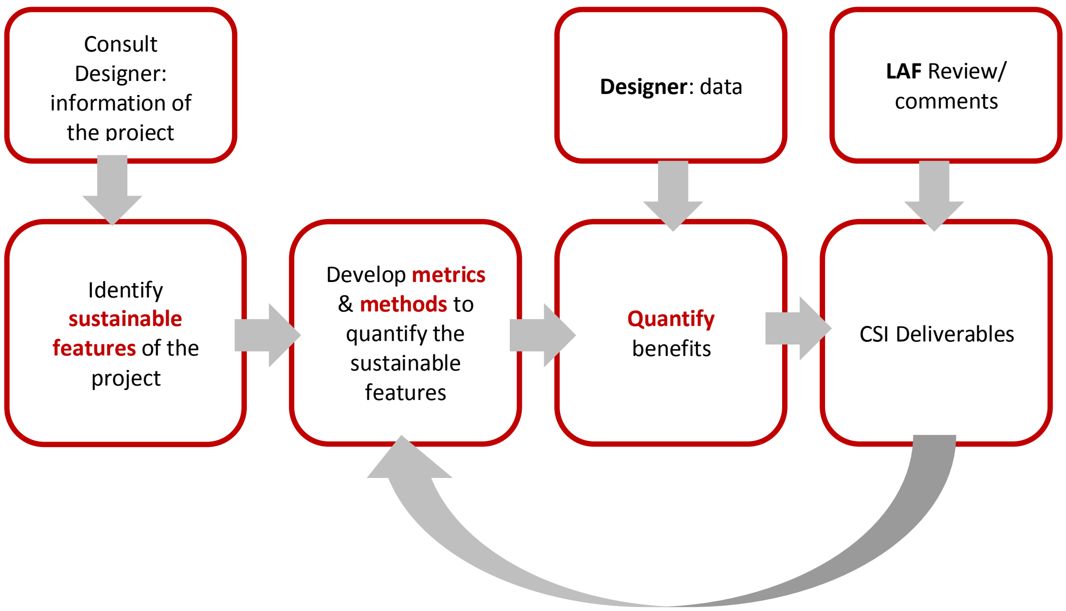

Figure 2.9. Procedure of Landscape Performance Quantification

The methods used in landscape performance case studies are also quite different from case to case. Environmental benefit quantification involves quite a few different methods, such as using devices to test project sites (water quality, noise level, etc.), using peer-reviewed measuring tools (PSI, ITree, etc), and citing previous studies. Economic benefits quantification is challenging, because the data research teams cited for analysis is often at city, regional or national scales. It is difficult to determine how much change can be attributed to a specific project. Social benefits are often measured through surveys and interviews. However, since research time is limited, and surveys normally take a long time to be approved and undertaken, few research teams conduct surveys.

Landscape performance is still new; there exist a number of problems in the metrics and methods. First, three aspects of sustainability include equity; however, the current social benefits fail to address the equity issue in its metrics and methods. Second, the difference in metrics makes it difficult for comparative study between different projects. Furthermore, since the methods used in each case study are often new, and have not been tested sufficiently in different case studies, the reliability and validity is not as good as we would like it to be.

The comparison of performance metrics and methods in architecture, transportation, urban planning and landscape architecture is summarized in Table 2.5. Performance measurement is more developed in architecture, urban planning and transportation. Landscape performance can benefit from experiences of such fields. First, building, transportation, and urban planning performance all emphasize that metrics should be linked to the goals and objectives of projects. That is, they need to measure what the projects are supposed to achieve. Currently, many research teams of landscape performance select metrics according to what data is available, failing to link goals and objectives with the metrics, and preventing the performance quantification from providing meaningful information to future designs. Second, the goals should not be limited to designers' goals, but should also include users' goals. Although, landscape performance metrics, such as job creation, users' satisfaction, and public health and safety, more or less address users goals, they are not as thorough. It would help to include user representatives in performance quantification process to allow their opinion to be fully expressed and understood by the research teams.

In addition, the experience from Probe and transportation performance suggests that standardized prototype would facilitate efficient data collection and comparative study throughout different projects. Currently, about 80 landscape performance case studies are published by LAF, proving abundant information. However, since each case study uses different methods and metrics, it is difficult to summarize meaningful information to guide future design. Standardized prototype measuring system for landscape performance would allow reviewers to compare the cases and better inform future decision making.

Furthermore, transportation and urban planning performance measurements include metrics of efficiency and productivity, which allows comparison between cost and benefit. Currently, cost is not sufficiently considered in landscape performance quantification. This information is as important as benefit for decision making. I would suggest including cost-effectiveness metrics in landscape performance quantification. These metrics can be reported as "$n per pound carbon sequestered" (efficiency) or "n visitors attracted per $1000" (productivity).

Social benefits are not well documented in landscape performance quantification. One reason is that under the tight timeframe, the research teams feel difficult to develop, conduct, and analyze survey. Urban planning and transportation provides detailed guidelines on how to conduct survey and trained observer rating. Both methods are quite suitable for social benefits quantification. I would suggest using these methods to develop several example questionnaire and observer training guidelines. Therefore, future research teams can adopt and modify the examples to facilitate social benefits quantification.

Table 2.5. Comparison of performance metrics and methods in architecture, transportation, urban planning and landscape architecture

	Metric type	Metric selection criteria	Methods	Demand for standard methods
Architecture	Quantitative Qualitative	Appeal widely to clients Be applicable to a range of buildings Simple Comprehensive in detail Practical Relatively cheap Speedy turn-round of results Capable of dealing with subtle changes Provide unambiguous factual data which are easy to interpret Based on a robust core methodology Continuity Where possible, have capability for international application	**POE:** TM 22 energy survey Building Use Studies' occupant questionnaire **Other review:** Interview Focus group Workshop Questionnaire Diaries Group walkabout	Yes
Transportation	Input Output Outcome	Linked to goals and objectives Limit number of measures Make it understandable Reflect customer point of view Consider time frame Set performance standards Track external factors Select measures based on performance rather than availability of data		Yes
Urban planning	Input Output Outcome Efficiency Productivity	Relevance to mission and objective Easy to understand Feasibility of data collection Costs Uniqueness Manipulability Comprehensiveness	Program and agency records Customer survey Trained observer rating Special technical equipment	
Landscape architecture	Quantitative	Linked to applied sustainable solutions Linked to availability of data	Vary greatly across projects	Yes

Conclusion

Landscape performance was initiated in 2010 to measure the outcomes of constructed landscape projects and inform future design decision making. It is still new and has many gaps. The purpose of this study is to explore and compare performance measurement in four design/planning fields, including architecture, transportation, urban planning and landscape architecture and make recommendations on how to improve landscape performance in the future. The comparison results are summarized in Table 2.6. Recommendations for landscape performance are summarized as follows:

1. Landscape performance can be better defined as "the measure of the extent to which landscape solutions fulfill their intended performance criteria and contribute toward achieving sustainability."
2. Selection of landscape performance metrics should be linked to goals and objectives rather than data availability.
3. The goals of users are also important. User representatives can be included in landscape performance, such that their goals can be fully understood by the research teams.
4. Input (costs) need to be considered in landscape performance by including cost-effectiveness metrics.
5. Some performance can only be measured by qualitative metrics. They should be also included.
6. It is necessary to develop performance criteria/benchmarks for typically used landscape solutions.

7. It is necessary to develop robust core prototype measuring system to facilitate efficient data collection and comparative studies through projects.
8. It would be helpful to select a few best case studies to participate in an on-going long-term monitoring to complement cross-sectional CSI studies.
9. Output and outcome needs to be clarified in landscape benefits. “Create n miles of trail” is an output metric. “Increase residents’ daily exercise by n time” is an outcome metric. Performance benefits should focus on outcome metrics.

Table 2.6. Summary of performance comparison in architecture, transportation, urban planning and landscape architecture

	Definition	Reason for measuring	Performance comparison base	Year started	Framework	Involved parties	Frequency	Consideration of costs	Metric type	Metric selection criteria	Methods	Demand for standard methods
Architecture	"the process of systematically comparing the actual performance of buildings, places, and systems to explicitly documented criteria for their expected performance"	• Provide feedback regarding successful experience and reveal problems • Improve design quality	Performance criteria (benchmarks)	1960s	Step-by-step along six phases of the life cycle of a building 1. Planning 2. Programming 3. Design 4. Construction 5. Occupancy 6. Adaptive reuse/recycle	• Client • Designer • Programmer • User representative • Commission agencies • Users	POE :on-going monitoring, every 2-5 years.	Yes	Quantitative Qualitative	• Appeal widely to clients • Be applicable to a range of buildings • Simple • Comprehensive in detail • Practical • Relatively cheap • Speedy turn-round of results • Capable of dealing with subtle changes • Provide unambiguous factual data which are easy to interpret • Based on a robust core methodology • Continuity • Where possible, have capability for international application	POE: • TM 22 energy survey • Building Use Studies' occupant questionnaire Other review: • Interview • Focus group • Workshop • Questionnaire • Diaries • Group walkabout	Yes
Transportation	"the ongoing monitoring and reporting of program accomplishments, particularly progress toward pre-established goals"	• Improve performance, contribute to knowledge, motivate behavior and ensure control • Improve accountability • Evaluate needs and facilitate communication and decision making regarding resource allocation	Costs	1980s	Comparison of costs and benefits. Costs: • Time • Money • Property loss and injury • Discomfort • Environmental degradation Benefits: • Access to activities and entertainment • Enabled markets • Economic and social development	• Community • Traveler • Transportation agency	On-going long term monitoring	Yes	Input Output Outcome	• Linked to goals and objectives • Limit number of measures • Make it understandable • Reflect customer point of view • Consider time frame • Set performance standards • Track external factors • Select measures according to performance rather than availability of data		Yes

Table 2.6 Continued

	Definition	Reason for measuring	Performance comparison base	Year started	Framework	Involved parties	Frequency	Consideration of costs	Metric type	Metric selection criteria	Methods	Demand for standard methods
Urban planning	"measurement on a regular basis of the results (outcomes) and efficiency of service or programs"	• Improve accountability • Inform decision regarding budgeting	Costs & Benchmarks	1940s	Cost-effectiveness evaluation. Focus on efficiency and productivity of programs and services. Inputs vs. Outputs (outcomes)	• Program agency • Customer • Trained observer	On-going long term monitoring	Yes	Input Output Outcome Efficiency Productivity	• Relevance to mission and objective • Easy to understand • Feasibility of data collection • Costs • Uniqueness • Manipulability • comprehensiveness	• Program and agency records • Customer survey • Trained observer rating • Special technical equipment	
Landscape architecture	"the measure of efficiency, with which landscape solutions fulfill their intended purpose and contribute toward achieving sustainability"	• Collect evidence for sustainable solutions and reduce uncertainties during design • Promote ecologically and culturally sustainable design practice	Intended purpose of designers	2010	Assess projects in the three aspects of sustainability: Environmental – Economic – Social	• Designer • Research fellow • Research assistant • User	One time measurement	Not sufficient	Quantitative	• Linked to applied sustainable solutions • Linked to availability of data	Vary greatly across projects	Yes

CHAPTER III

A STUDY OF LANDSCAPE ARCHITECTURE FOUNDATION'S CURRENT CASE STUDY INVESTIGATION PROGRAM*

Chapter Summary

Landscape performance, as defined by Landscape Architecture Foundation (2014), is "the measure of efficiency with which landscape solutions fulfill their intended purpose and contribute toward sustainability." It is an effort LAF made to collect scientific evidence for landscape projects.

The purpose of this study is twofold: 1) to identify gaps of the Landscape Performance Series' Case Study Investigation (CSI) program through studying benefit composition, project type, size, location, distribution and completion date; 2) to explore whether landscape's environmental, economic and social benefits are conflicting or converging for sustainability.

In this study, the data used are LAF's 76 landscape performance case studies published by 2011, 2012 and 2013 CSI programs. The results indicate that landscape performance benefits are not balanced; environmental benefits are better documented, however social and economic benefit documentation was improved in 2012/2013 CSI cases. Most projects are located in urban areas and projects are not evenly distributed to different size groups and project types. Completion date of projects does not have a

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significant influence on number of benefits created. Conflicts exist between environmental and social benefits, environmental and economic benefits, and social and economic benefits as well. Understanding the interrelationship between the environmental, economic and social benefits allows designers to enhance the compatible relationships, mitigate the conflicting relationships and create high-performing landscapes in the future.

Introduction

The term "landscape performance" has caught attention of landscape architecture research communities recently. Landscape Architecture Foundation (LAF) began to advocate the importance of knowing performance of built landscapes in 2010. This effort starts from an inquiry among high-profile design firms on performance of their past built projects. The result is that very few firms were confident in articulating what landscape performance is and most did not know how to measure it. One of the common problems is that no firm collects data pre, during and post project periods. LAF's simple inquiry leads to a concern that the landscape architecture field and discipline is lack of rigorous scientific training, which can be a serious disadvantage in multi-disciplinary collaborations. Subsequently many efforts have been devoted into the landscape performance research such as Landscape Performance Series (LPS) and Case Study Investigation Program (CSI) by LAF. Although landscape performance is still in its infancy, it catches increasing attention from researchers and practitioners and has been growing rapidly in recent years. It provides organized feedback of landscape solutions, reduces uncertainties of design decisions and contributes to success of sustainable development.

LAF defines landscape performance as "the measure of efficiency with which landscape solutions fulfill their intended purpose and contribute toward achieving sustainability." Particularly, the theoretical framework of landscape performance is built upon the sustainability triad: environment, economy and society. Under this framework, participating landscape projects are required to be examined in the three environmental, economic and social aspects to document the benefits created in the three aspects. As Campbell (1996) describes, sustainable development is the balance of the three goals: 1) environmental protection, 2) economic development, and 3) social equity; in order to achieve sustainable development in the center of the sustainability triangle, we need to resolve the conflicts among the three goals (see Figure 3.1).

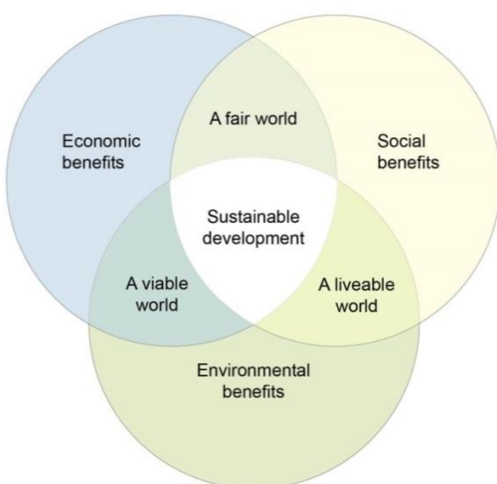


Figure 3.1. Framework of Sustainable Development
(Adapted from Sustainable Site Initiative)

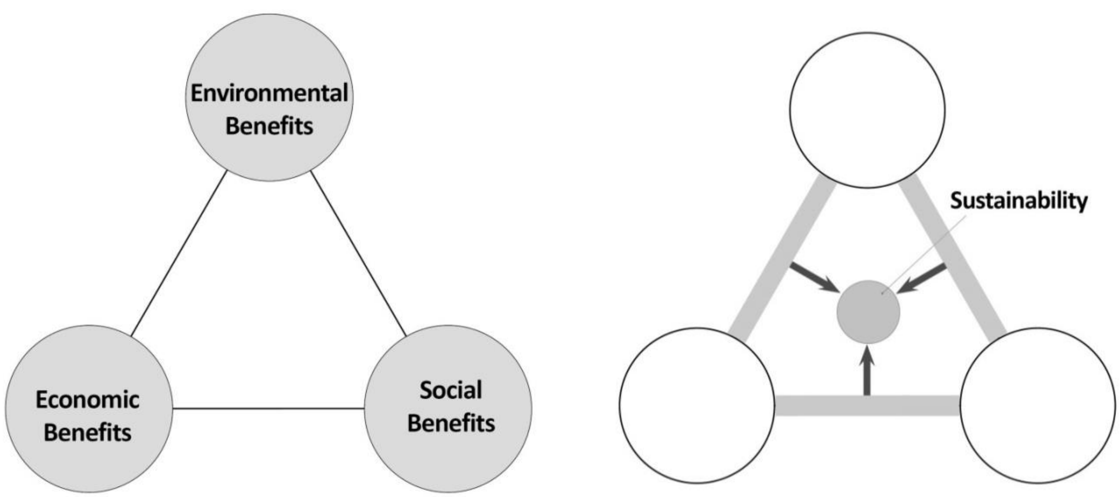
Quite a few planning ideologies were developed to achieve this balance, such as new urbanism, smart growth, transit-oriented development (TOD), and conservation subdivisions. In addition, numerous design solutions were created for the same purpose, such as reusing/recycling materials, using renewable energy resources, using arid-tolerant and native species, and applying low impact development (LID) techniques. These planning and design solutions have been widely employed in the past two decades; however, very limited data and evidence were collected to prove that to what extent these solutions have improved the environment, boosted economic development and benefited public health and safety. This leaves a gap in the field of landscape architecture, and makes it difficult to demonstrate how landscape architects contribute to sustainability.

Various efforts have been made to fill this gap, such as Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND), Sustainable Site Initiative (SITES), and LAF's LPS. LEED-ND and SITES are both rating systems, providing guidelines and performance benchmarks for sustainable land design (USGBC, 2014; SITES, 2014). These rating systems have promoted application of sustainable landscape solutions, such as smart site, materials reuse/recycle, energy/water saving, and pedestrian-oriented design. To obtain LEED or SITES certifications, landscape projects need to employ a wide range of these solutions. However, from an evaluation point of view, the scoring process of these rating systems is mostly based on prediction rather than actual measurement. For instance, we believe reusing/recycling materials would save construction cost and benefit the environment; however, how much is saved in cost, and to what extent the environment is improved remain unclear.

LAF creates LPS as "an on line interactive set of resources to show value and provide tools for designers, agencies and advocates to evaluate performance and make the case for sustainable landscape solutions" (LAF, 2014). Different from LEED-ND and SITES, LPS is intended to actually quantify landscape performance of built projects through a series of call for "Case Study Investigations (CSIs)." By far, the CSI program is in its fourth year; more than 29 research teams and more than 52 leading landscape architecture firms have participated in it. The CSI research is built upon a collaboration of faculties, students and leading practitioners. Under the collaboration, firms provide projects' baseline information, faculties, as team leaders, develop performance benefit metrics and quantification methods, and students, as research assistants, quantify and document landscape performance benefits (LAF, 2014). By now, more than 90 landscape cases have been analyzed and documented. It needs to be noted that, many cases are under the review and publishing process, and by the time when this study was conducted (January, 2014), only 76 cases were available online.

In my opinion, landscape performance has two levels of meanings. First, it measures whether or to what extent landscape solutions meet designers' intention, specifically, whether the applied landscape solutions create benefits that were envisioned. For example, do native species actually save 20% of potable water? Do LID techniques really sustain 100-year storm? Does a constructed wetland firmly reduce concentration of metals and nutrients in water? Does open space truly increase property value? And does living close to a trail system indeed increase residents' satisfaction? This level of meaning is represented in the three points of the triangle (see Figure 3.2a).

Second, it examines whether these benefits contribute toward sustainability. Paradoxical as it seems, we should not assume the benefits created always contribute toward sustainability. This level of meaning is represented in the connectors between the three points, which are the interrelationships between environmental, economic and social benefits (see Figure 3.2b). Theoretically, the three environmental, economic and social aspects of sustainability have interest clashes, determining that there are unavoidable conflicts among them (Campbell, 1996). These conflicts explain why we need to seek a balance between environment protection, economic development and



(a) Level 1 Meaning – landscape performance benefits

(b) Level 2 Meaning – whether interrelationships between environmental, economic and social benefits are converging and contribute toward sustainability

Figure 3.2. Two Levels of Meaning of Landscape Performance

social equity. It is quite possible that solutions to landscape problems in one aspect might cause problems in others. For example, economic development would possibly increase infrastructure demands, increase local population, rise resource consumption, pollute air and water quality, impact vegetation growth, and degrade wildlife habitat. Further, some ecological planning methods might also affect publics' satisfaction and as a result, people do not want to pay for them. Considering the above arguments, it seems that certain benefits would impede other benefits, and therefore result in tradeoffs in landscape performance.

The purpose of this study is twofold: 1) to identify gaps of the Landscape Performance Series' CSI program through studying benefit composition, project type, size, location, distribution and completion date; 2) to explore whether landscape's environmental, economic and social benefits are conflicting or converging for sustainability.

Methods

I conducted a literature review and assumption based case study. The assumptions I made include 1) the CSI research teams endeavored to document all quantifiable benefits, and the methods and results are reliable, and 2) for the purpose of benefit composition study, the numbers of each type of benefits represents how well the benefits are documented and the weight and significance of each benefit is considered the same. Certainly, the second assumption is not always true in real life; however given that each project has different goals, it is impractical to determine the weight of each benefit, so I used benefit numbers of each category and their relative ratios to the total number of benefits to roughly demonstrate each project's benefit composition.

The sample I used in this study is the 76 landscape performance cases published by the LAF in its 2011 and 2012/2013 CSI programs. In order to study the benefit composition, I classified benefits of each of the 76 landscape performance case studies into the three environmental, economic and social categories, and created a scale to represent benefit composition. In this scale, total benefit number is 100%, and the relative ratio of each of the three environmental, economic and social categories is calculated using the following equation:

$$R = \frac{number\ of\ each\ type\ of\ benefits}{(total\ number\ of\ benefits\ )} \times 100\% \qquad (3.1)$$

where R is the relative ratio of each benefit category. As shown in Figure 3.3, the top corner of the scale represents projects that report more economic benefits, the left bottom corner represents projects that report more environmental benefits, the right bottom corner represents projects that report more social benefits, and the triangle in the center represents projects that have similar numbers of environmental, economic, and social benefits.

With regard to exploring the interrelationships between benefits, I first reviewed literature and identified potential conflicts existing among environmental, economic and social benefits. Then I studied the classified benefits of each case study to identify any potential conflicts between their benefits.

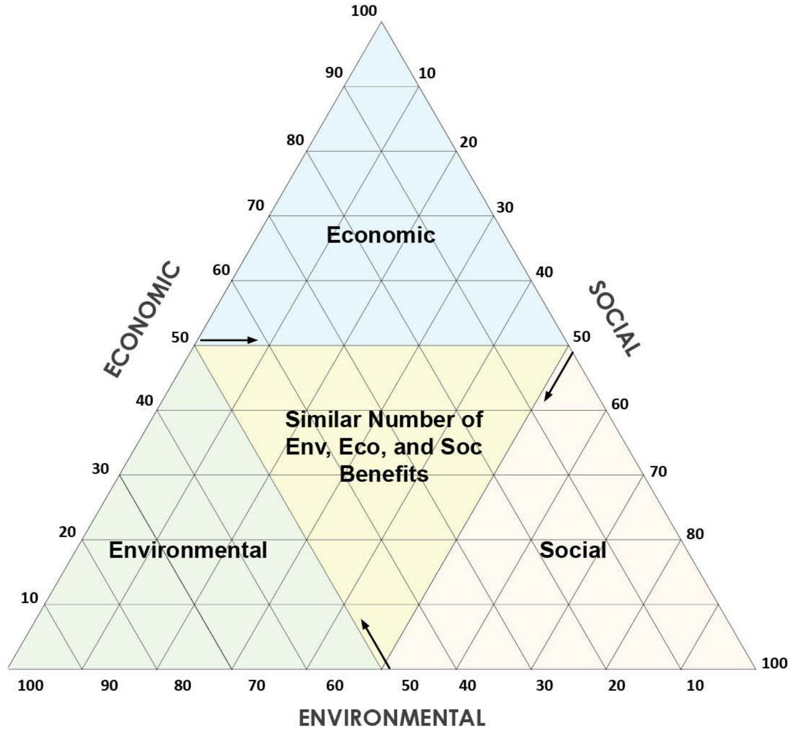


Figure 3.3. Landscape Performance Benefit Composition Scale.

Results and Discussion

<u>Review of the Current CSI Program</u>

Projects' Distribution

Among the 76 landscape performance cases we studied, seven are international cases including one from Australia, four from China, one from Italy, and one from South Korea. The distribution of the United State cases is illustrated in Figure 3.4. The green dots represent 2011 cases, and the orange dots represent 2012/2013 cases. The dots of larger sizes represent more than one cases are located at the same places. The figure indicates that, most cases are located in the northeastern and western parts of the country, with a few cases located in the mid-central states. There are few CSI cases located in northern and southeastern parts of the country.

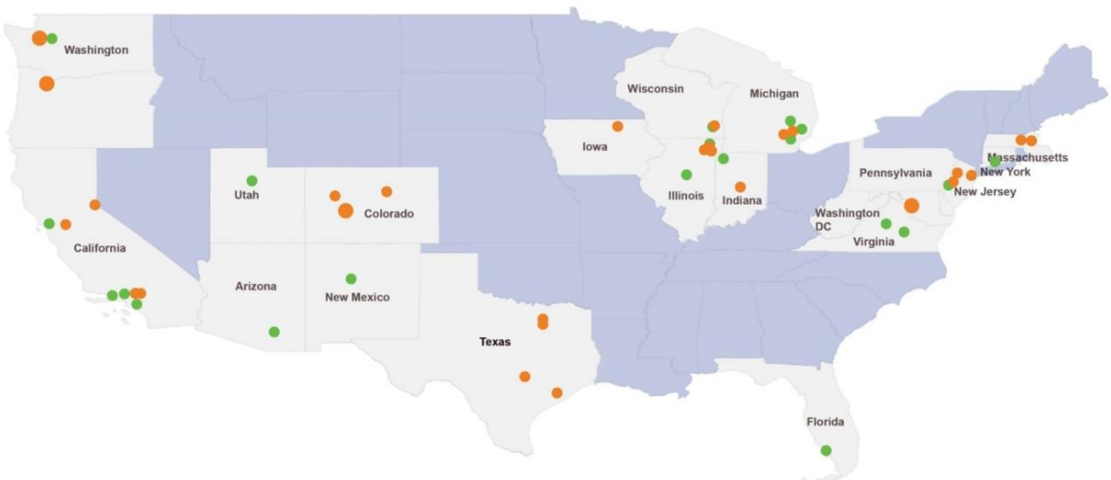


Figure 3.4. Distribution of the CSI Cases in the United States

Project Type

In 2011, 22 project types were included in CSI program, such as golf course, industrial park, community, stormwater management facility, natural preserve, and park. In 2012/2013 CSI programs, six new project types are added, including civic/government facility, wetland creation/restoration, single-family residence, resort/hotel, working landscape, and recreational trail. The summary of project types and the number of cases in each project type is shown in Table 3.1. In both years (2011 and 2012/2013), most project types studied are park, stormwater management facility, and natural preserve. Compared to 2011, cases in courtyard / plaza, streetscape, and wetland creation/restoration increase significantly, while cases in many other project types, such as conference, industry park, resort, playground and multifamily remain few. Certainly, some of these project types are less popular, so there is less cases for the CSI program to select from; however, community, multi-family residence and playground are quite common. Including more cases from these project types could help with conducting comparative studies between cases of the same type, and better contribute to future landscape designs of these popular project types.

Table 3.1. Project type of 2011 and 2012/2013 CSI case studies

Project Type	2011	2012	Total
Conference / Retreat Center	1		1
Golf course	1		1
Industrial park	1		1
Sports facility, other	1		1
Civic/Government Facility		1	1
Resort/Hotel		1	1
Working Landscape		1	1
Recreational trail		1	1
Community	2		2
Multi-family residence	1	1	2
Playground	1	1	2
Urban agriculture	2		2
Healthcare facility	1	2	3
Office	2	1	3
Other	1	3	4
Retail	2	2	4
Transportation	2	2	4
Single Family Residence		4	4
Garden / Arboretum	4	2	6
Waterfront redevelopment	2	4	6
School / University	4	3	7
Stream restoration	5	2	7

Table 3.1 Continued

Project Type	2011	2012	Total
Wetland creation/restoration		7	7
Streetscape	3	7	10
Nature preserve	7	5	12
Stormwater management facility	8	4	12
Courtyard / Plaza	6	11	17
Park	19	14	33

Project Size

I classified the 76 cases to five size categories: 1) less than 1 acre; 2) 1-10 acres; 3) 10-100 acres; 4) 100-1000 acres and 5) larger than 1000 acres. The result of project size study is shown in Table 3.2. In 2011, most cases are in “1-10 acres” and “10-100 acres”, limiting the generalizability of cases studies in the other three size categories. In 2012, the cases are more evenly distributed across three categories. This change helps increase CSI programs’ diversity and improves the reliability.

Table 3.2. Project sizes of 2011 and 2012/2013 cases

	Area ≤ 1 acre	**1-10 acres**	**10-100 acres**	**100-1000 acres**	**Area ≥ 1000 acres**
2011	3	16	14	3	3
2012/2013	8	11	9	5	4

Project Location

I also classified the 76 cases into rural and urban groups based on population densities of the places where the projects are located. The rural group includes both rural and suburban projects. The result is shown in Figure 3.5. In 2011, seven of 39 cases are located in rural and suburban areas, accounting for 18% or all cases. In 2012/2013 case studies, nine of 37 cases are located in rural and suburban areas, accounting for 24% of all cases. The result indicates that the rural projects increase slightly in comparison to 2011, but the majority of the projects are still located in urban areas.

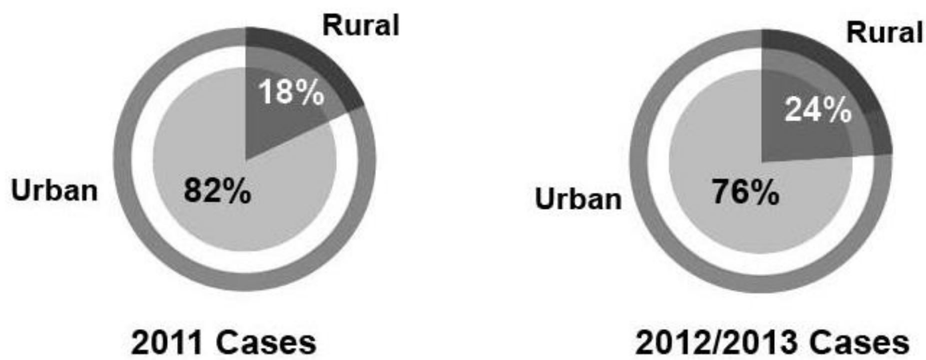


Figure 3.5. Project Location of 2011 and 2012/2013 Cases

Projects' Completion Dates

Landscapes develop and change overtime, some landscape performance benefits may need longer time to appear. For this reason, I studied completion date and benefit numbers of the CSI cases to test whether projects that were finished earlier create more benefits compared to newly finished projects. Figure 3.6 shows the completion dates of the 76 CSI cases. The majority of cases in both years were completed within five years. In order to capture the development and change of landscapes, I recommend selecting projects that were completed at different time periods, especially projects that are of similar type, size, and social context, such that we can comparatively study similar projects over time.

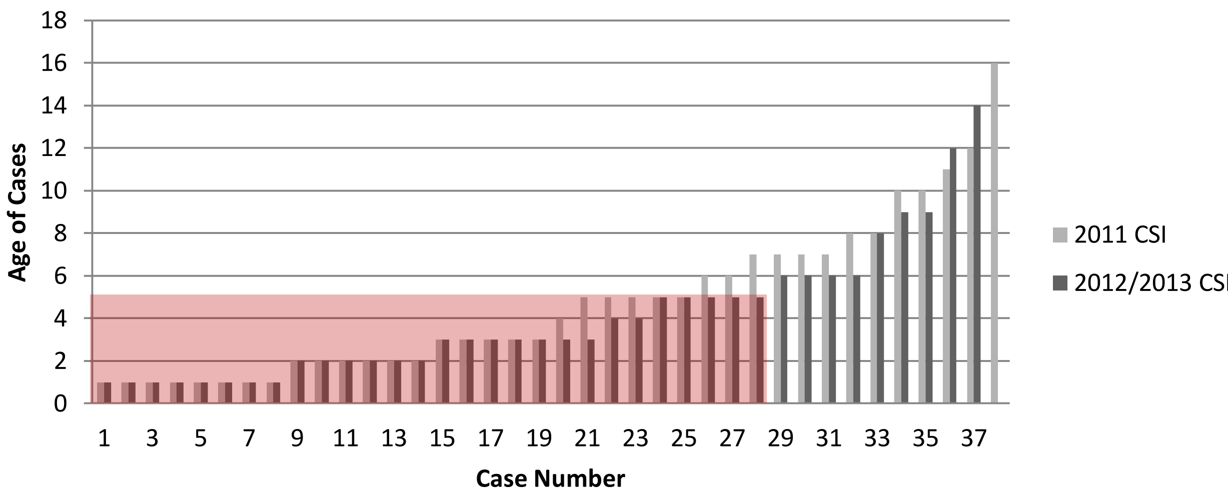


Figure 3.6. Projects' Completion Dates of 2011 and 2012/2013 Cases

Influence of Projects' Completion Dates on Benefits

The relationship between projects' completion dates and benefit number is shown in Figure 3.7. The x axis represents the 76 cases' age when the landscape performance quantification was conducted. The y-axis represents total number of benefits documented. The figure shows that the total numbers of benefits do not differ significantly throughout the different ages. In other words, the projects that were finished earlier do not generate more benefits in comparison to the newly finished projects. However, it needs to be noted that for projects that are built earlier, it is more difficult to collect baseline data. Moreover, LAF required that each case study should

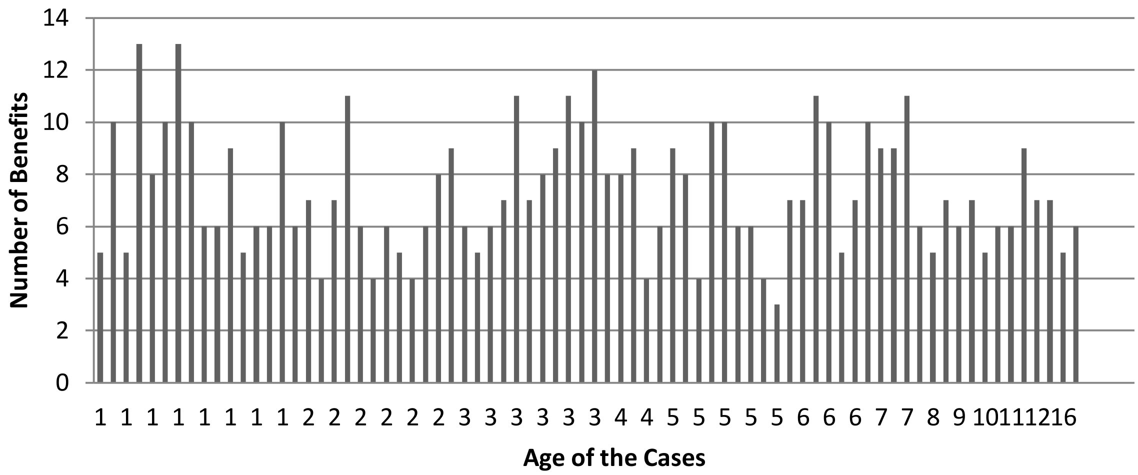


Figure 3.7. Relationship between Project's Completion Dates and Benefit Number

report at least five benefits. Under the tight timeframe and limited budget, research teams might choose to meet the minimum requirement.

Benefit Composition

The results of classifying and analyzing landscape performance benefits indicate not every project has benefits equally distributed into the three environmental, economic and social categories. Most case studies documented more environmental benefits than social and economic benefits. The benefit composition of 2011 cases is presented in Figure 3.8 and the benefit composition of 2012/2013 cases is presented in Figure 3.9. Figure 3.8 indicates in 2011 most projects (25 out of 39) are located toward the triangle's left bottom corner, where environmental benefits have a higher ratio, while economic and social benefits have lower ratios; among the 39 2011 cases, nine are located on the environmental bar, representing no economic benefits documented, and eight are located on the economic bar, representing no social benefits documented. While the benefit composition is improved in 2012/2013 CSI programs due to specific requirements of LAF – "each case study should report a minimum of five performance benefits and there should be at least one of each type – environmental, economic and social." In 2012/2013, majority of cases (22 of 37) are located in the central triangle in the scale, meaning that they have similar numbers of environmental, economic and social benefits; No cases is located on the economic bar, meaning that all projects have at least one social benefit documented, while there are still seven cases located on the environmental bar, representing that they have no economic benefits documented. We also calculated the average number of total, economic and social benefits. The results (Table 3.3) indicate that the number of all benefits increase in 2012/2013 CSI programs.

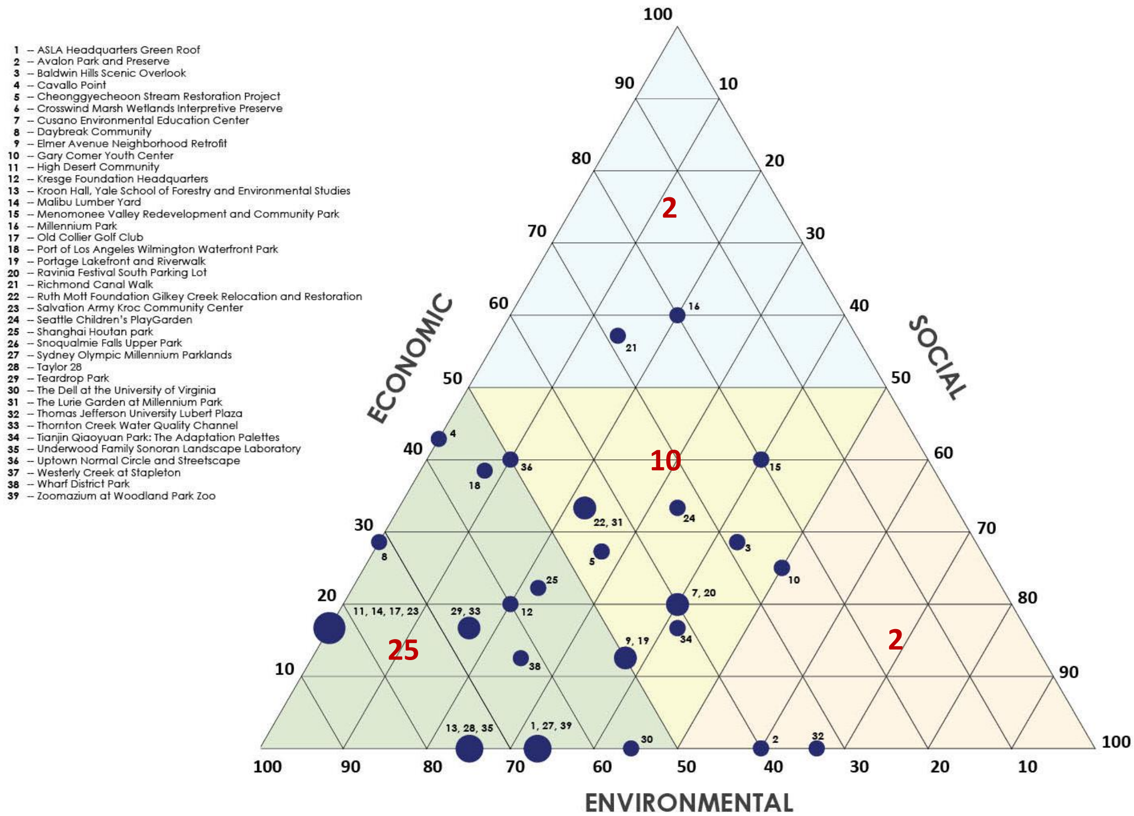


Figure 3.8. Benefit Composition of 2011 Cases.

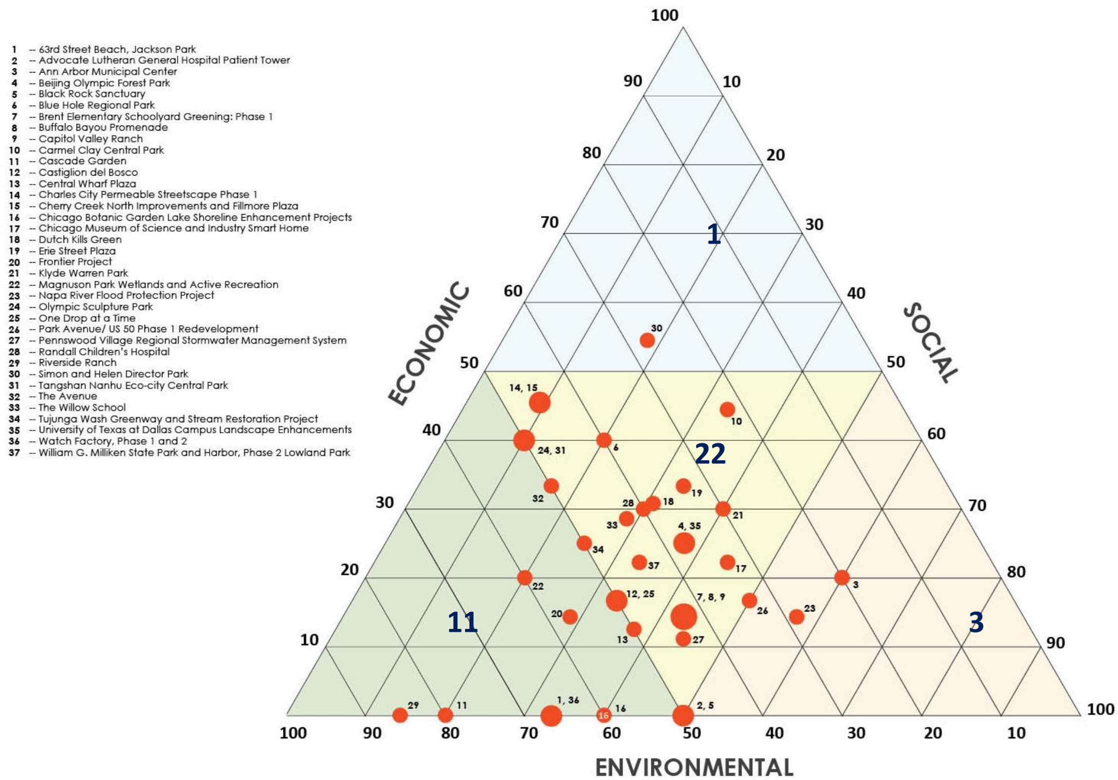


Figure 3.9. Benefit Composition of 2012/2013 Cases.

Table 3.3 Average number of benefits

	Total Benefits	Environmental Benefits	Economic Benefits	Social Benefits
2011	7	3.7	1.6	1.8
2012/2013	8	3.4	1.9	2.4

Interrelationships between Benefits

Despite the debate human is part of the nature, some researchers believe human is beyond ecologically normal for its superiority, in particular its advanced technology (Fowler and Hobbs, 2003). In the past decades, some substantial impacts of human activities on the natural environment have been identified. Wilcox and Murphy (1985) claim intensified human activity is among the most serious reasons for ecological value degradation and biodiversity loss. Thereafter, Dickman and Docasters (1989) indicate urban environment indirectly affects small mammals' populations, and Kozlowski (1999) reveals that soil compaction due to urban development negatively influences woody plants' growth. In addition, Rees (2003) argues that there is an unavoidable conflict between economic development and environmental protection from an ecological economics perspective. Rees (2006) also remarks migration and population growth in an individual region can exceed local biophysical limits, and thus accelerates natural resources depletion. Lately McMichael and Bulter (2011) purport industrialization, increasing population and rising consumerism have the risk of jeopardizing population health and causing ecological nonsustainability. Considering the above arguments, it seems as time goes by, certain benefits would impede other benefits, and therefore result in tradeoffs in landscape performance.

Based on literature review I summarized potential benefit conflicts that exist in landscape performance benefits as shown in Figure 3.10.

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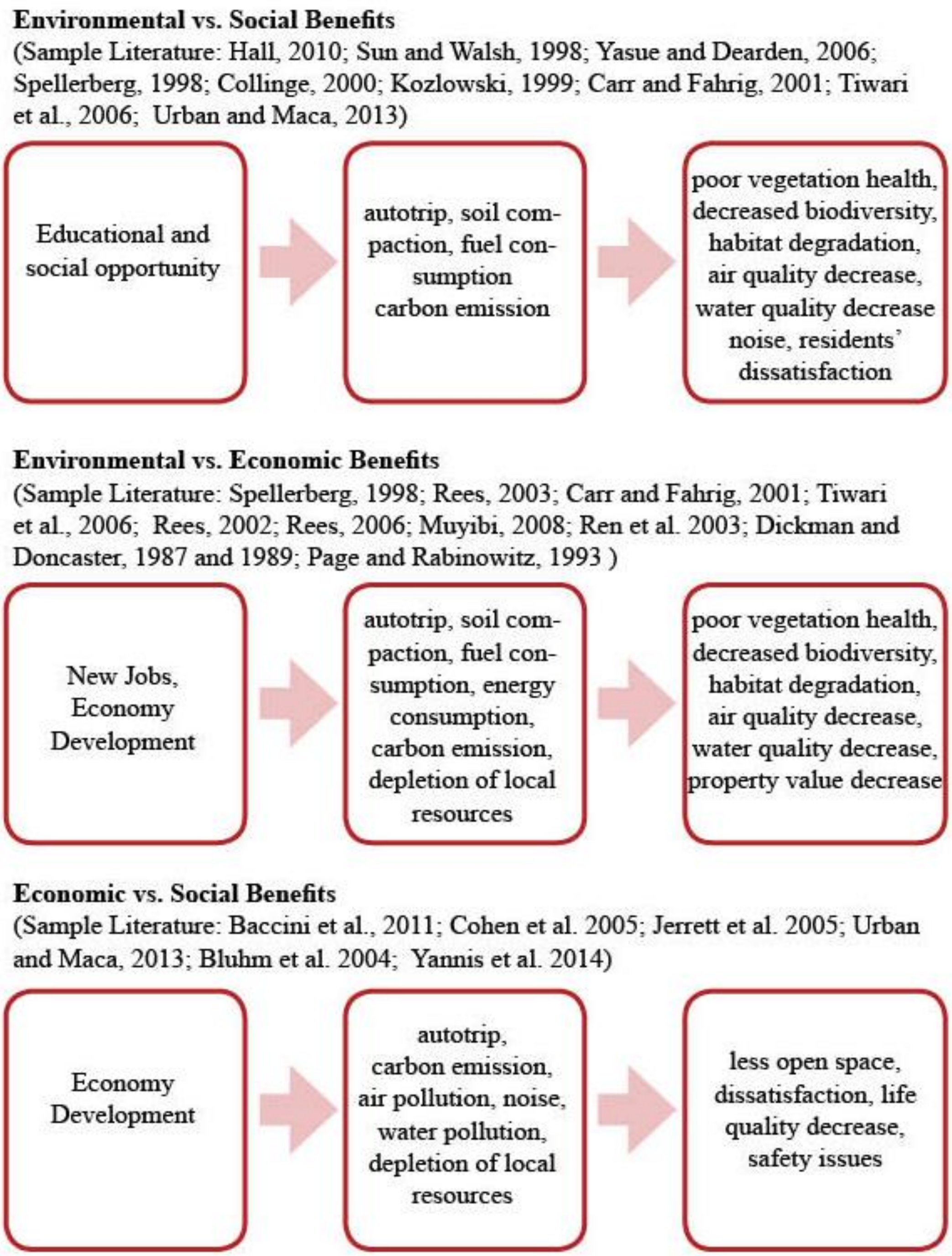

Figure 3.10. Potential Conflicts Summarized from Literature.

Then, based on the summary above, I studied the 76 CSI cases and identify potential conflicting and converging relationships between the environmental, economic and social benefits. The relationships are shown in the Figure 3.11, 3.12 and 3.13. In the figures, the single arrow represents supportive relationships, and the opposite arrows represent conflicting relationships. The numbers next to the arrows represent number of projects that probably have these relationships.

Environmental vs. Social

Among environmental benefits, Water, part of Carbon & Energy, and part of Other Benefits contribute to generating several social benefits, such as flood protection, increasing walkability, increasing users' satisfaction, fostering play, increasing public's eco-awareness, and producing food. These supporting relationships are identified in 14 landscape performance case studies. With regard to conflicts and tradeoffs between environmental and social benefits, some social benefits such as providing increasing recreational/social opportunities and providing increasing educational opportunities are very likely to increase autotrips, raise carbon emission and compact soil. As a result, plants and wildlife health would be hurt and several generated environmental benefits would be compromised. These benefits include increasing plant communities' ecological integrity, increasing the site's biodiversity, improving the site's ecological quality, and creating a variety of habitat types for native fauna and endangered species. These conflicting relationships are identified in 21 landscape performance case studies.

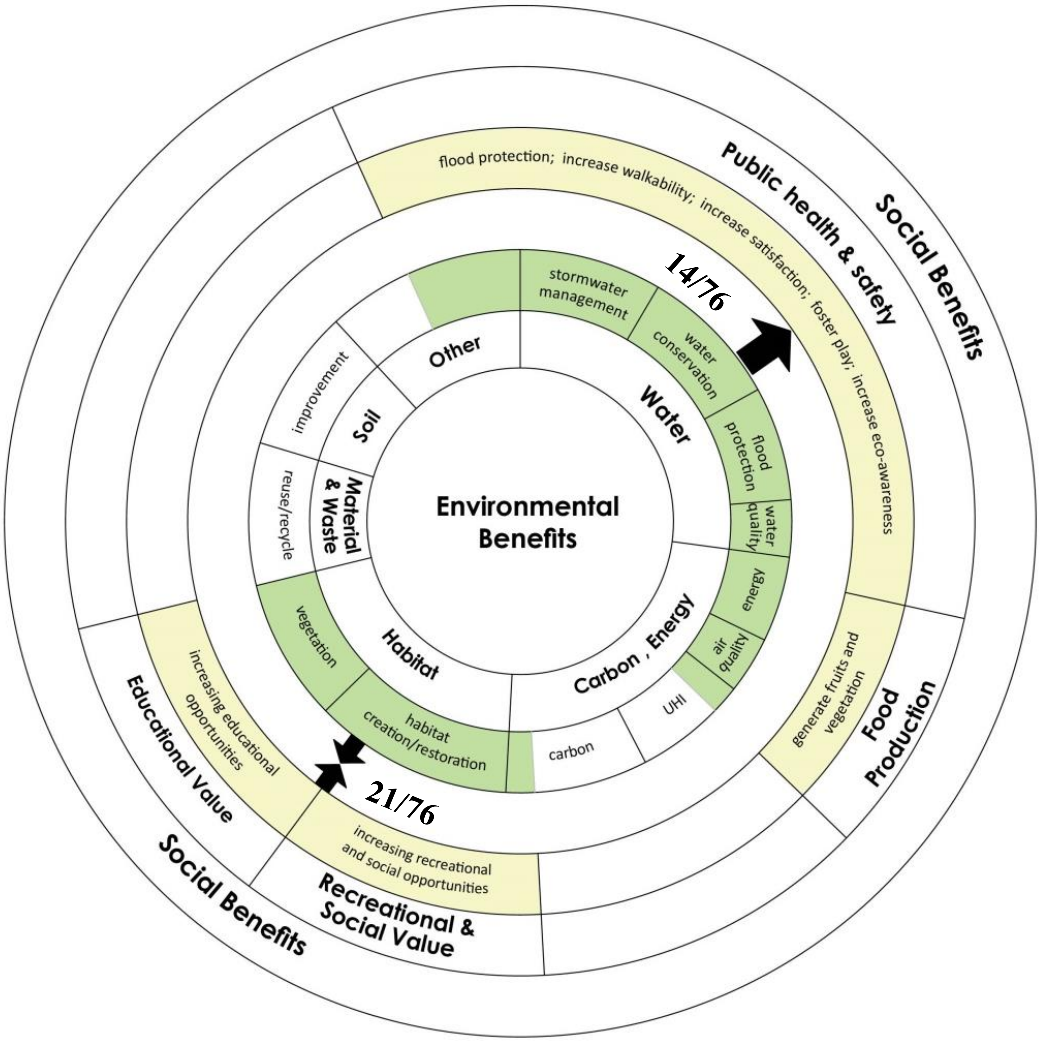

Figure 3.11. Interrelationships between Environmental Benefits and Social Benefits

Environmental vs. Economic

Among the environmental benefits, Materials Reuse/Recycle and Waste Reduction would help reduce construction costs, UHI mitigation and energy saving would help reduce electric bill and O&M costs, and air quality improvement, stormwater management, water conservation, flood protection, and water quality improvement

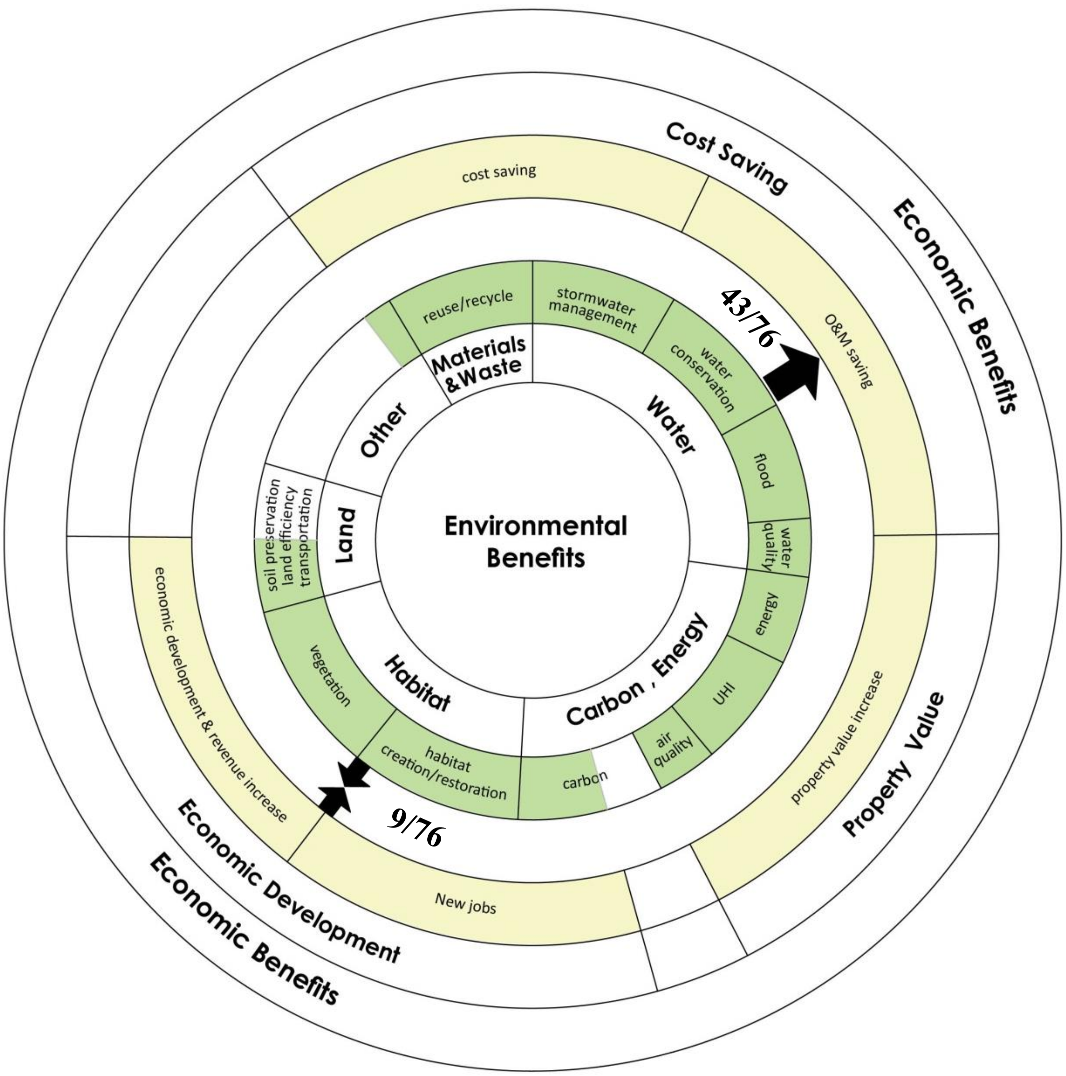

Figure 3.12. Interrelationships between Environmental Benefits and Economic Benefits

would help raise property value. These supporting relationships are identified in 43 landscape performance case studies. On the other hand, several environmental benefits (e.g. economic development, revenue increase, and new job creation) would possibly increase local traffic, boost infrastructure construction, and exacerbate human disturbance. Resultantly, numerous environmental benefits would be sacrificed through reducing open space, impacting vegetation health, decreasing local and regional biodiversity, and degrading wildlife habitat. These conflicting relationships are identified in nine landscape performance case studies.

Economic vs. Social

Social benefits and economic benefits are often closely associated. For example, economic benefits such as creating new jobs and saving construction and O&M costs normally would increase residents' satisfaction and benefit public health and safety. Similarly, social benefits such as providing increasing recreational/social opportunities often increase revenue, create new jobs, and sometimes raise property value as well. Among the 76 landscape performance case studies, 24 have these supporting relationships. However, the interrelationships of economic and social benefits are not always converging. As shown in Figure 3.13, economic benefits such as business development, when growing to a certain extent, would affect social benefits (e.g. reduced open space, degraded water/air quality, and increased noise level), and therefore decrease life quality, reduce residents' satisfaction and harm public health and safety.

These conflicting relationships are identified in 11 out of the 76 landscape performance case studies.

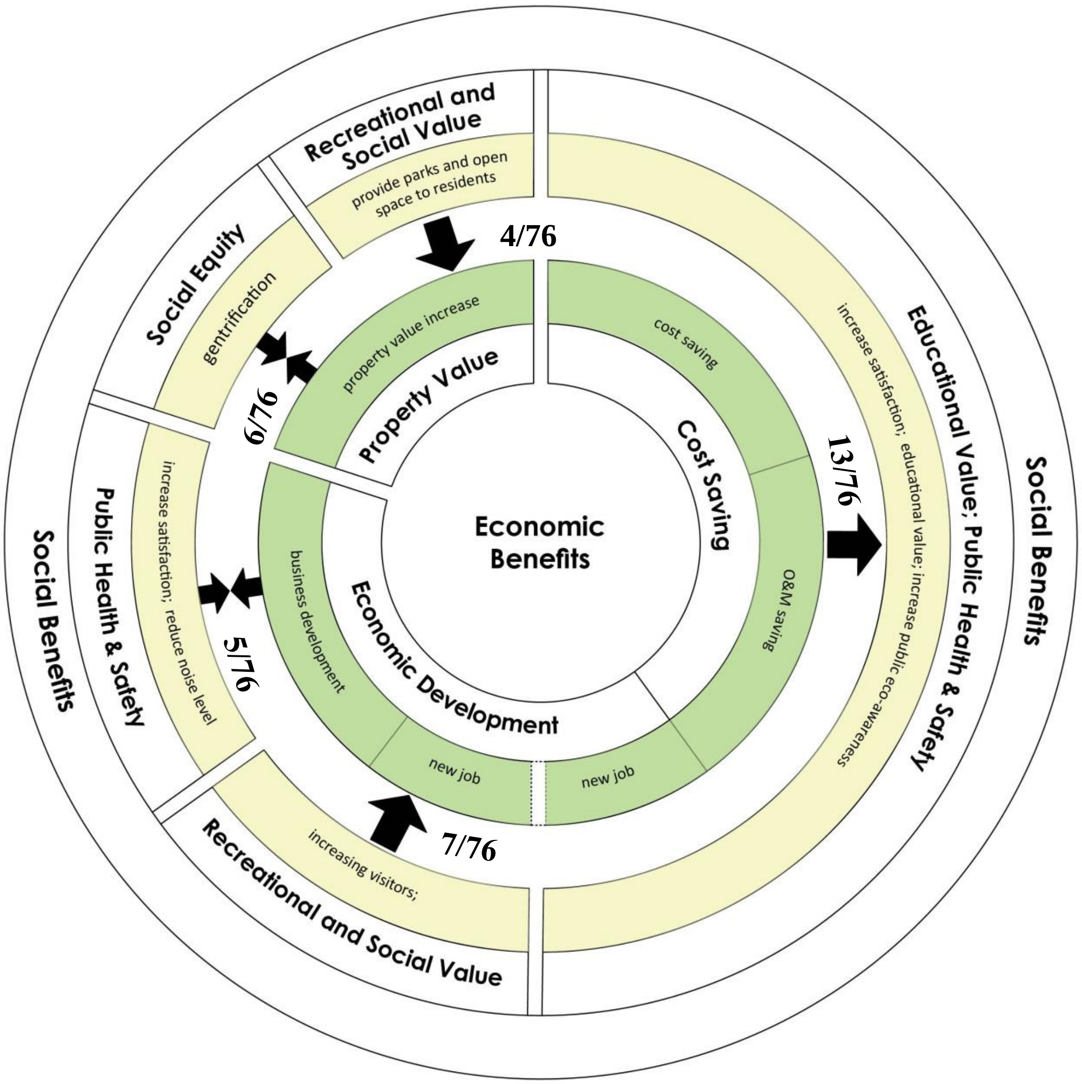

Figure 3.13. Interrelationships between Economic Benefits and Social Benefits

Conclusion

In this study, I analyzed the 76 landscape performance case studies in terms of project type, size, location, completion date, benefit composition, and interrelationships between benefits. The results indicate that environmental benefits are better documented in comparison to social and economic benefits, while quantification of social and economic benefits is improving. Most landscape performance case studies are located in urban areas while rural and suburban projects are increasing. In the CSI programs, most cases were built within five years, and the completion dates of projects seem to have no significant influence on the number of total benefits.

The three categories of environmental, economic and social benefits interact and sometimes conflict with each other. Without thoroughly understanding these interrelationships, designers would not be able to mitigate the conflicts and enhance the inter-dependencies, and sustainability will just be a vague goal (Campbell, 1996). This study summarizes potential conflicts in landscape performance, and I expect it to draw people’s attention to the relationships among the three categories of benefits, so that future policies and landscape developments will enhance compatible benefits, reduce conflicts and contribute toward sustainability.

CHAPTER IV

LANDSCAPE PERFORMANCE OF BUILT PROJECTS: COMPARING LANDSCAPE ARCHITECTURE FOUNDATION'S PUBLISHED METRICS AND METHODS

Chapter Summary

Landscape architecture is an evidence-based profession and discipline, in which creditable evidence is used to guide future design. In order to promote sustainable design practice, scientific evidence that supports design and presents performance needs to be collected. Landscape Architecture Foundation's Landscape Performance Series (LPS) is one of the efforts that attempt to collect this evidence. Built upon the sustainability triad, LPS is intended to quantify outcomes of applied landscape solutions in environmental, economic and social aspects through a collaboration of researchers and practitioners.

Landscape performance research is still in its infancy. There exist a number of gaps in its metrics and methods. This study includes two major tasks. The first is to compare the currently used metrics of landscape performance with other measuring systems in order to identify gaps and make recommendations on improving future landscape performance metrics. The second is to examine and discuss the reliability and validity of the methods that are frequently used in landscape performance quantification.

Introduction

Since being first put forward by the World Commission on Environment and Development, sustainable development has been developing expansively over the past thirty years. It emphasizes balancing sustainability's three aspects: preserving the environment, boosting the economic development, and improving equity (WCED, 1987; Campbell, 1996). Numerous planning and design practices, such as new urbanism, smart growth, transit oriented development, and mixed-use development, emerged to pursuit this balance. Moreover, research and practice on sustainable design strategies bloom, such as low impact development techniques, native species, renewable energy resources, and recycled materials.

Landscape architecture is an evidence-based profession and discipline, in which creditable evidence is used to guide future design. In order to further promote sustainable design practice, scientific evidence that supports design and presents performance needs to be collected. Various efforts have been made to collect this evidence. Examples of these efforts include Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND), Sustainable Sites Initiative (SITES), and Landscape Performance Series (LPS).

LEED-ND and SITES are rating systems. They consist of a series of metrics addressing different aspects of sustainability. Each metric is associated with a certain number of points. Design documents of participating projects are examined by the metrics to decide whether the projects can earn the points of the metrics. These rating systems recognize landscape projects' degree of sustainability and to some extent promote sustainable design practice.

LPS was initiated by Landscape Architecture Foundation (LAF). It is "an online interactive set of resources to show value and provide tools for designers, agencies and advocates to evaluate performance and make the case for sustainable landscape solutions" (LAF, 2014). Unlike LEED-ND and SITES, landscape performance is a backward evaluation system. That is, it quantifies performance of landscape solutions after a project is constructed rather than estimating or predicting outcomes based on design and construction documents.

Landscape performance quantification was conducted through a Case Study Investigation (CSI) program, a collaboration of faculty, students and design firms (LAF, 2014). For landscape performance evaluation, to decide what to measure (metrics) is especially important. Metrics are often selected based on what landscape solutions have been applied in a project and how well the metrics can reflect the performance of the solutions. Equally important to the metrics are the methods. If the quantification methods are not appropriate, the results would be misleading. Figure 4.1 shows the procedure of CSI program's landscape performance quantification.

This study includes two objectives. The first is to compare the currently used metrics of landscape performance with ecosystem services, checklists of LEED-ND and SITES, and building performance metrics to identify gaps and make recommendations on improving future landscape performance metrics. The second objective of this study is to examine and discuss the reliability and validity of the methods that are frequently used in landscape performance quantification.

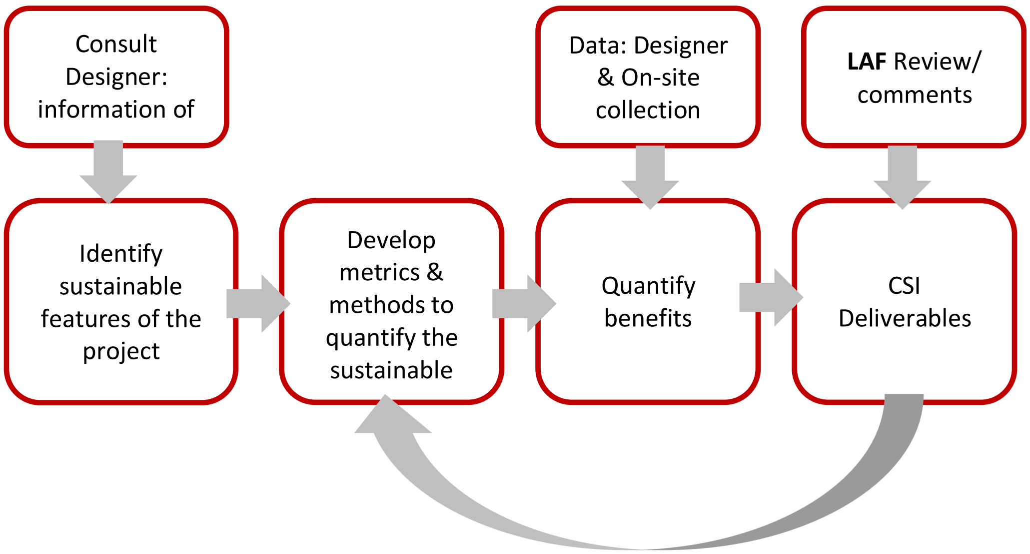

Figure 4.1. Procedure of Landscape Performance Quantification

Methods

The overarching goal of measuring landscape performance is to inform future design decision-making. If performance is not measured correctly, the results will be misleading, and problematic decisions will follow. Therefore, selecting appropriate metrics and methods is important. Landscape design creates and modifies ecosystems. One critical assessment in landscape performance is an effort to evaluate the ecosystem services provided by landscape projects. With that being said, I compared the CSI metrics against ecosystem services to identify gaps.

Besides landscape performance, other significant efforts in assessing sustainability of landscape projects include LEED-ND and SITES. LEED-ND and SITES are both rating systems, providing performance benchmarks for sustainable land design. I compared the CSI metrics against the checklists of LEED-ND and SITES to identify gaps.

Further, since landscape performance is derived from building performance, landscape performance metrics were also compared against a set of post-occupancy evaluation metrics of buildings to identify gaps.

Landscape performance research is still new. There are few guidelines on quantification methods. In many cases, readily available data determine what methods would be used. I selected several typically reported metrics and discussed their quantification methods. The examination standards are reliability and validity as defined by Pedhazur and Schmelkin (1991).

Results and Discussion

Analysis of Metrics

LAF classified landscape performance metrics into the environmental, economic, and social categories, as shown in Table 1. These metrics systematically evaluate ecosystem services that are created or changed by landscape projects. Ecosystems include provisioning services, regulating services, supporting services and cultural services (Millennium Ecosystem Assessment, 2005) (Figure 4.2). Under the landscape performance's framework, environmental metrics measure provisioning, regulating, and supporting services. Meanwhile, social metrics measure cultural services, and economic metrics measure monetary benefits associated with ecosystem services. Compared to the ecosystems services shown in Figure 4.2, environmental benefit metrics of the current CSI program address most provisioning and regulating services except for climate regulation, wind reduction, regulation of human disease, and storm protection (highlighted with red dash lines). Social metrics cover a majority of cultural services except for ecotourism, inspiration, and social relations. Therefore, I suggest LAF include these metrics in its future CSI programs. For example, wind reduction can be measured using an anemometer and reported as “reduced wind speed by *n* mph” or “reduced windy days by *n* days per year.” For another example, regulation of human disease can be measured by counting hospital visit and reported as “reduced employee/residents’ average number of hospital visit by *n* times.” Table 4.4 shows how the metrics can be added to the CSI benefit metrics and some examples of how these metrics can be measured and reported in CSI.

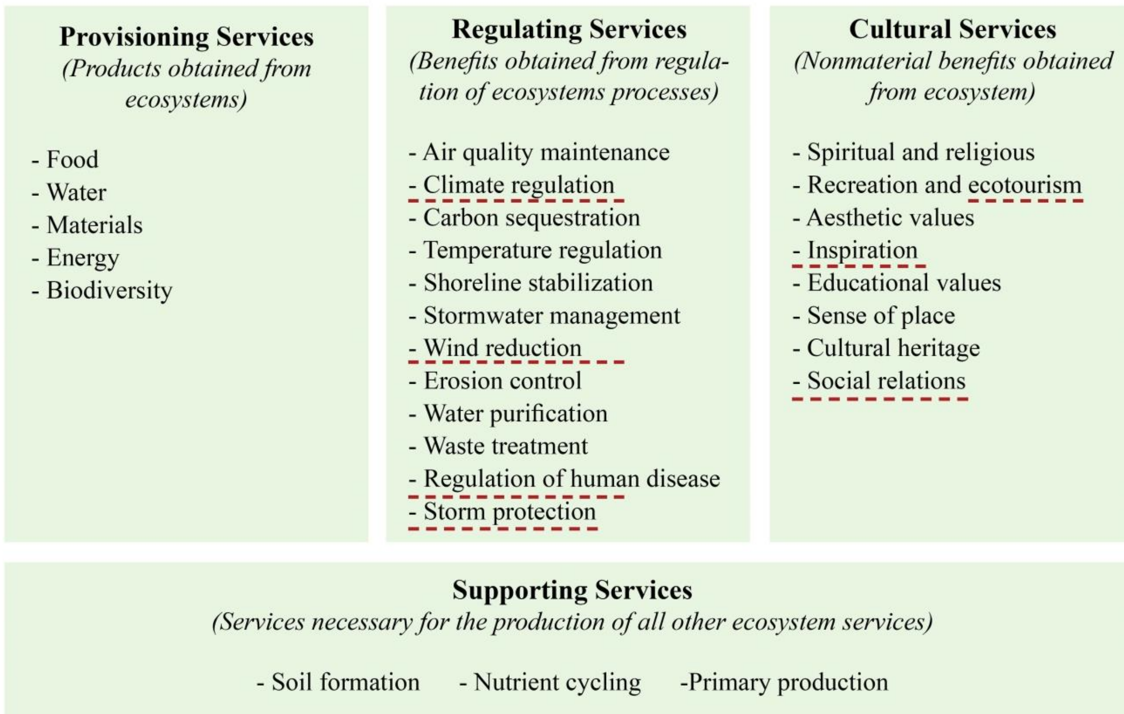

Figure 4.2. Ecosystem Services Related to Landscape Projects. (Adapted from: Millennium Ecosystem Assessment and the Economics of Change)

Table 4.1. Landscape performance metrics (following the sequence in the source) (Source: LAF, 2014)

Environmental	Land	• Transportation • Soil preservation • Soil creation/restoration • Land efficiency/preservation • Shoreline protection/restoration
	Water	• Stormwater management • Water conservation • Water quality • Flood protection • Groundwater recharge

Table 4.1 Continued

Environmental	Habitat	• Habitat reservation/creation/restoration • Restore corridor connectivity • Improve habitat quality • Increase biodiversity • Increase ecological integrity
	Carbon, Energy & Air Quality	• Energy use & emissions • Air quality • Temperature & urban heat island • Carbon storage & sequestration
	Material &Waste	• Reused/recycled materials • Local materials • Green waste • Waste reduction
Economic		• Property values • Construction savings • O&M savings • Replacement avoidance • Visitor spending • Tax revenue • Economic development • Job creation • Increase enrollment
Social	Public health & safety	• User's satisfaction • Life quality • Noise mitigation • Foster play/exercise • Walkability • Therapy/spiritual value • Traffic accident reduction • Crime reduction
		• Recreational & social value • Educational value • Food production • Scenic quality/views • Cultural heritage • Placemaking/sense of place • Equity

LEED-ND and SITES differ from landscape performance in a number of ways. First, LEED-ND and SITES evaluate landscape projects at the design and early construction phases, while landscape performance targets on landscape projects after they are built and occupied. Additionally, LEED-ND, SITES and the landscape performance metrics are organized differently. LEED-ND is organized according to scale: context/location, community pattern, and buildings. SITES is organized according to a project's life cycle: site selection, predesign, design, construction, and operation. Landscape performance is organized according to the sustainability triad: environment,

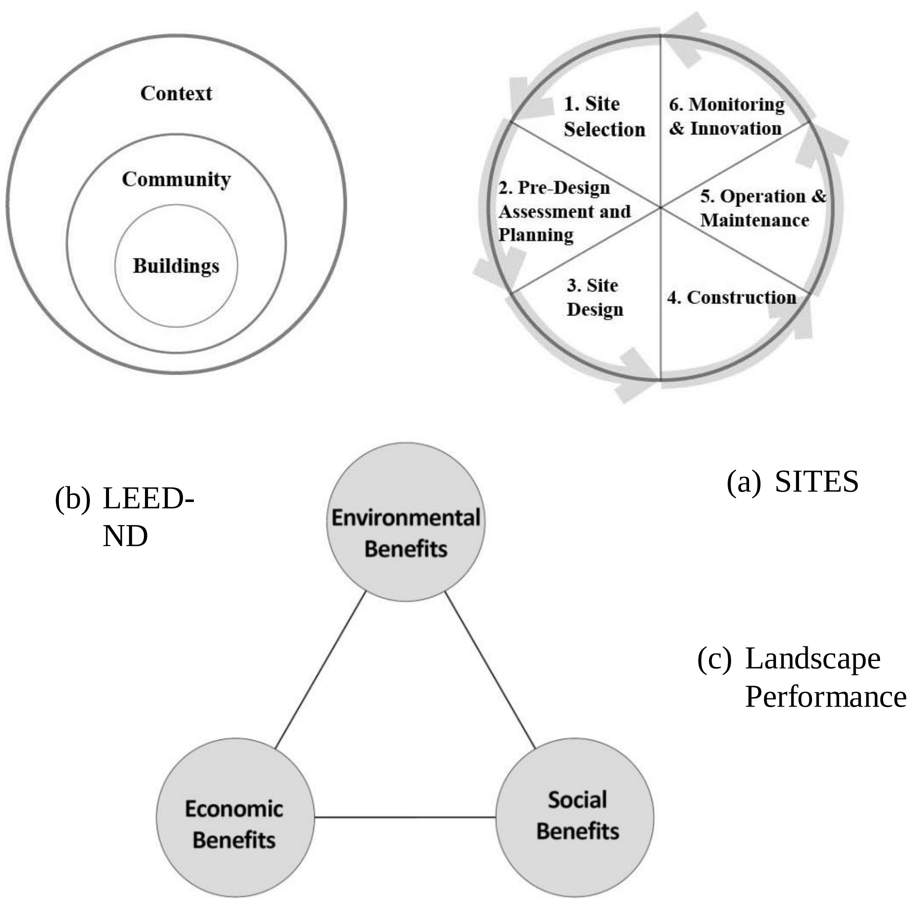

Figure. 4.3. Comparison of Frameworks between LEED-ND, SITES, and LPS

economy, and society (Figure 4.3). In terms of items that are measured, landscape performance is the only one that evaluates projects in the three environmental, economic and social aspects. LEED-ND focuses on environmental aspects, without addressing economic and social aspects. SITES focuses on environmental and part of the social aspects, without taking into consideration of economic aspects of sustainability.

Despite their differences, LEED-ND, SITES and LPS all attempt to evaluate landscapes' sustainability. Therefore, it is valuable to study the scoring categories of LEED-ND and SITES to identify potential gaps existing in landscape performance case study programs.

Table 4.2. LEED-ND rating system checklist (following the sequence in the source) (Source: USGBC, 2009)

Smart Location and Linkage	Smart location Imperiled Species and Ecological Communities Wetland and Water Body Conservation Agricultural land conservation Floodplain avoidance Preferred locations Brownfield redevelopment **Locations with Reduced Automobile Dependence** Bicycle Network and Storage Housing and Jobs Proximity Steep slope protection Site Design for Habitat or Wetland and Water Body Conservation Restoration of Habitat or Wetlands and Water Bodies Long-term Conservation management of Habitat or Wetlands and Water Bodies

Table 4.2 Continued

Neighborhood Pattern and Design	**Walkable Streets** Compact development Connected and open community Mixed-use neighborhood centers Mixed-income diverse communities **Reduced parking footprint** Street network Transit facilities Transportation demand management Access to civic and public spaces Access to recreation facilities **Visitability and universal design** Community outreach and involvement Local food production Tree-lined and shaded streets Neighborhood schools
Green Infrastructure	Certified green building Minimum building energy efficiency Minimum building water efficiency **Construction activity pollution prevention** Certified green building Building energy efficiency Building water efficiency Water-efficiency landscaping Existing building reuse Historic resource preservation and adaptive use Minimized site disturbance in design and construction Stormwater management Heat island reduction Solar orientation On-site renewable energy resources District heating and cooling Infrastructure energy efficiency Wastewater management Recycled content in infrastructure
	Solid waste management infrastructure **Light pollution reduction**
Innovative and Design Process	Innovation and exemplary performance LEED accredited professional
Regional Priority Credit	Regional priority

Table 4.3. SITES rating system checklist (following the sequence of the source) (Source: SITES, 2009)

Site Selection	Limit development of soils designated as prime farmland, unique farmland, and farmland of statewide importance
	Protect floodplain functions
	Preserve wetlands
	Preserve threatened or endangered species and their habitats
	Select brownfields or greyfields for redevelopment
	Select sites within existing communities
	Select sites that encourage non-motorized transportation and use of public transit
Pre-Design Assessment and Planning	Conduct a pre-design site assessment and explore opportunities for site sustainability
	Use an integrated site development process
	Engage users and other stakeholders in site design
Site Design – Water	Reduce portable water use for landscape irrigation by 50% from establish baseline
	Reduce portable water use for landscape irrigation by 75% or more from established baseline
	Protect and restore riparian, wetland, and shoreline buffers
	Rehabilitate lost streams, wetlands, and shorelines
	Manage stormwater on site
	Protect and enhance on-site water resources and receiving water quality
	Design rainwater/stormwater features to provide a landscape amenity
	Maintain water features to conserve water and other resources
Site Design – Soil and Vegetation	Control and manage known invasive plants found on site
	Use appropriate, non-invasive plants
	Create a soil management plan
	Minimize soil disturbance in design and construction
	Preserve all vegetation designated as special status
	Preserve or restore appropriate plant biomass site
	Use native plants
	Preserve plant communities native to the ecoregion
	Restore plant community native to the ecoregion
	Use vegetation to minimize building heating requirements
	Use vegetation to minimize building cooling requirements
	Reduce urban heat island effect
	Reduce the risk of catastrophic wildfire
Site Design – Material Selection	Eliminate the use of wood from threatened tree species
	Maintain on-site structures, hardscape, and landscape amenities **Design for deconstruction and disassembly**

Table 4.3 Continued

Site Design – Material Selection	Reuse salvaged materials and plants
	Use recycled content materials
	Use certified wood
	Use regional materials
	Use adhesives, sealants, paints, and coating with reduced VOC emissions
	Support sustainable practices in plant production
	Support sustainable practices in materials manufacturing
Site Design – Human Health and Well-Being	Promote equitable site development
	Promote equitable site use
	Promote sustainability awareness and education
	Protect and maintain unique cultural and historical places
	Provide for optimum site accessibility, safety, and wayfinding
	Provide opportunities for outdoor physical activity
	Provide views of vegetation and quiet outdoor spaces for mental restoration
	Provide outdoor spaces for social interactions
	Reduce light pollution
Construction	Control and retain construction pollutants
	Restore soils disturbed during construction
	Restore soils disturbed by previous development
	Divert construction and demolition materials from disposal
	Reuse or recycle vegetation, rocks, and soil generated during construction
	Minimize generation of greenhouse gas emissions and exposure to localized air pollutants during construction
Operation and Maintenance	Plan for sustainable site maintenance
	Provide for storage and collection of recyclables
	Recycle organic matter generated during site operations and maintenance
	Reduce outdoor energy consumption for all landscape and exterior operations
	Use renewable sources for landscape electricity needs
	Minimize exposure to environmental tobacco smoke
	Minimize generation of greenhouse gases and exposure to localized air pollutants during landscape maintenance activities
	Reduce emissions and promote to use of fuel-efficient vehicles
Monitoring and Innovation	Monitor performance of sustainable design practice
	Innovation in site design

The results of comparing landscape performance with LEED-ND and SITES indicate that they share many similarities in environmental benefits such as land preservation, soil preservation/restoration, water conservation, flood protection, habitat preservation/restoration, energy conservation, carbon reduction/sequestration and recycle and reuse of materials. Because LEED-ND and SITES evaluate the context and life cycle of a project, they include several metrics that are not currently used in landscape performance (as highlighted in bold red letters in Table 4.2 and Table 4.3). For example, both LEED-ND and SITES have a smart location category, which evaluates whether projects' site locations are close to existing transit systems/development and reduce users' dependence on automobiles. This metric can be added to landscape performance and represented as "reduced average autotrips by *n*%" or "reduced parking footprint by *n*." For another example, SITES has a metric, "design for deconstruction and disassembly." This metric examines whether landscape projects plan for recycling and salvage when they need to be demolished at the end of their life cycle. It can be added to LPS and reported as "reduced waste by *n* lbs." or "reduced the demand for waste transportation by n trucks, equals cost saving of $ *n*." Table 4.4 summarizes the LEED-ND and SITES metrics that are not included in LPS and provides examples of how to measure and report them.

Since landscape performance is derived from building performance, I also referred to building performance for metrics. Twill et al. (2011) claimed that for green buildings, there are ten potentially measureable ecosystem services; these ecosystem services, together with the social and economic benefits they provide, compose building performance evaluation metrics (Figure 4.4). Landscape performance can borrow some of these building metrics. For example, worker productivity could be added to landscape performance and reported as “increased employee’s productivity by *n*%” or “increased company’s annual revenue income by $*n*.” Table4. 4 includes the building evaluation metrics that can be added to LPS.

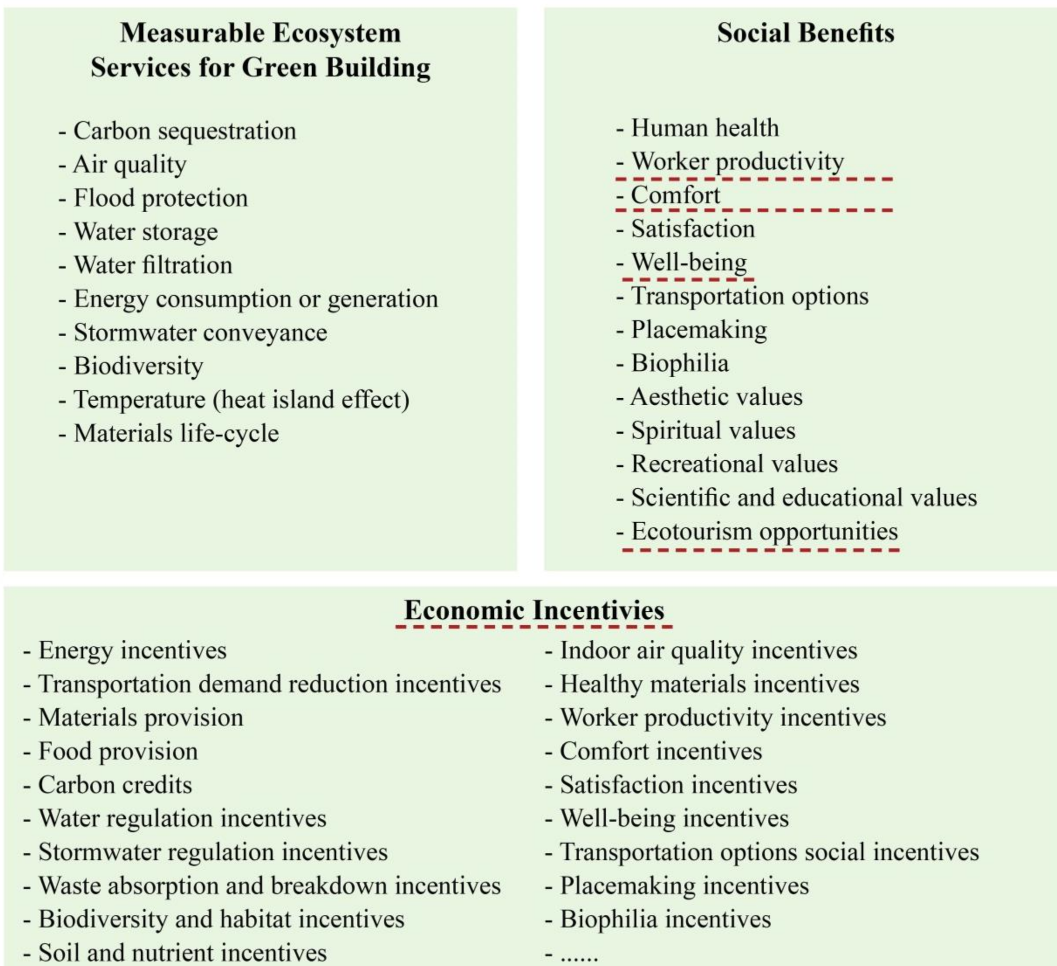

Figure 4.4. Building Evaluation Metrics (Source: Twill et al., 2011)

Table 4.4. Recommendations on metrics for future CSI

Benefit Categories		**Metrics**	**How can it be measured and reported?**
Environmental	Land	Smart location (LEED-ND & SITES)	• Reduced parking footprint by n% • Reduced automobile dependence by n%
	Water	Construction activity pollution prevention (LEED-ND)	• Prevented n% of pollutants from entering the water system.
		Storm protection (Millennium Ecosystem Assessment)	• Mitigated the damage of hurricane/large waves by n% or $n
	Carbon, Energy, Air Quality	Climate regulation (Millennium Ecosystem Assessment)	• Reduced extreme precipitation by n%; reduced drought days by n per year
		Wind reduction (Millennium Ecosystem Assessment)	• Reduced wind speed by n mph • Reduced windy days by n per year
	Material & Waste	Design for deconstruction and disassembly (SITES)	• Reduced the demand for waste transportation by n% • Reduced waste by n%
		Use certified wood (SITES)	• Reduced consumption of n wood by n, saving $ n in cost
		Use materials with reduced VOC (SITES)	• Reduced exposure to air pollution/VOC by n
Economic		Incentives due to sustainable solutions (Twill et al.)	• Obtained $n from n because of n • Reduced $ n tax due to applied sustainable solutions

Table 4.4 Continued

Benefit Categories	Metrics	How can it be measured and reported?
	Human diseases (Millennium Ecosystem Assessment)	• Reduced residents' exposure to pathogens by n% • Reduced hospital visit by n
	Light pollution reduction (LEED-ND and SITES)	• Reduced light pollution by n% • Reduced car accident by n% through light pollution prevention • n% of respondents who surveyed express that the light pollution is reduced
	Catastrophic wildfire (SITES)	• Reduced the risk of catastrophic wildfire by n%
Social	Worker productivity (Twill et al.)	• Increased productivity of employee by n% • Increased company's annual revenue by $n
	Well-Being (Twill et al.)	• Reduced medical spending by $n every year • Reduced hospital visit by n%
	Comfort (Twill et al.)	• Created comfort environment (temp. wind in a certain range)for n days in a year. • Improved comfort for n% of respondents who surveyed
	Ecotourism values (Twill et al.)	• Provided opportunity of ecotourism to n visitors • Increased revenue income by n due to ecotourism opportunities

Evaluation of the Currently Used Methods

LAF defines landscape performance as "the measure of efficiency with which landscape solutions fulfill their intended purpose and contribute toward achieving sustainability." As Pedhazur and Schmelkin (1991) argued, the quality of measurement often depends on reliability and validity of the measuring methods. Reliability, as they claimed, also known as internal consistency reliability, repeatability and stability, is used to determine whether a study result is consistent and reproducible. Meanwhile, validity is used to determine whether or to what extent an instrument measures what it is intended to measure; it can be further divided into three main aspects: content validity, criterion validity and construct validity (Pedhazur & Schmelkin, 1991).

Major Methods Used in the CSI Program

The CSI program is an effort to support design and assessment of multifunctional landscape. As every project of the CSI program is unique and research teams typically work separately, the documented landscape benefits and employed quantification methods vary from team to team. In our opinion, one drawback of the research methods is that almost all measurements are one time snapshots. Certainly, the cross-sectional snapshots evidence performance benefits created by sustainable landscape solutions. They also facilitate comparative study between sustainable and traditional developments. However, if our goal is to accurately quantify landscape performance benefits, the reliability and validity of many methods are questionable.

Haines-Young (2000) argued that landscape is a dynamic process rather than a state. Therefore, snapshots could not demonstrate the full spectrum of sustainability. Sustainability of landscapes depends on their ability to continue to provide ecosystem services in the future and their capacity to generate new types of benefits and reduction of associated cost (Haines-Young, 2000). If the benefit quantification methods can address such ability and capacity of a landscape, I believe that the landscape solutions are fulfilling their purpose and contributing toward sustainability. Next, I will discuss some widely reported metrics and their quantification methods in detail.

Methods for Habitat Preservation / Biodiversity Increase

Out of the 39 landscape performance case studies published by the 2011 CSI program, 23 reported "habitat preservation, creation and restoration." Animal and vegetation count is both time and cost consuming. Thus, most research teams cited study results from others. For example, Avalon Park and Preserve cited an Avalon Park and Preserve survey and compared it with the baseline Inventory of Natural Resources, Cheonggyecheon Stream Restoration Project cited studies of Revkin (2009) and Kim, Koh & Kwon (2009), and Old Collier Golf Club cited study results of Audubon International.

In terms of biodiversity, three projects employed the Plant Stewardship Index (PSI) to compare biodiversity of the study sites before and after construction (Avalon Park and Preserve, Cusano Educational Education Center, and Salvation Army Kroc Community Center).

Guaranteed by peer review, results of published studies have good criterion validity. However the reliability and content validity are arguable. Landscapes change and develop over time; the cited studies were conducted before landscape performance was documented; as time goes by, biodiversity is very likely to change together with landscape development and human activities. For this reason, the cited studies cannot fully represent the situation when the landscape performance was conducted. In addition, content validity is also debatable, because these previous studies conducted by other people might not address all aspects of biodiversity. For example, among the 23 case studies that reported biodiversity increases, most only have evidence for bird species increases. It is possible that other species like small mammals, fish, amphibians all decreased; therefore, we cannot conclude that the landscape projects increase the biodiversity of the site. As for the PSI scale, it is an approved biodiversity measurement in the Piedomont of Pennsylvania and New Jersey; so its criterion validity and reliability are good.

Comparing the two methods, the strength of citing other people's research is that it saves time and cost. The weakness is that the data were not collected specifically for the purpose of landscape performance quantification, which undermines its content validity. The PSI scale is good for both validity and reliability. However it is only valid in particular areas and cannot be used broadly to make a comparison between projects in different regions.

Methods for Stormwater Management (Runoff, Infiltration)

Various methods are employed to measure stormwater management. For example, ASLA Headquarters Green Roof used flow meters and gauges to monitor water quality and quantity. Marlibu Lumber Yard reported engineer's design parameter for bioretention, assuming it would perform as designed. Port of Los Angeles Wilmington Waterfront Park used the National Tree Benefit Calculator to estimate stormwater captured by trees. Some other projects such as Daybreak and Kresge Foundation Headquarters cited previous research.

The method of using flow meters and rain gauges to monitor stormwater quality and quantity is solid in reliability and validity. It allows first hand data to be collected specifically for the purpose of landscape performance quantification. The weakness of this method is that it could be costly when project sites are large. Further, in order to increase data's generalizability and reliability, research teams may need to collect data for a long time, which could be time-consuming and labor-intense. This method is applicable for small sites like a roof garden whose study boundary is clearly defined and requires only a few measuring devices.

Using design parameters to predict landscape performance is only acceptable as a substitute when real world data could not be obtained. For example it never rains since the project was constructed. However this is not a real measurement. The goal of CSI is to physically measure landscape performance and compare it with designers' intention. The prediction here does not achieve the goal and is not recommended in any situation.

However, using LAF's Benefit Toolkit to assess landscape benefits is different. iTree (formally National Tree Benefit Calculator) is a widely used tool in the CSI program, especially for calculating carbon sequestration. The tool is peer-reviewed software developed by USDA Forest Service and a number of cooperators. Its criterion validity and reliability are guaranteed. However, it's worth mentioning that the tool only provides a general estimation of tree performance rather than scientifically accurate value. Therefore, results might be different from true value, especially for project sites outside the US. Despite that, it is considered one of the best tools to measure tree benefits.

Methods for Water Conservation

Water conservation is another benefit that many projects documented (26 out of 39). Among the 26 case studies that documented this benefit, 9 reported reducing irrigation demand by planting native species or drought-tolerant species; 6 reported reducing water wasting by installing water-conserving plumbing fixtures/low-flow irrigation systems; and the other 11 reported reducing potable water consumption by using rain water, reclaimed water, brackish water, or recycled water for irrigation. The method used to quantify this benefit is reading water meters. It is reliable and valid.

However, literature indicates that native species often cause user's dissatisfaction. For example, Davies et al. (2004) claimed that the success of native species in urban areas largely depends on people's perception. For another example, Nassauer (1993) discovered that people prefer more traditional, orderly landscape. Most

CSI projects were built within five years, the long-term benefits of native species depend on how well people accept the “wild” landscape design. If they do not appreciate it, it is possible that the landscape will be changed back to a conventional design and the benefit of water consumption will be lost.

Furthermore, although using reclaimed water for irrigation saves potable water, its influence on vegetation growth and people’s health and satisfaction remain unclear. Long-term monitoring is necessary to ensure the benefit of saving water.

Methods for Material & Waste

Although material reuse/recycle and waste reduction is a benefit under environmental category, its value is occasionally represented through economic value by saving costs in construction. For example, the Port of Los Angeles Wilmington Waterfront Park reported that recycling cement and asphalt avoided hauling costs by $97,500 as estimated by a local hauling company, whereas, Portage Lake Front and Riverwalk cited the LEED document prepared by another company, indicating that 75% of the waste was recycled. Although both research teams demonstrated that materials recycle and reuse was economical, they used a more piecemeal approach, which is problematic in content validity. Port of Los Angeles Wilmington Waterfront Park addressed cost saving in hauling deposit, but overlooked the cost saving in construction materials. Portage Lake Front and Riverwalk merely paid attention to cost saving in materials, ignoring cost saving in transportation. Additionally, both case studies failed to acknowledge that materials reuse and recycle might require extra labor and techniques which could be costly. Furthermore, reused and recycled materials might have less durability and shorter lifespan. These missing elements undermine the validity of measurement.

Methods for Economic Development

Economic development is challenging to quantify due to difficulties in data collection and variable selection. Many economic data are collected at city, county, region, and national levels, which makes it difficult to determine how much economic growth can be attributed to a particular landscape project. The Cheonggyecheoon Stream Restoration Project compared the number of increased business and number of increased working people in the project area with the downtown Seoul. Millennium Park used number of increased residential units/occupancy and tourism within a 6-year period to demonstrate business growth. Both methods involved comparison; the Cheonggyecheoon Stream made a cross-sectional comparison between project area and the city downtown, while Millennium Park made a longitudinal comparison of the area close to the site over time. These comparisons factored out influence of other variables and increased the reliability and validity of the methods. When historical data of a project area are available, a longitudinal comparison can be conducted to demonstrate how local economy grows over time. When economic data in several different regions at a certain time are available, a cross-sectional comparison can be conducted to observe how the economy of a region where a landscape project is located exceeds other regions.

Methods for Public Health and Safety

Similar to economic development, public health and safety are also difficult to quantify. The metrics that are currently used in CSI include “resident / employee satisfaction,” “walkability,” and “noise level.” Noise level reduction is normally quantified through on-site measuring or experts estimation. Similar to using flow meters and rain gauges to monitor stormwater, the reliability and validity of using devices to measure noise level on site are good. Resident/employee satisfaction and walkability are often measured through surveys or interviews. Reliability and validity of surveys and interviews usually depend on how surveys and interviews are designed and conducted. Since survey and interview questionnaires are often not published, I do not discuss their reliability and validity here.

Conclusion

This paper examines the currently used landscape performance metrics by comparing them with ecosystem services, building performance evaluation metrics and those in the checklists of LEED-ND and SITES. This paper also discusses the reliability and validity of several widely used methods in LPS.

Compared to other evaluation and rating systems, landscape performance is the only one with a framework that addresses three aspects of sustainability. LEED-ND assesses landscape projects from large scale (context) to small scale (building). SITES assesses landscapes throughout their life cycle. The different perspectives of these two rating systems can help improve the comprehensiveness of the landscape performance metrics. Furthermore, building performance evaluation and post-occupancy evaluation are more developed than landscape performance. They include quite a few metrics that can be borrowed to complement the currently used landscape performance metrics. The metrics that can be added to landscape performance include the following:

- Environmental
    - Smart location
    - Construction activity pollution prevention
    - Storm protection
    - Climate regulation
    - Wind reduction
    - Design for deconstruction and disassembly
    - Use certified wood
    - Use materials with reduced VOC
- Economic
    - Incentives due to sustainable solutions
- Social
    - Human disease control
    - Light pollution reduction
    - Catastrophic wildfire
    - Worker productivity
    - Well-being
    - Comfort

- Ecotourism

Landscape performance research is still new. The experience in quantifying performance in the environmental, economic and social aspects is limited. Research teams often select metrics and methods according to the availability of data and their preference to some extent. As such, methods generally differ from project to project, which makes it difficult to guarantee the reliability and validity of methods and results. I recommend developing standardized data collection guidelines to reduce the dependence of methods on data availability. Moreover, as the database of the Landscape Performance Series expands, I suggest developing standardized quantification methods, which not only increases the reliability and validity of results, but also makes comparative study possible.

CHAPTER V

INTEGRATING LIFE-CYCLE COSTS WITH LANDSCAPE PERFORMANCE: COST COMPARISON AND COST-BENEFIT ANALYSIS

Chapter Summary

Landscape performance is an effort that the Landscape Architecture Foundation (LAF) made to quantify the outcomes of sustainable landscape solutions. It shows how sustainable landscape solutions provide benefits in the environmental, economic and social aspects of sustainability. Landscape performance provides evidence for sustainable solutions, and promotes measurable sustainable design practices. However, the current landscape performance framework does not fully consider the costs of performance benefits. Benefits are not generated for free, and the costs of benefits are important for decision making. Cost not only allow cost comparison between conventional and sustainable solutions, but also facilitate cost-benefit study of sustainable solutions. The purpose of this chapter is two-fold. First, it creates a new framework to include cost in landscape performance quantification. Second, it explores credible methods of monetizing non-market landscape performance benefits to help with the cost-benefit comparison of sustainable solutions.

The results show that life-cycle cost can be integrated into the framework of landscape performance. Cost can be calculated by the present worth or annualized methods. The representation of cost can be combined with benefit using efficiency and productivity metrics. Due to the difficulty in determine dollar value of many

environmental and social benefits, costs of sustainable solutions seem higher than benefits in many cases. I suggest adopting the eight ecosystem evaluation methods that are accepted in the literature to help estimate the value of non-market landscape performance benefits.

Introduction

Study of landscape performance has been attracting growing attention in the field of landscape architecture lately. Landscape performance is defined by the Landscape Architecture Foundation (LAF) as "the measure of efficiency with which landscape solutions fulfill their intended purposes and contribute toward achieving sustainability." Unlike previous assessment research or rating systems, the framework of landscape performance builds upon the sustainability triad, which requires projects to be investigated in the three environmental, economic and social aspects. Currently, landscape performance quantification is undertaken through a Case Study Investigation (CSI) program supported by LAF. In this CSI program, researchers cooperate with leading practitioners on quantifying performance benefits of built landscape projects. Landscape performance promotes measurable sustainable design practice by collecting evidence of sustainable developments and reducing uncertainties during decision-making. For example, quite a few published case studies demonstrate that recycling materials preserves natural resources, saves costs in materials purchasing and transporting, and provides opportunities for education. This information is based on actual measurement of landscape solutions' performance and provides valuable guidelines for future design. To date, LAF has published about 80 landscape performance case studies online. These cases provide "an online interactive set of resources" for future designers and agencies" (LAF, 2014).

However, it is worth noting that the current framework of landscape performance does not fully consider the costs of performance benefits, leaving a gap in the research subject. Benefits are not generated for free. Rather, they are "cost embedded benefits"[*]. It is well known that high initial cost is one reason that prevents some sustainable solutions from being widely employed, such as green roofs and solar panels. Despite the benefits that will come along, clients prefer more profitable solutions. Therefore, including cost in the landscape performance research framework would provide more comprehensive information and better facilitate future decision-making.

Including cost in landscape performance's framework has two major advantages (Figure 5.1). First, it allows a cost comparison between sustainable and conventional solutions. This comparison could help designers and clients determine which solutions to employ. Second, it facilitates a cost-benefit analysis between sustainable solutions' costs and benefits. This information offers designers additional information to select sustainable solutions based on budget. For example, assuming that one goal of a project is to remove pollutants in stormwater runoff. Many sustainable solutions can help achieve this goal, such as constructed wetlands, bioretention ponds, and native species landscaping. The results of cost-benefit analysis could help determine which solution is the most cost-effective in pollutant removal.

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[*]"Cost-embedded benefits" was coined by Forster Ndubisi during a conversation in 2014.

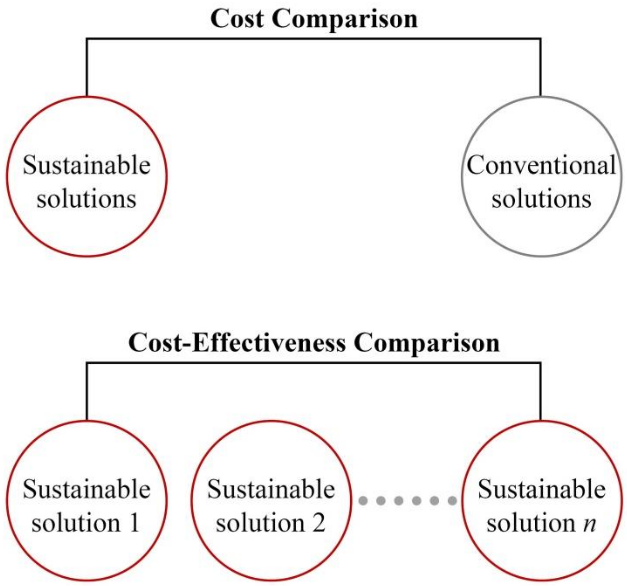

Figure 5.1. Two Types of Comparison Enabled by Cost Information.

This paper has two primary objectives. The first objective is to create a new framework to include cost in landscape performance quantification and demonstrate how the framework will work by a case study. The other objective is to explore creditable methods of monetizing non-market landscape performance benefits to further facilitate the cost-benefit comparison of sustainable solutions.

Methods

This study was performed in three steps. First, I reviewed literature regarding life-cycle cost and adopted a framework to refine the current landscape performance framework. The literature reviewed includes Life Cycle Costing in Sustainability Assessment (Schau et al., 2011), Environmental Life Cycle Costing (Hunkerle et al., 2008), Measuring Progress Toward Sustainability Principles, Progress, and Best Practices (Fiksel et al., 1999), An Economic and Environmental Total Life Cycle Costing Methodology and a Web-Based Tool for Environmental Planning of Buildings (Haddad et al., 2007), Life-Cycle Cost Analysis (National Institute of Building Science, 2010), Lean and Clean Management (Romm, 1994), Life Cycle Assessment: Principles and Practice (Scientific Application International Corporation, 2006), and Design to Life Cycle by Value-Oriented Life Cycle Costing (Janz & Westkamper, 2007).

Second, I used a constructed wetland in a landscape performance case study – Cross Creek Ranch, Fulshear, TX – conducted by Li et al. (2013) to demonstrate how to calculate landscape solutions' life-cycle cost and how to report cost-embedded benefits. Cost information is normally confidential and not allowed to be released. For this reason, the data used in this demonstration was first estimated based on a study – Constructed Wetlands Treatment of Municipal Wastewater (USEPA, 2000) – and then adjusted by the Cross Creek Ranch's project manager in SWA, Houston.

As discussed above, cost is often compared with benefit to help designers and clients make decisions. However, most environmental and social benefits are not reported in dollar value format, making the comparison indirect. Thus, in the third step, I explored literature regarding reliable methods of valuing non-market ecosystem services and discussed their possibility of monetizing the current landscape performance benefits.

Results and Discussion

Including Cost in the Framework

Cost is defined in Merriam-Webster online dictionary (2014) as "the amount or equivalent paid or charged for something" or "loss or penalty incurred especially in gaining something". Its first meaning refers to the resources needed, and its second meaning refers to the tradeoffs that come along. As discussed in Chapter 2, cost is important for decision-making, and it has been included in the frameworks of urban planning and transportation performance measurement. In urban planning performance measurement, cost is resource used to generate outputs and outcomes (Hatry, 1999), while in transportation performance measurement, cost not only includes resources but also tradeoffs such as property loss and injury, travelers' discomfort, and environmental degradation due to transportation systems (Dahlgren, 1998).

Landscape performance measures a landscape project's outcomes in the environmental, economic, and social aspects. The three aspects have interest clashes, determining that there are unavoidable conflicts and tradeoffs between the environmental, economic and social benefits (Campbell, 1996; Luo & Li, 2014). These conflicts and tradeoffs are important for decision-making and should be included in landscape performance for future designers' consideration. However, since conflicts and tradeoffs might not appear immediately after a project is constructed, and they are often difficult to quantify, I suggest including them in the framework as accessional statements rather than an element to be summed up for cost comparison or cost-benefit analysis.

This paper primarily discusses the costs that can be included in cost comparison and cost-benefit analysis. Tradeoffs are not a focus of this study.

Cost comparison should not be limited to initial capital cost. Compared to conventional solutions, some sustainable solutions have higher initial capital costs. However, it does not mean they create less value than conventional solutions. Sustainable solutions' high initial costs are partly because the skills and techniques of these solutions are relatively new. These costs are likely to decrease as the skills and techniques mature and experiences accumulate. Despite the high initial costs, many sustainable solutions consume less water and energy during operation, require less maintenance, and have a much longer life span, resulting in lower total life-cycle costs. For example, some native species require zero fertilizer and irrigation inputs when established, saving costs in water and fertilizer compared to conventional lawns. For another example, a survey conducted by Zentralverband Gartenbau e.V. in 1996 (ZVG, 1996 as cited by Greenroofs.com, 2013) shows that adding a green roof helps extend a conventional roof's life span by at least 20 years. Therefore, landscape performance should consider a sustainable landscape solution's life-cycle cost rather than its initial capital cost only.

The life-cycle cost that should be included in landscape performance is adopted from Life-Cycle Cost Analysis by National Institute of Building Science (2010). The cost calculation is shown as follows:

$$\boldsymbol{LCC = I + Repl + E + W + OM\&R + O - Res}$$

where

LCC : Total life-cycle cost in present value (PV) dollars of a given alternative

I: Initial cost

Repl: Capital replacement cost

E: Total energy cost

W: Total water cost

OM&R: Total operating, maintenance, and repair cost

O: Total other costs, if any – contract administration cost, financing costs, employee salaries and benefits, and so forth

Res: Residual value (resale value, Salvage value) less disposal cost

There are two types of commonly used methods to represent life-cycle cost: present worth and annualized methods (Kirk, 1995). The present worth method converts all costs to "equivalent costs at one point of time" (Kirk, 1995); while, the annualized method "expresses all life cycle costs as annul expenditures" (Kirk, 1995).

Project costs are often confidential and not allowed to be released to the public. Because of this fact, it is difficult to integrate cost into the research framework of landscape performance, which in turn limits landscape performance's contribution to future decision-making. One alternative would be combining cost with benefit to report efficiency and productivity metrics. Efficiency metrics measure the ratio of cost to benefit, while productivity metrics measure the ratio of benefit to cost (Hatry, 1999). These metrics show landscape solutions' cost-effectiveness and provide a basic understanding of "how much the benefits would cost?" and "how many benefits every

$1 could create?" The new landscape performance framework that includes cost is shown in Figure 5.2.

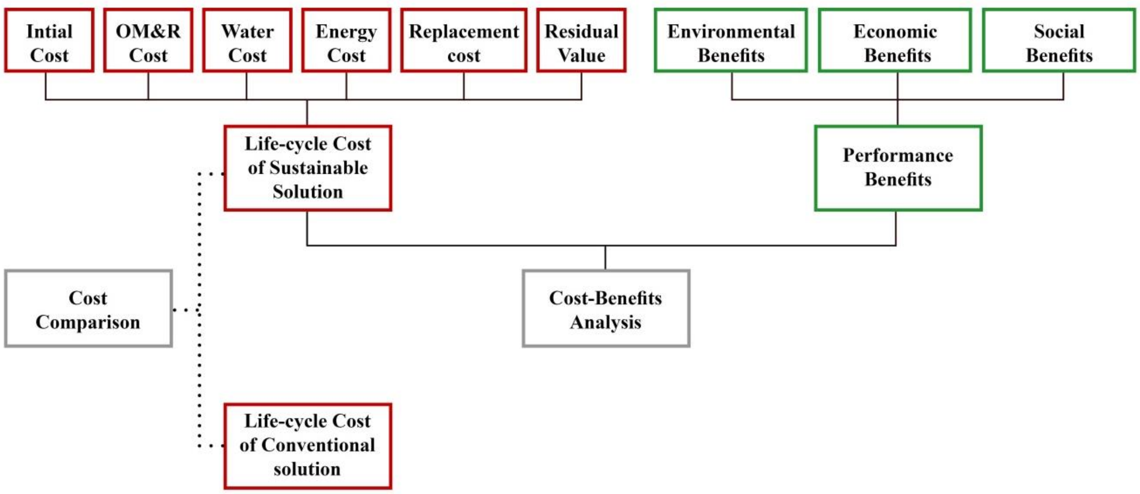

Figure 5.2. The Framework of Landscape Performance with Costs Being Included

Case Study of a Constructed Wetland in Texas

Cross Creek Ranch is a 3,200 acre master planned community in Fulshear, Texas designed by SWA Group, Houston. The community promotes a life style that connects with nature. In the community, a wide range of sustainable landscape solutions were employed to pursue this goal. Examples of the solutions include a wetland creek/retention wastewater treatment system, continuous naturalized landscape infrastructure, reforestation, interconnected wildlife corridor, and diverse passive recreation systems (Li et al., 2013). The phase one of Cross Creek Ranch was completed in 2011 and it was selected as one of LAF's 2012 CSI case studies.

The Cross Creek Ranch case study was conducted through a collaboration of two professors and a PhD student from Texas A&M University and the designer of Cross Creek Ranch from SWA. Considering the limited timeframe and budge, the research team used a snapshot cross-sectional method to quantify environmental benefits (Li et al., 2013). They evaluated performance of the constructed wetland and restored creek/detention lake system as well as the naturalized landscapes (Li et al., 2013). This paper uses the constructed wetland to demonstrate an example of life-cycle cost calculation and representation.

The constructed wetland is about 50 acres in total area. It is designed to further purify the entire community's greywater after it is pre-treated to 90% clean by a wastewater treatment plant nearby. To examine the performance of the wetland and creek/detention lake system, the research team collected water samples from seven locations based on flow direction of the treatment wetland and restored creek system (Figure 5.3). The numbers 1, 2, 3 in Figure 5.3 represent the start point, midpoint and end point of the constructed wetland. Later on, the water samples were sent to the Soil, Water and Forage Testing Laboratory of Texas A&M University for analysis; the pollutants analyzed include total nitrogen (N), total phosphorus (P), total potassium (K), total calcium (Ca), total magnesium (Mg), total sodium (Na), total zinc (Zn), total iron (Fe), total manganese (Mn) and total suspended solids (TSS) (Li et al., 2013).

Benefits

According to the Cross Creek Ranch case study (Li et al., 2013), the constructed wetland created two primary benefits explained below.

- The wetland reduced concentration of nitrogen by 47%, phosphorous by 80%, potassium by 20%, calcium by 46%, magnesium by 9%, sodium by 32%, zinc by 7%, copper by 33%, and manganese by 56%.

- The wetland saved $603,490 by reducing potable water usage for irrigation by 121,671,400 gallons from 2009 to 2012 through usage of reclaimed water in the constructed wetland for irrigation.

1. Beginning of the 90% cleaned sewage water pumped into the treatment wetland.

2. Mid-point of the treatment wetland.

3. End of the treatment wetland.

4. Mid-point between 3 and 5.

5. Ultimate outlet of the treatment wetland and creek/detention lake system of Phase I into the creek.

6. Influent location of Flewellen Creek into the Cross Creek Ranch site.

7. Outlet of the two water systems (wetland and creek/detention lake system & Flewellen Creek).

Figure 5.3. Sampling Locations of the Water Quality Analysis in Cross Creek Ranch. （Source: Li et al., 2013. ）

Costs

The itemized initial costs of the constructed wetland are shown in Table 5.1. In addition to initial construction costs, constructed wetlands consume energy to operate and need to be maintained regularly. The USEPA study (2000) shows that the O&M cost of a similar-sized wetland is $1,169/acre per year (adjusted to 2008 dollars using 3% inflation rate), thus the operation and maintenance cost for the Cross Creek Ranch wetland is $21,044 per year. According to Shutes (2001), the lifespan of constructed wetlands is around 20 years for organic waste treatment. The Cross Creek Ranch constructed wetland treats organic waste of municipal wastewater; therefore, its lifespan is assumed to be 20 years.

Table 5.1. Itemized initial construction costs of the Cross Creek Ranch constructed wetland.

	Survey/ Geotechnic	Clear & Grub	Earthwork	Media	Plants & Planting	Control Structures	Plumbing	Total Initial
1997 dollar ($/acre)*	1,651	3,501	9,704	10,554		8,016	7,003	
2008 dollar ($/acre)	2,285	4,846	13,433	14,609	65,340	11,096	9,694	
CCR Costs	41,137	87232	24,1787	262,966	1,279,357	199,728	174,488	2,286,695

* Source: USEPA, 2000. Constructed Wetlands Treatment of Municipal Wastewater.

The life-cycle cost is often represented in two methods: present worth and annualized methods. For cost comparison between traditional and sustainable solutions, either method is appropriate. However, for cost and benefit comparison, which method to choose depends on how benefits are reported. If benefits are reported using an annualized approach, so should the costs. For example, quite a few landscape performance case studies reported that trees on the project site sequester n lbs. of carbon dioxide every year. In this case, costs can be represented in annualized approach to allow an annual cost-benefit comparison. For another example, many other case studies reported that recycling materials saves construction costs by $n. The saving happens only once and will not recur every year. In this case, costs can be represented in a present worth format.

For the demonstration purpose, life-cycle cost of the CCR constructed wetland is calculated using both methods. The value obtained from the present worth method is used to calculate efficiency and productivity metrics, while the value obtained from the annualized method is used to compare with the benefits.

Present Worth Method Calculation

In this method, a 10% discount rate, a 20-year life cycle, and a differential escalating rate for O&M costs of 3% are assumed. The costs of the Cross Creek Ranch constructed wetland are shown in Table 5.2.

Table 5.2. Costs of the Cross Creek Ranch constructed wetland

Type of cost	Cross Creek Ranch Constructed Wetland
Initial cost	$ 2,286,695
O&M (annual)	$21,044
Life span	20 years

O&M (present worth) = $\$21044 \times 10.764 = \$226,518$

Total present life-cycle costs = $\$2286695 + \$226518 = \$2{,}513{,}212$

Annualized Method Calculation

In this method, a 12% financing rate and a 20-year life cycle are assumed.

Initial Cost (annualized) = $\$2286695 \times 0.1339 = \$306{,}188$

Total life-cycle cost = $\$306188 + \$21044 = \$327{,}232$ per year

Report Cost Embedded Benefits using Efficiency and Productivity Metrics

According to the Cross Creek Ranch landscape performance case study (Li et al., 2013), the constructed wetland reduces concentration of nitrogen by 47%, phosphorous by 80%, potassium by 20%, calcium by 46%, magnesium by 9%, sodium by 32%, zinc by 7%, copper by 33%, and manganese by 56%. The efficiency of each nutrient or metal element removal is:

- Efficiency of nitrogen removal = $\$2513212 \div 47 = \$53,473$ per 1% removal
- Efficiency of phosphorous removal = $\$2513212 \div 80 = \$31{,}415$ per 1% removal

  ……

- Efficiency of manganese removal = $\$2513212 \div 56 = \$44{,}879$ per 1% removal

The productivity of the constructed wetland regarding pollutant removal is, for every $1000,

- Nitrogen = $47\% \div 2513212 \times 1000 = 0.02\ \%$

- Phosphorous = $80\% \div 2513212 \times 1000$ = 0.03%

……

- Manganese = $56\% \div 2513212 \times 1000 =$ 0.02%

So the cost embedded benefits can be reported by incorporating benefits with efficiency or productivity metrics as the following:

Efficiency (values in parentheses are costs for every 1% of removal):

- The wetland reduces concentration of nitrogen by 47% ($53,473), phosphorous by 80% ($31,415), potassium by 20% ($125,661), calcium by 46% ($54,635), magnesium by 9% ($279,246), sodium by 32% ($78,538), zinc by 7% ($359,030), copper by 33% ($76,158), and manganese by 56% ($44,879).

Productivity:

- Reduces concentration of nitrogen by 47%, phosphorous by 80%, potassium by 20%, calcium by 46%, magnesium by 9%, sodium by 32%, zinc by 7%, copper by 33%, and manganese by 56%. For every $1000 spent on the constructed wetland, 0.02% of nitrogen, 0.03% of phosphorous, 0.01% of potassium, 0.02% of calcium, 0.004% of magnesium, 0.01% of sodium, 0.003% of zinc, 0.01% of copper, and 0.02% of manganese were removed.

Cost-benefit Comparison

The constructed wetland saved $603,490 by reducing potable water consumption for irrigation from 2009 to 2012. The average annual cost saving in irrigation is:

Average annual cost saving$= \$603490 \div 3 = \$201{,}163$

The total life-cycle cost per year of the constructed wetland is $327,232. A comparison between the annual costs and benefits shows that costs are higher than benefits. However, we could not conclude that constructed wetland is not cost-effective. The first reason is that constructed wetlands' costs depend largely on size; the larger a wetland is, the lower its life-cycle cost (USPEA, 2000). It is quite possible that for larger constructed wetlands, the benefits outweigh the costs. More importantly, the value of the constructed wetland's non-market benefits is not considered in this comparison. Examples of these benefits include wildlife habitat creation, water quality improvement, education and ecotourism opportunity, and residents' satisfaction increase.

This leads to a demand of estimating the value of non-market landscape performance benefits and counting it in landscape performance's cost-benefit analysis. The next section will explore conventional economic valuation methods that are accepted in peer-reviewed literature and discuss their application in monetizing non-market landscape performance benefits.

Monetizing Environmental and Social Benefits

The value of products and services are often determined through market transactions; since ecosystem services are hardly traded in markets, their value is difficult to determine (Twill et al., 2011). Over the past decades, the importance of non-market ecosystem services are increasingly recognized and a growing body of research was conducted to develop methods for valuing non-market ecosystem services (Farber et al., 2006; Twill et al. 2011; Bateman et al., 2013; United Nations, 2014). Landscape performance investigates built landscape projects' performance benefits in the environmental, economic and social aspects. The benefits in the three aspects can also be considered as the ecosystem services provided by landscape projects. Thus, the methods developed to value non-market ecosystem services can be borrowed to value non-market landscape performance benefits. Below is a list of ecosystem service valuation methods that are accepted in peer-reviewed literature.

1. Avoided costs (AC)
2. Market methods (MM)
3. Replacement cost (RC)
4. Travel cost (TC)
5. Production approaches (PA)
6. Hedonic pricing (HP)
7. Contingent valuation (CV)
8. Conjoint analysis (CA) (Farber et al., 2006; Twill et al., 2011)

<u>Avoided costs (AC)</u> – The avoided cost method estimates the value of ecosystem services based on the costs that would incur in the absence of those services (Farber et al., 2006; Twill et al., 2011). This method is widely used in landscape performance measurement.

Examples of landscape performance benefits that can be valued by AC:

- Saved $ n in material costs by reusing coal ash to produce foundations and bricks used in park construction.

- Saved $ n in water cost by using drought tolerant species.
- Avoided $ n in annual mowing costs by creating meadow instead of lawn.

Market methods (MM) – The market methods estimate the value of ecosystem services based on the market value of its services or good (Farber et al., 2006). Several landscape performance case studies that are about harvesting fruits, vegetables, and wine use this method to estimate the benefits' value.

Example of landscape performance benefits that can be valued by MM:

- Produce an estimated n lbs. of organic vegetables each year, which have an approximately value of $ n.
- Produce approximately n bottles of wine annually from the vineyards, which has an estimated value of $ n.

Replacement costs (RC) – The replacement costs method estimates the value of ecosystem services by the costs that will incur to replace the same services by human-made systems (Farber et. al., 2006; Twill et al., 2011).

Example of landscape performance benefits that can be valued by RC:

- Preserve historical habitat for rare species. A human-made habitat of similar functions would cost approximately $ n.
- Reduce TSS, pollutants and nutrients entering water body by using a constructed wetland. A wastewater treatment plant of similar functions would cost approximately $ n.

Travel costs (TC) – The travel costs method uses required travel expenses that people pay to enjoy ecosystem services to reflect the value of the services (Farber et. al., 2006; Twill et al., 2011). This method can be used to estimate the value of large parks, city plazas and recreational destinations.

Example of landscape performance benefits that can be valued by TC:

- Provide recreation and educational opportunities to n visitors, whose average travel expenditure is about $ n.
- Attracts an average of n visitors daily, who contribute up to $ n in travel related spending.

Production approaches (PA) – The production approaches value ecosystem services by the economic value of products resulting from the service (Farber et al., 2006).

Example of landscape performance benefits that can be valued by PA:

- The newly constructed courtyard increases the company's annual income by $ n through improving employees' productivity.
- Generate $ n in annual revenue from recreational and facility rental fees.

Hedonic pricing (HP) – The hedonic pricing method estimates the value of ecosystem services based on what people are willing to pay for the associated goods (Farber et al., 2006; Twill et al., 2011).

Example of landscape performance benefits that can be valued by HP:

- The lake increases property value of nearby houses by $ n.

- The value of properties with views to the mountain is approximately $ n higher than others.

Contingent valuation (CV) – The contingent valuation method values ecosystem services by asking people whether they are willing to pay or accept compensation for some changes in ecosystem services (Farber et al., 2006). This method is currently not used in landscape performance metrics quantification; however, it has a good potential in monetizing environmental and social benefits.

Example of landscape performance benefits that can be valued by CV:

- n% of residents surveyed express that they are willing to increase the HOA fee by $ n to improve air quality.
- n% of the surveyed house renters express that they are willing to pay $ n more for the houses that are closer to a transit station.

Conjoint analysis (CA) – The conjoint analysis method estimates the value of ecosystem services by asking people to choose or rank different service scenarios (Farber et al., 2006). This method is similar to the contingent valuation because they both evaluate ecosystem services based on people's preference. The difference is that instead of asking people how much they are willing to pay, conjoint analysis provides different scenarios that already have prices, and the value of particular ecosystem services is estimated by price difference between the scenarios.

Example of landscape performance benefits that can be valued by CA:

- n% of people surveyed express that the intensive green roof with real grass, large trees and seating areas are preferred despite $ n extra costs.

As discussed before, avoided costs and market methods are frequently used in landscape performance quantification. Many research teams reported avoiding/saving costs because of recycling material, using reclaimed water for irrigation, reducing the demand for maintenance and etc. Several research teams also used market methods value to estimate value of fruits, vegetable, and wine produced on sites. While, other methods including replacement cost, travel cost, production approaches, hedonic pricing, contingent valuation, conjoint analysis are not widely used in landscape performance at this moment. Several reasons might contribute to this situation. First, these methods are more complicated than avoided costs and market methods, involving more professional knowledge and skills that landscape architects normally do not have. For example, it might be difficult for a landscape architect to decide the replacement cost of a historical habitat for rare species without help from experts in natural resources and wildlife.

Additionally, travel cost, hedonic pricing, contingent valuation and conjoint analysis methods are often applied through survey and interview. Under the tight timeframe and budget, it is difficult to develop, approve, and undertake survey and interview. Moreover, cost information is not usually released, further impeding application of some methods. Lastly, to date, LAF only requires research teams to report environmental, economic and social benefits, and does not urge them to put a money value on all benefits.

Despite the difficulties, I suggest including these eight ecosystem evaluation methods in landscape performance quantification. They have a good potential of valuing landscape performance's non-market environmental and social benefits and could facilitate cost-benefit analysis discussed earlier. Further, using these standardized methods would allow comparative study across different landscape performance case studies. In order to apply these methods efficiently, help from experts in economics and social science might be needed. Table 5.3 illustrates the possible methods for the current landscape performance benefits.

Table 5.3. Possible methods for monetizing the current landscape performance benefits.

Environmental Benefits		**Most appropriate methods**
Habitat		
Habitat Preservation/ Creation/ Restoration	Restore and enhance native habitat/historical habitat	RC, CV, HP, TC
	Create a variety of habitat types for native fauna / for endangered species and rare species	RC, CV, HP, TC
	Set aside habitat as wildlife preserve	RC, CV, HP, TC
	Restore connectivity of corridor	RC, CV, HP
	Restore and protect waterfront	RC, CV, HP, TC
	Restore piped stream to a more naturalized profile	RC, CV, HP
	Increase number of local fauna and biodiversity	RC, CV, HP, TC
Vegetation	Increase the ecological integrity of plant communities (Plat Stewardship Index)	RC, CV, HP, TC
	Create meadow instead of lawn, improving ecological quality of the area	CV, CA, HP
	Increase biodiversity of the site/create a variety of habitat types for native flora	RC, CV, HP, CA, TC
	Add new trees/high rate of tree establishment	CV, HP, CA
	Preserve existing trees/extend lifespan of trees	AC, CV, HP
Water		
Stormwater Management	Reduce runoff, peak discharge, flash flooding, and bank erosion	AC, RC, CV
	Infiltrate stormwater to recharge groundwater	CV, CA
	Remove culverts and restore streams to improve the site's water conveyance capacity	HP, CV, CA
	Reduce impervious surface	AC, CV, CA
	Reduce water velocities to reduce stream's shear stress/erosion force	AC, CV, CA
Water Conservation	Use drought-tolerant/native species to reduce irrigation water consumption	AC, MM, CV, HP, CA
	Restore native habitat to reduce water consumption	AC, MM, CV, HP, CA
	Use limited areas of irrigated landscape to reduce irrigation water consumption	AC, MM, CV, CA

Table 5.3 Continued

Environmental Benefits		**Most appropriate methods**
Water Conservation	Use water-conserving plumbing fixtures/low-flow irrigation system	AC, MM, CV, CA
	Use rain water/reclaimed water/brackish water/recycled water for irrigation, landscaping, and toilets	AC, MM, CV, CA
Water Quality	Reduce TSS, pollutants and nutrients entering water body	AC, CV, CA, HP
	Clean up polluted river water using biological processes/treat waste water in an onsite biomembrane reactor system	AC, CV, CA, HP
Flood Protection	Provide flood protection for xxx-year event (e.g., 200 year event), sustain flow rate, eliminate surface flooding	AC, CV, CA, HP
	Decrease upstream and downstream flooding	AC, CV, CA, HP
	Eliminate flood-related restoration and clean-up demand	AC, CV, CA, HP
	Decrease sub-watershed floodplain by increasing flood storage capacity	AC, CV, CA, HP
Carbon, Energy		
Urban Heat Island Effect	Replace roof with the vegetated roof	AC,CV, CA, HP
	Increase albedo by replacing the asphalt on the site with concrete permeable pavers	AC, CV, CA, HP
	Reduce regional air temperature	AC, CV, CA, HP
	Reduce surface temperature (roof)	AC, CV, CA, HP
Air Quality	Reduce emission (hydrocarbon, carbon monoxide, carbon dioxide, nitrogen oxides)	HP, CV, CA
	Remove air pollutants (e.g., small-particle)	HP, CV, CA
Energy	Generate electricity via photovoltaic modules	AC, MM, CV, CA
	Reduce building energy use	AC, MM
	Improve microclimate (warmer in winter and cooler in summer)	AC, MM, HP, CV, CA
Carbon	Preserve trees by using decomposed-granite mulch instead of woodchip mulch	AC, MM, CV, CA
	Replace motorized landscape equipment with hand weeding and prescribed burns	AC, MM
	Reduce carbon footprint / reduce carbon emission	HP, CV, CA
	Reduce auto trips/ increase bus and subway ridership	AC, MM
	Carbon sequestration	
Material, Waste		
Reuse and Recycle	Reuse on site materials	AC, MM
	Reuse materials from offsite (e.g., old railroad ties)	AC, MM
	Recycle local-sourced materials (e.g., concrete)	AC, MM
	Recycle construction waste/eliminate waste	AC, MM

Table 5.3 Continued

Environmental Benefits		**Most appropriate methods**
Land		
	Increase soil sequestration potential	PA, CV
	Treat contaminated soils	PA, CV
	Regularly perform biological soil test and balance soil microorganisms to maintain healthy levels of nitrogen in soil	PA, CV
	Improve soil alkalinity	PA, CV
Other		
	Increase open space	HP, CV, CA
	Reduce noise level	CV, CA
	Install combined sewer overflow interceptor to eliminate sewer discharge and reduce over flows	CV, AC
	Reduce long-term site maintenance cost by converting pavement and lawn to native landscape	AC, CV, CA
	Reclaimed former university parking lot to create a viable Sonoran Desert landscape	AC, CV, CA
	Reduce total area of building footprint	CV, CA, HP
Social Benefits		**Most appropriate methods**
Recreational & Social Value	Receive increasing visitors	TC, PA
	Provide parks and open space to residents	HP, CV, CA
Public Health & Safety	Increase resident's or employee's satisfaction	CV, CA, PA
	Increase walkability	HP, CV, CA
	Provide flood protection	AC, HP, CV, CA
	Reduce noise level	CV, CA
	Provide therapy to visitors	AC, CV, HP
	Foster playing	TC, CV, CA
	Provide educational opportunities to increasing visitors	TC, CV, CA, PA
Educational Value	Increase public awareness/understanding of sustainable planning and design	CV, CA
Food Production	Generate fruit and vegetables	MM
Economic Benefits		**Most appropriate methods**
Cost Saving	Cost saving	AC, MM
	O & M savings	AC, MM
Property Value	Property value increase	MM, HP, CV, CA
Economy Development	Economic development and revenue increase	MM, PA
	Revenue generation through new jobs	PA, MM

Conclusion

Landscape performance is evaluated by measuring landscape solutions' benefits. These benefits are cost embedded, and the cost is as important as benefit for decision-making. Currently, the landscape performance framework does not include cost for performance evaluation, leaving a gap in the subject. This paper adopts life-cycle cost and integrates it in the landscape performance framework. It also explores standard economic valuation methods and discusses their usage in monetizing the current landscape performance benefits.

The results show that there are two common methods of calculating landscape solutions' life-cycle costs: present worth and annualized methods. Which method to choose depends on how benefits are reported. Life-cycle costs allow future designers and clients to compare the costs of conventional and sustainable solutions and help them conduct cost-benefit analysis on landscape solutions. As for representation, cost embedded benefits can be reported using efficiency or productivity metrics. Efficiency metrics measure the ratio of cost to benefit, while productivity metrics measure the ratio of benefit to cost (Hatry, 1999). These metrics show cost-effectiveness of each landscape solution and help designers make appropriate design decisions according to budgets.

The result of the Cross Creek Ranch case study shows that in some cases costs are higher than benefits. It is partly because the value of many non-market benefits is difficult to determine and is excluded from the cost-benefit comparison. Currently, eight economic valuation methods are accepted in peer-reviewed literature, including avoided cost, market methods, replacement cost, travel cost, production approaches, hedonic pricing, contingent valuation, and conjoint analysis. These methods can be applied to monetize non-market landscape performance benefits and assist cost-benefit analysis. Lastly, it needs to be noted that, costs are size (scale) sensitive. That is, the costs of landscape solutions vary largely across different sizes. Future designers and reviewers need to recognize the influence of size so as to obtain more precise information and references.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Landscape Performance Series initiated by Landscape Architecture Foundation has been a significant effort that enhances performance measurement in the field of landscape architecture recently. With quantified performance data, the claims of benefits provided by landscape projects are scientifically sound and reliable.

This study compared landscape performance with performance measurement in architecture, urban planning, and transportation, analyzed and compared the published 2011 and 2012/2013 landscape performance case studies, examined the currently used quantification metrics and methods, and explored methods of including cost information in landscape framework.

The results showed that landscape performance documents performance benefits of sustainable strategies, reduces uncertainties during design and informs decision making. It provides evidence base for future designers and clients to estimate and compare sustainable strategies with conventional ones. Compared to the frameworks of other performance measurements and rating systems, landscape performance is the only one that requires projects to be investigated in the environmental, economic and social aspects of sustainability. Building performance often focuses on users' health, safety and satisfaction, buildings' function, and some social, cultural and aesthetic performance of buildings (Preiser & Vischer, 2005). Transportation and urban planning performance generally focuses on cost-effectiveness of programs and services (Dahlgren, 1998; Hatry, 1999). LEED-ND focuses majorly on environmental aspects of sustainability, and

SITES focuses on environmental and part of social aspects of sustainability. The framework of landscape performance not only quantifies environmental, economic and social benefits, but also considers the interaction between them. Moreover, landscape performance complement LEED-ND and SITES in sustainability assessment. The rating process of LEED-ND and SITES is primarily based on design documents at the design and early construction phases, which is a prospective analysis. In contrast, landscape performance emphasizes actually assessing the performance of a project after it is constructed and occupied, which is a backward analysis. Overall, landscape performance is a significant effort that systematically assesses landscape projects in the environmental, economic and social aspects of sustainability. It fills the gap in the field of landscape architecture and contributes toward ecologically and socially sustainable design practices.

However, since landscape performance research is still new, it has a number of gaps in its framework, metrics and methods. Below is a list of the gaps followed by recommendations on future improvement.

1. The definition of landscape performance is not precise. Efficiency normally refers to comparison between inputs and outputs rather than actual and intended purposes. So it is not as accurate to use efficiency to represent how landscape solutions fulfill their intended purposes. In addition, the "intended purpose" is normally not clearly defined in landscape performance case studies. In actuality, measured performance should be compared with explicitly defined performance

benchmarks to determine whether it is considered a performance that enhances sustainability.

Recommendation: Landscape performance is better defined as the measure of the extent to which landscape solutions fulfill their intended performance criteria and contribute toward sustainability.

2. There are no performance criteria/benchmarks.

   Recommendation: Develop performance benchmarks for typical landscape solutions with which measured performance can be compared.

3. Metric selection is often determined by readily available data resources.

   Recommendation: First, select metrics that are relevant to goals and objectives of projects; second, considering that users' goals are also important, I suggest including user representatives in performance quantification process.

4. Benefits and methods are very different across landscape performance case studies, making it difficult to compare study results and evaluate the reliability and validity of methods.

   Recommendations: Develop robust core measuring systems to facilitate efficient data collection and quantification.

5. Due to the short timeframe of the CSI program, most case studies were conducted using a cross-sectional snapshot of a landscape's performance, failing to provide information regarding long-term performance.

   Recommendation: Select several best cases to participate in an ongoing long-term monitoring (every 5-10 years) to collect longitudinal assessment data.

6. There is confusion between output metrics and outcome metrics.

   Recommendation: Use outcome metrics (e.g., increase residents' daily exercise by n times) instead of output metrics (e.g., create n miles of trail).

7. Sustainability triad includes equity; however, current social metrics do not address equity issues.

   Recommendation: include metrics regarding social equity.

8. Project composition is not balanced.

   Recommendations: 1) include more cases from community, multifamily, and playground; 2) include more cases that were completed earlier.

9. Economic and social benefits are not well documented.

   Recommendation: 1) develop several sample questionnaires for future research teams to adopt and modify; 2） include a research fellow or assistant from economic background in future research teams.

10. Some metrics are missing in comparison to LEED-ND, SITES and ecosystem services.

    Recommendations: add the following metrics – smart location, construction activity pollution prevention, storm protection, climate regulation, wind reduction, design for deconstruction and disassembly, use certified wood, use materials with reduced VOC, incentives due to sustainable solution, human disease control, light pollution reduction, catastrophic wildfire, worker productivity, well-being, comfort, and ecotourism.

Another pitfall of the current landscape performance is that costs of benefits are not included in case studies. Landscape performance benefits are cost embedded. Costs would facilitate future designers and clients to make appropriate decisions. Chapter V showed that life-cycle costs can be integrated into landscape performance quantification. The cost embedded benefits can be reported using efficiency and productivity metrics. In order to better facilitate cost-benefit analysis of sustainable solutions. I suggest adopting conventional economic valuation methodologies to help determine the dollar value of non-market landscape performance benefits.

In conclusion, assessing sustainable development has long been a difficult research subject in the field of landscape architecture, due to many factors, such as lack of funding, data resources and techniques. The CSI program groups researchers and practitioners to quantify landscape projects' performance benefits in the three aspects of sustainability, providing a sound framework of assessing sustainable developments. In this study, I made several recommendations to future landscape performance researchers and LAF. These recommendations are not to oppose the core framework of landscape performance quantification. Rather, I try to improve it to better quantify the outcomes of high-performing landscape projects and inform future sustainable design practices.

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