An International Framework for Sustainable Roadway Rating Systems

Manisa Veeravigrom

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Reading Committee:

Stephen Muench, Chair

Joe Mahoney

Carrie Dossick

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Abstract

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Manisa Veeravigrom

Chair of the Supervisory Committee:
Associate Professor Stephen T. Muench
Civil and Environmental Engineering

Increasing attention to greenhouse gas emissions, general environmental damage, human safety, and the general impact of transportation infrastructure on society has increased attention on designing and constructing infrastructure in a more sustainable manner. In recent years, a number of rating systems have been developed and are increasingly being used to measure and quantify the sustainability of infrastructure. However, there is no consistent framework for developing or analyzing these rating systems. Therefore, most rating systems consist of a piecemeal collection of sustainability best practices with little information on how they were developed or how they address the scope of sustainability. This can lead to significant issues in understanding the sustainability scope of these systems, what they implicitly prioritize, and how they can be transferred from one context to another. These issues come to the forefront with increasing international demand for these rating systems. Due to different rating system priorities, national contexts, and local circumstances, it is difficult, if not impossible, to apply one system universally. This research focuses on a subset of infrastructure, roadway projects, and proposes a framework that can be used to develop a sustainability rating system within the context of any country as well as evaluate and improve existing rating systems. The framework uses the Sustainable Society Index (SSI) categories and existing rating systems as a starting point

to develop 49 roadway topics. Using this framework to evaluate eleven existing rating systems shows that most systems focus more on environmental aspects and lack consideration of social and economic aspects such as accessibility, safety, and local employment, which can be particularly inappropriate in developing countries whose priorities are basic needs (e.g., access, safety, employment). The framework presented here can be helpful in (1) evaluating and comparing the sustainability scope of existing roadway systems, and (2) developing or adapting rating systems for new contexts.

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Chapter 1 Introduction

1.1 Background

Transportation plays a vital role in the everyday lives of human beings by linking them together both socially and economically. An efficient and safe transportation system can contribute greatly to quality of life and economic success in both urban and rural areas throughout the world. Unfortunately, transportation system infrastructure, operation, and its use can cause extensive environmental damage and impact on quality of life including air pollution, noise pollution, water pollution, disruption of ecology, and disintegrate community activities, and crashes (IPCC, 2013; EPA, 2012; Hedlund, el at., 2003). The statistics from Federal Highway Administration (FHWA) shows that crashes are the number one cause of deaths among Americans 1-34 years old. Vehicle operations on roads consume fossil fuels at an unsustainable rate contributing to Greenhouse gas (GHG) emissions, depletion of non-renewable resources, ecological degradation, human health issues, and political strife. Such issues have led to a growing movement to plan, build, operate and maintain transportation systems in a more sustainable manner. Roadways should be designed, constructed, and used in a way that supports social equity, economic development and environmental stewardship (Zietsman & Rilett, 2002).

Over the last ten years, there has been a proliferation of infrastructure rating systems. Clearly, they are arising from some desire to holistically quantify sustainability for this infrastructure and perhaps to provide direction for how to improve sustainability. In general, rating systems, which are performance measurement tools, have become popular and widespread in various industries for benchmarking and making decisions. The advantages of rating systems are that they provide

clear and easy communication about performance, shorthand meaning, and a convenient way to measure and benchmark performance (Muench el at., 2012).

In general, a sustainability rating system is a metric that measures sustainability performance of projects based on sustainability best practices (Muench el at., 2011). To date, more than fifty sustainability rating systems have been developed for use in civil infrastructure in different countries (Doyle el at. 2012). In the building industry examples of sustainability rating systems are the Building Research Establishment Environmental Assessment Method for buildings (BREEAM) in the United Kingdom (UK), Leadership in Energy and Environmental Design (LEED) in the U.S., Green Globes in Canada and the U.S., the Comprehensive Assessment of Building Environmental Efficiency (CASBEE) in Japan, and Green Star in Australia (BREEAM, 2013; USGBC, 2012; Green Globes, 2013; CASBEE, 2013; Green building Council Australia, 2013). For infrastructure in general, examples of rating systems are Civil Engineering Environmental Quality Assessment and Award Scheme (CEEQUAL) in the UK, Envision^{TM} in the U.S., and Infrastructure Sustainability (IS) in Australia (CEEQUAL, 2011; ISI, 2011; AGIC, 2012; FHWA, 2012). Examples of rating systems specifically for roadway projects are Greenroads and INVEST in the U.S., INVEST VicRoads in Australia, and Green Guide for Roads in Canada (TAC, 2012).

Most of these metrics have been created for use in developed countries such as U.S., U.K., Europe, Canada, and Australia, while a few have been internationally used such as LEED, BREAM, and Green Globes. The only rating system that claims international applicability for infrastructure projects and not just buildings, CEEQUAL International, comes from the U.K. and

was released in 2012. More recently, the building industry has begun to see rating systems released for developing countries such as TREES (Thailand) (TGBI, 2011), Pearl Building Rating System (PBRS) (Abu Dhabi) (UPC, 2013), and LEED India (IGBC, 2008). In sum, rating systems have largely originated in developed countries and now seem to be proliferating as country-specific systems with a few outliers that claim to be fully international.

This research focuses on sustainability rating systems for roadway projects. Based on the sheer number of different sustainable roadway rating systems, there appears to be an unstated recognition that there are different contexts within which to consider sustainable roads and each context demands some customization to make the rating system reflect the owner's values. Brown et al. (1987), Clark (1994), Kohler(1999), and Anderson (2008) agree that different location and time scales may lead to different meanings of sustainability because of diversity of geography, climate, culture and historic value, economic, political system, and national resources in each country. These differences can significantly influence priority issues on sustainability solutions; so it may not be appropriate to develop a system in one country and apply it everywhere.

Another issue is that has become apparent with the proliferation of rating systems is that it is often not possible to understand a rating system scope, weighting or the entirety of its intended audience using existing documentation. There are very few systems that have documented their logic (i.e., scope, weighting, and methods). While such logic likely exists on some level, the lack of documentation means there is no explicit method (vetted or not) that developers can follow to alter a rating system based on context or develop a new rating system for a new context.

In sum, there appear to be two main issues that are becoming clear with the proliferation of sustainability rating systems both in developed countries and worldwide:

1. Context sensitivity. There is a reasonable demand for creating rating sustainability systems all over the world based on the sheer number generated. The idea that people can take one such system and universally apply it worldwide is inappropriate because sustainability is context sensitive; different approaches and different national priorities (Sev, 2011; Nwokoro and Onukwube, 2011; Ozolins, 2010; Liang, 2012; Saynajoki el at., 2012) imply that a performance metric like a rating system should be customized to the context within which it will be used.

2. No guiding framework. A framework that defines sustainability and provides an objective approach to identifying key subcategories of sustainability and classifying sustainability best practices could be useful in (1) developing rating systems for specific contexts, and (2) analyzing existing rating systems to better define their scope and focus. Notably, there is no documented framework for developing sustainability rating systems (Dondero el at., 2012). Based on this dissertation's review of twelve different rating systems, there is little documented evidence any sort of consistent framework was used to guide the inclusion/exclusion, or weighting of best practices.

1.2 Goal and Scope

The goal of the research is to develop a global framework for the creation, modification, and analysis of sustainability rating systems for roadways. This framework will be tested by analyzing the existing Greenroads rating system (version 1.5) and creating a new modified Greenroads for use in Thailand. The reasons why Greenroads specifically was selected are that

the author has participated in Greenroads and the system is free of use and focus only on roadway projects.

Specifically, this research will:

- Review the state-of-the-practice for sustainability rating systems in roadway projects in order to identify which indictors are or should be addressed and what weight systems has been used;
    - Review existing roadway sustainability rating systems and sustainable implementation frameworks.
- Develop a framework for creating, modifying, and analyzing a rating system for any country that addresses two main issues: context sensitivity, and transparency.
    - Define a method to assign credits and weighting for developing a roadway design and construction sustainability rating system, and address national priorities and needs within this framework.
- Evaluate the framework based on case studies in order to refine and validate on current practices;
    - Analyzing Greenroads within the context of this framework,
    - Modifying Greenroads for Thailand using this same framework.

The contributions of this research to the state-of-knowledge in rating systems is the creation of a logical method for developing and analyzing sustainability rating systems by mapping between an overarching view of sustainability and the structure of a specific rating system.

The anticipated outcomes are:

1) A framework. A framework that using for a starting point for any country that will develop a roadway sustainability rating system for their use in order to help their agencies integrate sustainability into their project.
2) Greenroads analysis. The framework is used to analyze an existing rating system in order to better define its scope and influence.
3) Greenroads Thailand. A rating system for Thailand will be developed based on the existing Greenroads Rating System. This serves as an example of how to develop a system in developing countries.

1.3 Organization

This proposal is divided into five chapters:

- Chapter 1 provides an introduction, goal, and research design to this study;
- Chapter 2 provides the definitions of sustainability, sustainability in transportation, and sustainability in roadway projects;
- Chapter 3 contains a review and evaluation of existing sustainable roadway rating systems;
- Chapter 4 proposes the international framework for sustainable roadway rating systems;
- Chapter 5 addresses the analyze Greenroads by using the international framework;
- Chapter 6 develops the methodology how to use the international framework to develop rating systems in any country. Greenroads will be modified for use in Thailand as a case study.
- Chapter 7 provides a summary and conclusion.

Chapter 2 Background

2.1 Introduction

This chapter describes (1) the comprehensive definitions of sustainability that are widely being used by the general public, (2) the background of Greenroads rating system which is used in this research, and (3) national boundaries as proxies for context.

2.2 Sustainability Definition

This section defines what sustainability meaning used is specific to this research. There are a number of sustainability and sustainable development definitions in widespread use today; however, these definitions tend to be too broad or vague for use in a research endeavor. Rather than offer another sustainability definition, this research takes existing definitions and adapts them. An explicit definition of sustainability is significant because it can provide guidelines for developing and benchmarking of sustainability rating systems, and can be adapted for use in practical ways.

There appears to be some consensus on sustainability definitions in that they include (Maslow, 1943), (Zietsman & Ramani, 2011), (Anderson, 2008), (Brown el at.1987), (A/RES/42/187), (Harris, 2001):

(1) Expectations of humans. Consideration of goals and needs of humans such as safety, esteem, and self-actualization;

(2) The holistic consideration of economic, social, and environmental issues. Integrated with these three aspects in solution by developing projects to meet human expectations but which do not harm natural resources, and which support economic growth;

(3) Long-term perspective. These systems are persistent and should be optimized for continuous use/existence rather than for a specific instant in time; for example, consideration of long-term consequences of today's activities such as minimizing the use of non-renewable material and water, and protecting of habitat and natural resources for future generations;

(4) Spatial consideration. Define boundaries of projects in terms of geographic space.

The definition used for this research: A sustainable roadway project is one that, over the long term, meets human needs, users resources economically, and maintains or improves the surrounding environment. In other words, this research adopts the three fundamental dimensions of sustainability, which consider environmental, economic, and social aspects, and then integrate four sustainability principles as a background for developing the system.

2.2.1 Common Definitions of Sustainability

Most definitions of "sustainability" are theoretically based without much concern for practical application. The majority of popular sustainability definitions refer to three basic components of sustainability to be considered holistically: environmental, social, and economic (often referred to as the "triple bottom line"). Other versions are: ecology, equity, and economy; or people, planet and profit.

The most prevalent versions of sustainability definitions come from the United Nations 1987 report of the World Commission on Environment and Development (stated as "*Our Common Future*" or "The Brundtland Commission Report") which defines sustainability as

"…development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (A/RES/42/187).

2.3 Sustainability in the Transportation Context

Over the past 10 years, there has been extensive research on what is loosely referred to as "sustainable transportation" for example, OECD, 1997, Litman and Burwell, 2006; Zietsman and Ramani, 2011; Amekudzi et al., 2011). The general key issues relate basically to access, equity, safety, human health, choice of transportation mode, emission and waste, and ecological systems. It is important to distinguish between what sustainability is and what sustainability is not in the transportation projects. In *NCHRP Report 708: A Guidebook for Sustainability Performance Measurement for Transportation Agencies* (Zietsman & Ramani, 2011), Zietsman and Ramani (2011) provide the definition of sustainability in the transportation context. Their research applies a set core of sustainability principles in practice for developing sustainable transportation projects.

> *Sustainability entails meeting human needs for the present and future, while:*
>
> - *Preserving and restoring environmental and ecological systems.*
> - *Fostering community health and vitality.*
> - *Promoting economic development and prosperity.*
> - *Ensuring equity between and among population groups and over generations.*
>
> (Zietsman & Ramani, 2011)

In sum, sustainable transportation projects tend to first meet user expectations. Then, effects from projects do not degrade environment and ecology systems. Agencies should manage money and natural resources wisely and efficiently in long-term perspective. In addition to these points,

governance issues should be considered as well. It is important to develop goals, visions and policies integrated by sustainable concepts in the planning phase.

2.4 Greenroads

This research uses the Greenroads Rating System to test the framework in Chapters 6 and 7. Greenroads is a US-based rating system for measurement of sustainability in roadway projects (Muench et al., 2011), which was originally developed at the University of Washington with the assistance of CH2M HILL between 2006 and 2011. Sustainability best practices described within Greenroads are divided into two types: mandatory and voluntary. There are eleven mandatory practices, called Project Requirements. No point is allocated for completing these Project Requirements. There are 37 voluntary activities, called "voluntary credits" or VC worth 108 points total. Each activity is assigned a point value from 1 to 5 depending upon its impact on sustainability and these activities are divided into five categories:

- Environment & Water (EW)
- Access & Equity (AE)
- Construction Activities (CA)
- Materials & Resources (MR)
- Pavement Technologies (PT)

In additional, a sixth VC category called "Custom Credits" includes a maximum of ten points, which may be earned by a project that implements sustainable or innovative ideas that can be turned into their own credits. There are four achievement or certification levels that can be earned by meeting all of eleven project requirements and earning a number of voluntary points to meet the award levels as shown below:

- Bronze: 32-42 VC points (30-40% of total)
- Silver: 43-53 VC points (40-50% of total)
- Gold: 54-63 VC points (50-60% of total)
- Evergreen: 64 or more VC points (>60% of total).

Greenroads as the platform for their national own rating systems (Greenroads Foundation, 2013).

2.5 Summary

- Sustainability definition is a guideline for developing roadway sustainability rating systems.
- The definition used is sustainable projects should primarily respond to basic human needs and enhance safety and health; then, environmental damage should be considered and the outcome of a project should boost economic growth and enhance the wellbeing of future generations.
- The fundamentals of sustainability principles are the expectations of humans, the holistic of ecology, equity, and economy, the long-term perspective, and boundary conditions in time and location.
- In sustainable transportation context, the key issues relate basically to access, equity, safety, human health, choice of transportation mode, emission and waste, and ecological systems.

Chapter 3 A Review of Roadway Rating Systems State-Of-The Practice

There are more than 50 existing sustainability rating systems in various stages of use and development today and they appear to be increasing in popularity (Doyle et al., 2012). This chapter reviews twelve existing rating systems for roads by: 1) providing details on the twelve existing sustainability rating systems that are applicable to roads; 2) comparing these; and 3) drawing conclusions based on the review and comparison including why it is not advisable to use one universal rating system worldwide.

3.1 Sustainability Rating Systems

A rating system is a tool that offers a convenient way to convert complex situations into simple ones for users to understand sustainability, and voluntary and point-based systems (Muench et al.,2012). Generally, it sacrifices details and nuance for simplicity and clarity. It is designed to promote best practices, provide guidance, and measure sustainable performance based on fundamental sustainable values in terms of environmental health, equity, and economic benefits. They address the different approaches and the level of details. Most of them are focused on individual infrastructure projects (e.g., a building or road). Ultimately, these rating systems seek to advance the state-of-the-practice in sustainable infrastructure and can be viewed as behavior modification tools used to achieve this goal.

Stated advantages to using rating systems are (Muench et al., 2012), (Nelson & Frankel, 2012):

1) Awarding a number of points for achieving sustainable solutions,
2) Allowing for simplified communication benefits and goals,
3) Providing guidance to stakeholders in their innovation solutions,

4) Providing meaning and concentrated information, and comparability of the results, and
5) Highlighting effective practices to meet sustainability solutions.

Stated drawbacks are (Muench et al., 2012), (Nelson & Frankel, 2012):

1) Due to the fact that sustainability is a complex philosophy with multiple aspects, they try to eliminate detail to be simple to apply,
2) The set of indicators are based on developers' decisions rather than based on consensus' decisions in most cases,
3) They likely do not fully address sustainability,
4) Users will concentrate more on pursuing points rather than meeting sustainable solutions, resulting in poorer projects,
5) The rating systems are not flexible and adaptable,
6) It is hard to address future perspectives and long-range effects in the system,
7) They tend to measure on design (input) rather than performance (outputs).

3.1.1 Fifteen Rating Systems for Road Projects

The following fifteen sustainability rating systems are selected for review because they are relevant to road projects and have been developed in recent years. The review covers basic facts about each including, overview, owner, scope, start year, status, background, rating scale, and subcategories within the system. The systems vary considerably in quality, scale, and intent. This review groups these systems using public information as follows: 1) Mature: a system has been released Version 1 at least four years and have officially rated at least ten projects; 2) Fully operational: a system has been released Version 1 for less than four years and

have officially rated at least one project; 3) Pilot phase: a system has not been released Version 1 and doing pilot projects only; 4) Development: at early stage of development or internal pilot projects.

3.1.1.1 ***Mature:*** *a system has been released Version 1 at least four years and have rated at least ten projects*

CEEQUAL	
Overview:	Civil Engineering Environmental Quality Assessment and Award Scheme is an assessment and award scheme based on United Kingdom regulation for improving sustainability in civil engineering projects. It is a tool to assess sustainability infrastructure projects in the U.K. and the Republic of Ireland, a credit-based assessment method, and a third party system for assessment.
Owner:	CEEQUAL Ltd, owned by a group of fifteen organizations, including the ICE, ACE, CECA and CIWEM.
Scope:	Civil engineering and public realm projects in the U.K. and Ireland
Start:	2003
Status:	Version 5 of manual was launched on October 2012
Background:	CEEQUAL was originally created by a team led by the Institution of Civil Engineers, supported by the Institution's R&D Enabling Fund and the UK Government. For CEEQUAL international has collaboration contracts with AGIC (the Australian Green Infrastructure Council) and ASCE (American Society of Civil Engineers) (CIRIA and Crane Environmental, 2010).
Rating Scale:	Pass, Good, Very Good, and Excellent.
Category:	9 categories: Project Strategy, Project Management, People and Communities, Land use (above and below water) and Landscape, The Historic Environment, Ecology and Biodiversity, Water Environment (fresh and marine), Physical Resources Use and Management, and Transport.
Number of Project rated:	More than 260 final awards and almost 100 interim client and design award, update February 2015 (CEEQUAL, 2015)

GreenLITES	
Overview:	Green Leadership in Transportation Environmental Sustainability is a sustainability rating system for transportation infrastructure, a self-certification program, and a mandatory rather than voluntary program.
Owner:	New York State Department of Transportation (NYSDOT) and it is used by the NYSDOT.
Scope:	Transportation infrastructure projects including project designs, operations, and maintenance process.
Start:	2008.
Status:	The project design certification program in Version 2.1.0 is available (April 2010) at www. nysdot.gov/programs/greenlites. Revised twice (version 1.0 in 2008, and version 2.0.x in 2009)
Background:	GreenLITES was started in September 2008. Modeled on LEED and Greenroads version 0.5 (McVoy et al. 2010).
Location:	New York.
Rating Scale:	Certified, Silver, Gold, and Evergreen.
Category:	The scorecard contains 5 categories and 175 credits: Sustainable Site, Water Quality, Materials and Resources, Energy and Atmosphere, and Innovation.
Number of Project rated:	221 projects (NYSDOT, 2012)

Greenroads	
Overview:	Greenroads is a rating system for roadway design and construction. It is point-based and voluntary, applicable to all U.S. road projects, and a third party system for assessment.

Greenroads	
Owner:	Greenroads Foundation.
Scope:	Roadway design and construction.
Start:	2006.
Status:	Fully deployed Version 1.5 available to review projects at www. greenroads.org. Over 120 case studies have been used to test and verify the rating systems (Anderson & Muench, 2012)
Location:	U.S.
Rating Scale:	Certified, Silver, Gold, and Evergreen.
Category:	6 categories and 118 points: Environment & Water (EW- up to 21 points), Access & Equity (AE – up to 30 points), Construction Activities (CA up to 14 points), Materials & Resources (MR up to 23 points), Pavement Technologies (PT up to 20 points), and Custom Credits (up to 10 points)
Number of Project rated:	Tested on over 120 projects and 22 certified projects (more than 27 registered), updated June 2015, (Greenroad, 2015)

LEED-ND	
Overview:	Leadership in Energy and Environmental Design for Neighborhood Development is a rating system focused on the design, construction and operation of neighborhood development combining with the principles of smart growth and urbanism, and green building. It is a third party certification program, point-based and voluntary and applicable to all U.S., and international neighborhood.
Owner:	U.S. Green Building Council (USGBC) (501 c3 non-profit organization)
Scope:	Neighborhood developments.
Start:	2007
Status:	LEED 2009 for Neighborhood Development Rating System at www.usgbc.org.
Background:	There are nine rating systems with in LEED. The original, LEED for New Construction, came out in 1998, which was originally developed by USGB. At present, LEED consists of more than 16,000 member organizations, over 168,000 LEED professional credential holders, and 491 government organizations comprising LEED legislation, executive orders, resolutions, ordinances, policies and incentives. With LEED-ND, USGBC and Natural Resource Defense Council (NRDC) collaborate to create LEED-ND. The pilot projects opened in July 2007. Updated 08/08/12 and there were 112 projects participating: Stage 3 Certified projects: 13; Stage 2 Certified Plans: 70; Stage 1 Certified Plans: 29 (USGBC, 2012).
Rating Scale:	Certified, Silver, Gold and Platinum.
Category:	4 categories and 106 maximum points: Smart Location and Linkage, Neighborhood Pattern and Design, Green Construction and Technology, and Innovation and Design Process.
Development:	Multiple public comment periods and responses from USGBC member committees.
Number of Project rated:	143 certified projects, updated March 2015 (USGBC, 2015).

SITES™	
Overview:	Sustainable Site Initiative™ is a sustainability rating system for landscape design, construction, operation, and maintenance.
Owner:	The Sustainable Site Initiative.
Scope:	Land development including design, construct, operate, and maintain landscapes.
Start:	2005.
Status:	SITES V2 Rating System and Reference Guide
Background:	A partnership of the American Society of Landscape Architects, the Lady Bird Johnson Wildflower Center, and the United States Botanic Garden. The U.S. Green Building Council is eventually working in as a part of a future LEED system (Sustainable Site Initiative, 2013).
Rating Scale:	One Star, Two Stars, Three Stars, and Four Stars.
Category:	6 categories: Site Selection, Pre-Design Assessment and Planning, Site Design-Water, Soil and Vegetation, Materials Selection, Human Health and Well-Being.

SITES™	
Number of Project rated:	46 certified projects, updated March, 2015 (Sustainable Site Initiative, 2015)

3.1.1.2 ***Fully operational:*** *a system has been released Version 1 for less than four years and have rated at least one project.*

CEEQUAL International	
Overview:	CEEQUAL International is an assessment and award scheme based on United Kingdom regulation to improve sustainability in civil engineering projects for international projects. It is a tool to assess sustainability infrastructure projects outside the UK and Ireland, a credit-based assessment method, and a self-assessment. CEEQUAL International is based on CEEQUAL Version 5. These levels of certification are the same as the certification levels for U.K. and Ireland. However, unlike CEEQUAL for U.K., a weighting system of CEEQUAL international is different. Because of differences in location, the system needs to create a new weighting system based on its local condition, practices and regulation (CEEQUAL, CEEQUAL international, 2012).
Owner:	CEEQUAL Ltd, owned by a group of fifteen organizations, including the ICE, ACE, CECA and CIWEM.
Scope:	Civil engineering and public realm projects outside the UK and Ireland projects
Start:	2011.
Status:	The CEEQUAL Version 5 Projects Assessment Manual was launched on 2012.
Background:	CEEQUAL will set the weightings for local country or region. Weight systems based on fourteen topic areas: effects on neighbors, users and the workforce; material use, waste management, land and sea-bed use, transport, landscape issues, historic environment, ecology and biodiversity, waster environment, relation with the local community and other stakeholders, energy consumption & carbon emissions, water resources, flood risk, and restoration of contaminated land. Feescale zones for international project awards divide into three different locations: Europe & Northwest Africa, Gulf State & Middle East, and Rest of the World. The first formal verified assessments using CEEQUAL International is Sweden and further assessments in Hong Kong (CEEQUAL, 2012).
Rating Scale	Pass, Good, Very Good, Excellent
Category:	Project Strategy, Project Management, People & Communities, Land use & Landscape, Historic Environment, Ecology & Biodiversity, Water Environment, and Physical Resources: Use & Management, and Transport.
Number of Project rated:	1 certified project

Envision™	
Overview:	Envision™ is a sustainability rating system for civil infrastructure projects. It is a web-based and point-based voluntary system and applicable to all civil infrastructure projects and is both a self–evaluation and a third-party system.
Owner:	Institute for Sustainable Infrastructure (ISI), a joint venture of the American Society of Civil Engineers (ASCE), American Council of Engineering Companies (ACEC) and the American Public Works Association (APWA).
Scope:	All civil infrastructure projects including planning, design and construction.
Start:	2010.
Status:	The rating system has been tested on 18 projects. Envision™ 2.0 was published on February 16, 2012.

Envision™	
Background:	Established in early 2010, working with CEEQUAL. Then, collaboration between the ISI and

	the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure in the fall of 2011 (ISI, 2011).
Location:	North American including the U.S. and Canada.
Rating Scale:	Improved, Enhanced, Superior, Conserving and Restorative.
Category:	5 categories 60 criteria: Quality of life, Leadership, Resource Allocation, Natural World, and Climate and Risk.
Number of project rated	6 certified projects (ISI, 2015)

INVEST	
Overview:	Infrastructure Voluntary Evaluation Sustainability Tool is a sustainability rating system for roadway projects including planning and policy, project development as well as operations and maintenance by presenting best practices. It is point-based and voluntary, a self-evaluation tool, and application to all U.S. road projects.
Owner:	FHWA
Scope:	Highways and Transportation including System Planning (SP), Project Development (PD), and Operations and Maintenance (OM).
Start:	2010
Status:	Available as a pilot version at www. sustainablehighways.org Version 1.1 was published on January, 2015.
Location:	US.
Background:	Created by the FHWA in coordination with the contractor team of CH2M HILL and the University of Washington. It is based on ideas from Greenroads and GreenLITES (FHWA, 2012)
Rating Scale:	Bronze, Silver, Gold, and Platinum
Category:	Three categories and 60 criteria ranging 1-15 points: System Planning, Project Development, and Operation & Maintenance.
Number of Project rated:	24 certified projects

Infrastructure Sustainability (IS)	
Overview:	A rating system for infrastructure projects in Australia is divided in three types: Design rating, As Built rating, and Operational rating. It is a point system and a self-evaluation system.
Owner:	Australian Green Infrastructure Council (AGIC).
Scope:	Infrastructure projects including design, construction and operation.
Start:	2008.
Status:	Completion on February 2012. The rating system has been tested on 15 pilot projects.
Owner:	Australian Green Infrastructure Council (AGIC).
Start:	2008.
Status:	Completion on February 2012. The rating system has been tested on 15 pilot projects.
Background:	AGIC and experts from industries were developed the rating (AGIC, 2012).
Location:	Australia.
Category:	15 categories and 100 maximum points: Management Systems, Procurement and Purchasing, Climate Change Adaptation, Climate Change Adaptation, Energy and Carbon, Water and Materials, Discharges to Air, Land & Water, Land, Waste, Ecology, Community Health, Well-being and Safety, Heritage, Stakeholder Participation, Urban and Landscape Design, and Innovation.
Number of Project rated:	Current registered about 10 projects

STARS	
Overview:	Sustainable Transportation Analysis and Rating System is a performance-based planning and rating system focused on transportation plans, projects, and employer programs. It is a points-based system.

STARS	
Owner:	The North American Sustainable Transportation Council.
Scope:	Transportation project with planning and operation.
Start:	2008.
Status:	Pilot Project Application Manual Version 1.0 was released in 2012
Background:	Collaboration among public agencies (the Santa Cruz County Regional Transportation Commission and (SCCRTC) and the Portland (Oregon) Bureau of Transportation, private sector firms (CH2M HILL, Parsons Brinkerhoff, ECONorthwest, Brightworks and Confluence Planning), and the non-profit organization sponsoring STARS, the North American Sustainable Transportation Council (STC). Modeled from LEED (North American Sustainable Transportation Council, 2012).
Location:	U.S.
Category:	8 Categories: Access and Mobility, Safety and Health, Equity, Economic Benefit, Cost Effectiveness, Climate and Energy, Ecological Function, and Community Context.
Number of Project rated:	7 certified projects

GreenPave	
Overview:	A sustainability rating system for pavement design and construction in Ontario, a point-based rating system, and focuses on pavement component.
Owner:	Ministry of Transportation Ontario.
Scope:	Pavement projects including design and construction.
Start:	2008.
Background:	Modeled after LEED, Greenroads and GeenLITES and Alberta's Green Guide for Roads. Joint between the University of Waterloo, Center of Pavement and Transportation Technology (UW CPATT) and MTO.
Location:	Canada.
Rating Scale:	Bronze, Silver, Gold, and Trillium
Category:	4 categories: Pavement Design Technologies, Materials and Resources, Energy and Atmosphere, and Innovation and Design process (Greenpave, 2014)
Number of Project rated	41 certified projects (Chan,Bennet,& Kazmierowski, 2013)

3.1.1.3 ***Pilot phase:*** *a system has not been released Version 1 or doing pilot projects only*

INVEST_VicRoads	
Overview:	An Integrated VicRoads Environmental Sustainability Tool is a rating system for road projects in Australian. It is point-based and voluntary and application to all road projects.
Owner:	The roads Corporation of Victoria, Australia (VicRoads)
Scope:	Road projects including design and construction
Start:	2011
Status:	Available as a pilot version at www.vicroads.vic.gov.au. Version 1.0 came out in March 2011
Location:	Australia
Background:	Created by VicRoads (VicRoads, 2011).
Rating Scale:	1 star, 2 star, 3 star, 4 star, and 5 star.
Category:	11 categories and 240 maximum points: Air Quality, Behavioural change & capacity building, Biodiversity, Cultural heritage, Energy, Noise management, Resource management, Road design, Stakeholder engagement, Urban design, Waterway and Water management.

3.1.1.4 ***Development:*** *at early stage of development or internal pilot projects.*

BE^{2}ST-in-Highways^{TM}	
Overview:	Building Environmentally and Economically Sustainable Transportation Infrastructure-Highway construction project is a self-evaluation tool in rating highway construction project and rehabilitation. It uses life cycle analysis (LCA) and life cost cycle analysis (LCCA) techniques to evaluate sustainability with a quantitative assessment of the impact.
Owner:	University of Wisconsin.
Scope:	The life cycle analysis and life cycle cost analysis with a highway construction project in during planning and designing projects particular on recycled materials.
Start:	2010.
Status:	Unknown.
Background:	Developed by recycled materials resource center university of Wisconsin-Madison. The Burlington bypass project was conducted as a case study in order to modify the functionality of the BE^{2}ST and calibrate its weighting (Lee et al., 2010).
Location:	U.S.
Rating Scale:	Bronze (50%), Silver (75%), Gold (90%)

Green Guide for Roads	
Overview:	A Green Guide for Roads can apply all roads and highways in urban and rural areas in Canada and a self-assessment tool.
Owner:	The Transportation Association of Canada (TAC) Urban Transportation Council and Chief Engineers' Council.
Start:	2010
Scope:	All types of road in urban and rural areas including planning, design, construction and maintenance.
Status:	Green Guide for Roads started in May 2010. The Canadian Guide for Greener Roads was released in April 2015.
Background:	Developed by the MMM Group with guidance from the project steering committee including Ecoplans Limited, McCormick Rankin Corporation, and Enermodal Engineering, and modeled from LEED (TAC,2015).
Location:	Canada.

I-LAST^{TM}	
Overview:	Illinois-Livable and Sustainable Transportation Rating System and Guide is a sustainability performance metric system and a guideline documentation for state highway projects. It is a point system and a self-evaluation system. However, and it is not being used.
Owner:	Illinois Department of Transportation (IDOT)
Scope:	All highway projects including design phase activities, design decisions, and construction.
Start:	2009.
Status:	I-LAST version 1.01 was published in January 2010. Available at www.dot.state.il.us/green/documents/I-LASTGuidebook.pdf.
Background:	Created by the Illinois Department of Transportation, the American Consulting Engineers Council-Illinois Chapter, and the Illinois Road and Transportation Builders Association (IDOT, 2010).
Location:	Illinois.
Rating Scale:	No internal certification program.
Category:	8 Categories and 228 (233) maximum points; Planning, Design, Environmental, Water Quality, Transportation, Lighting, Materials, Innovation.

STEED	
Overview:	Sustainable Transportation Engineering & Environmental Design is a sustainability checklist for highway and roadway transportation projects including project development and project construction as an internal program. However, it is not an external standard for all use.
Owner:	H.W. Lochner, Inc.
Scope:	Highway and roadway transportation projects including planning, environmental, design, and As-Built.
Start:	Unknow.
Status:	STEED 2.1 was released in October 2010.
Background:	STEED was started 2008 and was developed by H.W. Lochner, Inc. (Lochner, 2010).
Location:	U.S.

3.2 The Rating System Evaluation Method

An in-depth evaluation of the sustainability rating systems was conducted to better understand how they work in practice. The evaluation criteria is a compilation based on Muench et al. (2011) and then the other similar criteria have been pointed out based on Atlee and Kirchain (2006), Sadowski et al. (2011), Nguyen and Altanas (2011), and AlWaer and Kirk (2012) shown in Table 3.1. To evaluate the rating systems, a set of criteria will be used to help determine the performance of rating systems in terms of efficiency, effectiveness and applicableness. Twelve tools, including CEEQUAL, Envision, GreenLITES, Greenroads, INVEST, INVEST_VicRoads, IS, LEED-ND, Green Guide for roads, I-LAST, STARS, and STEED are evaluated. These tools are selected because of similarity to each other in roadway scope, and availability of documentation on their websites and also on research databases as listed in Table 3.2. SITES^{TM}, GreenPave, and BE^{2}ST-in-Highway^{TM} are not included in the evaluation.

Table 3.1: Criteria for Sustainability Rating Systems

Muench et al.(2011)	Atlee and Kirchain(2006)	Sadowski et al.(2011)	Nguyen and Altan(2011)	Retzlaff (2008)	AlWaer and Kirk (2012)
Sustainability definitions					
Scope and context sensitivity	Addresses a clear goal, appropriate to task and goals /objects and clear		Applicability, stages of building	Scale and Scope	Assessed buildings and scope of assessment applicability

Muench et al.(2011)	Atlee and Kirchain(2006)	Sadowski et al.(2011)	Nguyen and Altan(2011)	Retzlaff (2008)	AlWaer and Kirk (2012)
	system boundaries				
Validation	Consensus on validity	Input verification and validation of results	Accuracy and Verification		Measurability and data
Stakeholder involvement	Stakeholder involvement in indicator development, and/or responsiveness to stakeholder expectations	Stakeholder Involvement	Development Approach Consensus-based, LCA, Expert Opinion	Communication	
Precisely defined credits and actions	Clear uniform definition of indicator		Data collection, Documentation , Measurability, Convenience		
Transparent	Adequately document and of known quality	Disclosure of Methodology Information Sources Accessibility	Availability of the system and information, Easy to access		Transparent: uncertainties and errors
Weight and scoring logic	Subjective Elements Explicit Representative environmental conditions and impacts and responses		Weightings, Whole Lifecycle Assessment, Efficiency	Prioritization	Benchmarking and the calculation process
Substantiated credits	Consistent with other relevant indicator sets				
Encourage improvement on current practice		Focus on the Future			
Relation of existing regulation	Based on regulation and international standards				
Independent third-party rating, dynamic			Data Gatherer		
Dynamic Nature of the System	Updated regularly with reliable procedures	Regular review	Update		System maturity
	Simple, easy to apply (User friendly) Understandable, easy to interpret and evaluate	Easy	Ease of use	Interfacing issues	
	Comparability		Result Presentation Clarity and Comparability		Communicability
				Local adaptation	Sustainability scales-universal applicability and adaptability

The twelve sustainability rating systems being reviewed are listed in section 3.1.1.1 (Zietsman & Ramani, 2011). The information for each rating system was primarily collected through publicly available data such as websites, manuals, conference proceedings, presentations, and journal

articles. The details of documentation are listed in Table 3.2. The following sections describe the evaluation results by criterion. Table 3.14 summarizes these results.

Table 3.2: Reference Documentation for Evaluation

Rating Systems	Documents
CEEQUAL	CEEQUAL International (2012)
Envision™	Document from the website (www.sustainableinfrastructure.org)
GreenLITES	- Moving Towards Sustainability: New York State Department of Transportation's GreenLITES Story (McVoy, et al. 2010) - GreenLITES project Design certification Program (NYSDOT,2010)
Greenroads	The Greenroads Manual V 1.5 (Muench et al. 2011)
INVEST	Manual of INVEST V 1.0 (FHWA, 2012)
INVEST_VicRoads	The manual of INVEST_VicRoads V 1.0 (VicRoads, 2011)
IS	Infrastructure Sustainability Council of Australia (ISCA) from the website (http://www.isca.org.au/is/about-is/is-rating-tool) (AGIC, 2012)
LEED-ND	LEED 2009 for Neighborhood Development rating system (USGBC, 2011)
Green Guide for roads	Transportation Association of Canada (2010)
I-LAST™	- Livable and Sustainable Transportation Rating System and Guide (IDOT, 2010) - The Development of I-LAST ™ Illinois-Livable and Sustainable Transportation (Knuth & Fortmann, 2011)
STARS	Pilot Project Application Manual Version 1.0 (North American Sustainable Transportation Council, 2012)
STEED	STEED Manual Version 2.1 (Lochner, 2010)

3.2.1 Sustainability Definitions

A rating system provides its own explicit sustainability definition. Such a definition should help define the rating systems scope and priorities.

Criteria: a definition is specifically given in primary literature for the system.

Ten systems give a sustainability definition excluding IS and Green Guide for roads as shown in Table 3.3.

Table 3.3: Sustainability Definition in Each System

Rating Systems	Sustainability Definition
CEEQUAL	In the three-legged model of sustainable development, which seeks to achieve economic, social and environmental success at the same time and may thus be connected to triple-bottom-line reporting
Envision™	Sustainability including: quality of life, leadership, resource allocation, natural world, and climate and risk.
GreenLITES	Sustainability is "commonly understood to describe any human use of resources that does not exhaust those resources."

Rating Systems	Sustainability Definition
Greenroads	7 E's of Sustainability: ecology, equity, economy, extent, expectations, experience, and exposure.
INVEST	The principles of the triple bottom line
INVEST_VicRoads	Sustainability transport is "The ability to meet the needs of society to move freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values today or in the future."
IS	-
LEED-ND	to transform the way buildings and communities are designed, built and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life
Green Guide for roads	-
I-LAST™	The Brundland Commission
STARS	The triple bottom line and The Natural Step
STEED	The Brundland Commission

3.2.2 Scope and Context Sensitivity

A rating system has clearly articulated scope and provides limitations. There are two scopes to consider in the research 1) project types, functions, sizes, and categories, and 2) the sustainability scope: what areas of sustainability are addressed and to what level of sustainability. In this research, the scope of roadways is divided up into four simplified categories: planning, design, construction, and operations and maintenance (Haas & Hudson, 1978; Muench et al. 2011). A defined scope allows users to correctly apply the rating system to an appropriate project, understands its capabilities and limits, and provide useful results.

Activities in each category as defined by this evaluation are:

- Planning: pre-design activities: alternative analysis, location, and justification.
- Design: final right-of-way footprint and all designs, contract documentation, and environmental documentation and specifications.
- Construction: road building activities such as site preparation, surface preparation, excavation, installation of services, and utilities and construction.

- Operations and maintenance: all post-construction activities: rehabilitation, roadway maintenance such as cleaning, roadway paving and patching, and road weather management.

  Criteria: a system provides a clear scope and identifies which stages of the project or types of projects are addressed.

The result of the evaluation is shown in Table 3.4. Eleven of them provide a clear scope. Eleven systems focus primarily on the design and construction phase of projects, while STARS focuses on project planning and design. The scopes of GreenLITES, INVEST_Vicroads, and IS, do not address the planning phase of projects. All twelve systems claim they can be implemented on projects of any size.

In the second type of scope, the sustainability scope: Most systems adopted sustainability definition from The Brundland Commission report or triple-bottom-line principle for using in their definition, however, all rating system did not provide much information on how they address the scope of sustainability. Thus, this research will attempt to address the sustainable scope by developing a framework based on the sustainability definition and using it to review rating systems. Then, a framework will analyze in order to address the full range of sustainability scope, establish implicit priority and transfer from one context to another. The research will be identified the gaps between theory and practice.

Table 3.4: Stages of Roadway Projects Addressed by the Systems

Rating Systems	Planning	Design	Construction	Operations
CEEQUAL	Yes	Yes	Yes	-
ENVISION™	Yes	Yes	Yes	Yes
GreenLITES	-	Yes	Yes	Yes
Greenroads	Partially	Yes	Yes	Partially
INVEST	Yes	Yes	Yes	Yes
INVEST_VicRoads	-	Yes	Yes	-

Rating Systems	Planning	Design	Construction	Operations
IS	-	Yes	Yes	Yes (operation and decommissioning)
LEED-ND	Yes	-	-	-
Green Guide for Roads	Yes	Yes	Yes	Yes
I-LAST™	Yes	Yes	Yes	Yes
STARS	Yes	Yes	-	Yes
STEED	Yes	Yes	Yes	-

3.2.3 Tested

A rating system has been tested and has verified its functionality and calibrated its weighting on actual projects to correspond accurately to the real situation. "Actual projects" means that data from actual road projects (as opposed to a theoretical project) is used.

Criteria: a system has been tested with actual projects.

A system has been tested with actual projects to ensure the appropriateness and credibility of the system and help to develop its indicators to fit into best practices. It can reflect priority issues in each project. Indeed, Tested makes the system more relevant to potential users. Eight of the rating systems have been tested on actual projects throughout the documents produced to date for these rating systems. In contrast, published records of testing on actual projects of INVEST_VicRoads, I-LAST, Green Guide and STEED were not found as shown in Table 3.5.

Table 3.5: Tested a System on Actual Projects

Rating Systems	Tested on Actual Projects
CEEQUAL	Tested
Envision™	Tested
GreenLITES	Tested
Greenroads	Tested
INVEST	Tested
INVEST_VicRoads	Not found
IS	Tested
LEED-ND	Tested
Green Guide for Roads	Not found
I-LAST™	Not found
STARS	Tested
STEED	Not found

3.2.4 Stakeholder Involvement

Stakeholders are people or organizations that are directly or indirectly involved in or affected by the rating system. Stakeholder collaboration during the design phase of a rating system ensures that it reflects community values and desires. A robust group of active stakeholders can help ensure the rating system addresses the full range of sustainability issues, considers all meaningful points of view, and suggests best practices that are vetted by relevant industry.

Criteria: Stakeholders are engaged in the process of developing a rating system in terms of public meetings, workshops, focus groups, advisory boards, or public comment periods.

Seven of the rating systems claim some sort of evaluation by stakeholders as shown in Table 3.6.

Table 3.6: Stakeholder Involvement in Each System

Rating Systems	Stakeholder Involvement
CEEQUAL	Several organizations participated in the development process in CEEQUAL and in The weighting process such as King Environmental and Confederation of Construction Clients etc.
Envision™	Stakeholders have participated in the development process.
GreenLITES	Stakeholders have participated in the development process.
Greenroads	To a lesser degree conducted an open public comment process
INVEST	Stakeholders are engaged in the process of developing a rating system
INVEST_VicRoads	-
IS	A global review panel for reviewing the system
LEED-ND	To a greater degree conducted an open public comment process
Green Guide for Roads	-
I-LAST™	-
STARS	-
STEED	-

3.2.5 Relation to Existing Regulations and Improvement on Current Practice

A rating system must be different than existing regulations; otherwise, it is not useful to implement it since agencies have to do actions to meet regulations or standards. Thus, it may not be appropriate for a rating system. It also cannot conflict with existing regulations since asking for an action counter to what is required by law will never result in that action is done. Therefore,

the only logical space for a rating system to exist is to ask for the best practices that are: 1) consistent with current regulations, and 2) in addition to improvements on current standards and regulations. Thus, some actions covered by existing regulation should not earn high scores in a rating system because they are already controlled by law. Then, credits should go above and beyond current regulation. Moreover, the system should give more points in new sustainable practices that agencies have not usually done until recently.

Criteria: an action is encourage agencies to improve the current practice and consistent with current regulations.

All systems can improve the current practice and consistent with current regulations. Eight systems address existing regulation and standard as shown in Table 3.7.

Table 3.7: Relation to Existing Regulations in Each System and Improvement on Current Practice

Rating Systems	Relation to Existing Regulations and Improvement on Current Practice
CEEQUAL	Of 208 credits, 41 credits address existing regulation and standard.
Envision™	Of 58 credits, 10 credits address existing regulation and standard.
GreenLITES	Of 20 credits, 3 credits address existing regulation and standard.
Greenroads	Of 48 credits, 4 credits address existing regulation and standard.
INVEST	Of 60 credits, 5 credits address existing regulation and standard.
INVEST_VicRoads	Of 44 credits 13 credits address existing regulation and standard.
IS	No credit addresses existing regulation and standard.
LEED-ND	Of 53 credits, 6 credits address existing regulation and standard.
Green Guide for Roads	-
I-LAST™	No credit addresses existing regulation and standard.
STARS	No credit addresses existing regulation and standard.
STEED	Of 60 credits 4 credits address existing regulation and standard.

3.2.6 Weighting and Scoring Logic

Every rating system has an implicit scoring and weighting system whereby each sustainability best practice, or credit, is given a point value and a method for totaling points is used to arrive at a final evaluation, grade, or certification. Users should understand the scoring system and its underlying logic.

Criteria: Weight and scoring logic are explained and transparent.

Four systems (Greenroads, ENVISION, INVEST and LEED-ND) are transparent with their weighting and scoring logic as shown in Table 3.8.

Table 3.8: Weighting and Scoring Logic in Each System

Rating Systems	Weighting and Scoring logic	Document
CEEQUAL	-	-
Envision™	A weighting system is related to sustainability assessment of the project. Different point values depend on: 1) Local/regional context, 2) Objective standards, 3) Stakeholder input.	Institute for Sustainable Infrastructure & Zofnas Program for Sustainable , 2012
GreenLITES	The weight point values based on the impact on sustainability.	NYSDOT,2010
Greenroads	The weighting mechanism is that points are weighted on U.S. priority and vary on sustainability impact and duration of impacts; for example, one point represents the lowest impact and five points represent the highest impact.	Muench et al., 2011
INVEST	The weight point values based on sustainable impact.	FHWA, 2012
INVEST_VicRoads	-	-
IS	-	-
LEED-ND	The weightings process, value is based on the outcomes and "impact categories". Impact categories relate with components in terms of global climate change, human health, water resources, biodiversity and ecosystem services, material resources, and community. The impact categories include: a) Reduce contribution to global climate change, b) Enhance individual human heath, well-being, and vitality, c) Protect and restore water resources, d) Protect, enhance, and restore biodiversity and ecosystem services, e) Promote sustainable and regenerative material resource cycles, f) Build a greener economy, g) Enhance community: social equity, environmental justice, and quality of life.	USGBC, 2012
Green Guide for Roads	-	-
I-LAST™	-	-
STARS	-	-
STEED	-	-

3.2.7 Types of Evaluation

Generally, rating systems can be 1) third-party rating systems, 2) self-evaluation, and 3) both. The independent third-party rating provides the highest level of credibility and avoids the appearance of impropriety due to eliminate the biased results. Nowadays, organizers increasingly

demand substantiation of rating systems relying on trustworthy third-party certifiers more than other options (UL Environment, 2013). Most systems are designed for a self-evaluation by providing a manual and a checklist. A self-evaluation tool can also be acceptable if a system tends to advertise itself that it can be used for self-evaluation.

Criteria: What kind of system it is; third-party rating, self-evaluation, or other?

The results are shown in Table 3.9. Six of them are consistently available self-evaluation systems; whereas, CEEQUAL, ENVISION, Greenroads, INVEST_Vicroads, LEED-ND, and STARS are independent third-party rating systems.

Table 3.9: Types of Evaluation in Each System

Rating Systems	Types of Evaluation
CEEQUAL	A third-party rating system
Envision™	A third-party rating system
GreenLITES	A self-evaluation system
Greenroads	A third-party rating system
INVEST	A self-evaluation system
INVEST_VicRoads	A third-party rating system
IS	A self-evaluation system
LEED-ND	A third-party rating system
Green Guide for Roads	Being developed
I-LAST™	A self-evaluation system without awards
STARS	A third-party rating system
STEED	A self-evaluation system without awards

3.2.8 Well-defined Credits and Actions

Each credit is defined clearly or more precisely. The system provides point values in which projects can earn points for achieving actions. In general, terms that are vague such as “maximize”, “as much as possible”, and “most efficient use of” lend themselves to subjective, undocumented, and unreproducible interpretation. An example of a credit that has a clear requirement and an objective means to determine its accomplishment would be PD-11 Bicycle Access from the FHWA’s INVEST rating system (FHWA, 2012):

***"1 point**. Implement new (or improve existing) features (such as those mentioned above) for existing bicycle facilities that improve safety and connectivity. Current facilities do not qualify for this criterion without additional effort, such as upgrades, improvements, or construction of new facilities such as: added signage or minor access improvements for bicycles, installing bicycle detectors in driving lanes or granting signal priority, adding bicycle-friendly stormwater drains, code-required dimension upgrades, resurfacing existing bicycle lanes, or adding new streetside bicycle storage facilities (lockers, racks, etc.). The attempt to enhance bicycle transportation experience should be deliberate and a direct result of the project. No credit is given for improvements and retrofits to bring existing facilities up to required standards.*

OR

***2 points**. Implement features (such as those mentioned above) in the design and construction of new bicycle facilities that enhance safety, connectivity, aesthetics, comfort, and environment. New facilities include physical or constructed changes to the roadway structure, dimensions, or form that provide safe, convenient, and attractive bicycle access within the right-of-way (ROW) or roadway corridor. To be eligible for this credit, the bicycle facilities must be Class I (separated) or Class II (bike lanes); lanes shared with motorized vehicles and shoulders do not meet this requirement, except under certain circumstances.*

Scoring Sources

The project is considered to have met this criterion if the requirements above can be reasonably substantiated through the existence of one or more of the following documentation sources (or equal where not available):

1. *Purpose and Need addressing bicycle access within the roadway project, including how it fits with existing land uses and/or existing General and Transportation Plans, project analysis, or a Bicycle Master planning process.*
2. *Results of public input on proposed bicycle facilities, if any.*
3. *Copy of the contract specification and plans for proposed bicycle facilities.*
4. *Total cost associated with new or improved bicycle facilities."* (FHWA, 2012).

An example of a vague credit with no objective means to determine its accomplishment would be CEEQUAL 9.4.2 On-Site Waste Management:

"9.4.2 Have appropriate options for disposal been considered and implemented? If No, score 0. If yes, score 6." (CIRIA and Crane Environmental. (2010).

Criteria: A system consists of well-defined credits and is quantifiable in specification-like language; for example, if the action has been done, the project can earn three points. The results are shown in Table 3.10. Eight systems have precisely defined credits and four of them did not provide precisely defined credits excluding CEEQUAL, I-LAST, Green Guide for Roads, and STEED. While CEEQUAL requires presenting evidence to confirm the actions, there is still unclear description of the credits, leading to confusion. Of 208 credits, 36 do not exhibit well-defined actions. All credits of I-LAST, and STEED are illustrated in general and broadly, and are not based on achievement processes, activities examples, and reasonable substantiation requirements of how to achieve criteria because they are intended to focus on continual improvement rather than certificate levels. Green Guide for Roads does not make public any manuals online.

Table 3.10: Well-defined Credits and Actions in Each System

Rating Systems	Well-defined Credits and Actions
CEEQUAL	Of 208 points, 36 do not exhibit well-defined actions: "9.4.2 On-Site Waste Management:" "Have appropriate options for disposal been considered and implemented? If No, score 0. If Yes, score 6." It is unclear that which options should consider in "appropriate options"
Envision™	Well-defined credits
GreenLITES	Well-defined credits
Greenroads	Well-defined credits
INVEST	Well-defined credits
INVEST_VicRoads	Well-defined credits
IS	Well-defined credits
LEED-ND	Well-defined credits
Green Guide for Roads	-
I-LAST™	Of 145 points, 12 do not exhibit well-defined actions. "T-3b Improved intersection designs for pedestrians (1 to 2 points)" "One to two points will be awarded to projects that improve pedestrian intersections including elements beyond simple crosswalks, such as countdown signal heads, narrower lanes (to shorten crossing distance) and pedestrian median or corner refuge islands. Points vary according to level of accommodations." In this case, it is hard to decide which project should get one or two points because it does not include specific actions in the criteria.
STARS	Well-defined credits

Rating Systems	Well-defined Credits and Actions
STEED	Of 153 points, 43 do not exhibit well-defined actions. "Land & Geology: The project reduces upstream flood impacts". It is too short a description and is ambiguous about the criteria; therefore, assessors can include almost everything to earn this credit.

3.2.9 Substantiated Credits

In addition to requirements, a credit can be substantiated by supporting discussions on its relevance, strengths and weaknesses, empirical evidence examining its effectiveness, and implementation suggestions. All these items can assist the user in determining if the credit is appropriate for the project's context.

Criteria: A system offers supporting discussions on each credit including strengths and weaknesses, empirical evidence, and implementation suggestions.

Their documentation provides credits, criteria, action, and checklists. However, most systems do not state the weaknesses and provide suggestions for strategies in each credit excluding; Greenroads and INVEST_VicRoads. Only Greenroads provides empirical evidence, weaknesses and implementation suggestions, and INVEST_VicRoads provides strategies in each credit as shown in Table 3.11.

Table 3.11: Substantiated Credits in Each System

Rating Systems	Substantiated Credits
CEEQUAL	-
Envision™	-
GreenLITES	-
Greenroads	Empirical evidence, weaknesses and implementation suggestions
INVEST	-
INVEST_VicRoads	Strategies
IS	-
LEED-ND	-
Green Guide for Roads	-
I-LAST™	-
STARS	-
STEED	-

3.2.10 Dynamic Nature of the System

A rating system is periodically updated. Regular updating ensures that credits remain relevant and can be changed or eliminated based on current practice. As a minimum, a rating system that encourages improvement on current practice must be updated periodically to reflect changes in standard practice.

Criteria: A system has updated in recent years or there are plans to update.

The results are shown in Table 3.12. Eight of them have released more than one version of their program excepting I-LAST™, Green Guide for Roads, and STEED.

Table 3.12: Dynamic Nature of the System in Each System

Rating Systems	Initiated	Dynamic Nature of the System
CEEQUAL/CEEQUAL International	2008/2011	Updated in recent years and completed the manual version 5 in 2012
Envision™	2010	Updated in recent years and completed the manual version 2 in 2012
GreenLITES	2008	The current manual (V 2.1) in 2010
Greenroads	2006	Updated in recent years and completed the manual version 1.5 in 2011
INVEST	2010	The current manual (V1.1) in 2015
INVEST_VicRoads	2011	The latest update manual in 2011
IS	2008	Updated in recent years and completed in February 2012
LEED-ND	2007	Updated in recent years and the latest update manual in 2013
Green Guide for Roads	2010	The first manual in 2015
I-LAST™	2009	Not been updated in recent years and has not yet been used. Version was released in 2010
STARS	2008	Updated in recent years. STARS-Plan, STARS-Project, and the STARS Safety, Health and Equity Credits were only released in 2012
STEED	Unknown	The first checklist in 2010

3.2.11 Usability

A rating system is simple, logical, and user-friendly. In general, an easy-to-use system is better than a complicated one. It is hard to decide whether a system is easy because it is a subjective assessment. Thus, if the system has options to help users such as Frequently Asked Questions (FAQs), instruction, contact information and web-based interface, users have benefits from them

by interacting with the system and asking questions. These options will make the system easy to use.

Criteria: A system provides help and support functions such as FAQs, help section, e-mail contact etc., or provide a free user manual.

Keeping systems simple and straightforward is significant for users. The system would be easy to use, well-defined, and straightforwardly understandable, and easy to interpret and evaluate for the general public and non-expert users. Indeed, the system should be easy to communicate and reliable. Ten systems provide help functions such as FAQs or provide email and contact information, with the exception of GreenLITES, IS, Green Guide for Roads, and I-LAST. User manuals of three systems are not available for free as show in Table 3.13.

Table 3.13: Usability

Rating systems	Usability	User Manual
CEEQUAL	Contact Information	Version 5 is not available for public viewing and can only be downloaded by CEEQUAL-trained assessors/verifiers only.
Envision™	Contact Information	Available on-line
GreenLITES	Contact Information	Available on-line
Greenroads	Chat, contact information	Available on-line
INVEST	FAQs, contact information	Available on-line
INVEST_VicRoads	-	Available on-line
IS	Contact Information	Available for purchase
LEED-ND	Contact information, helps pages.	Available on-line
Green Guide for Roads	Contact Information	Available for purchase
I-LAST™	-	Available on-line
STARS	Contact Information	Available on-line
STEED	Contact Information	Provide by requested via email

3.2.12 Summary

From the review of twelve existing sustainability rating systems for infrastructure and roadway projects of the state-of-the-practice, no systems addressed all criteria. Most systems mentioned

sustainability definitions based on the triple bottom line principle or the Brundtland Commission report. Some systems have their own definitions of sustainability beyond the standard three dimensions. However, all rating systems consist of a piecemeal collection of sustainability best practices with little information on how they address the scope of sustainability, which can lead to significant issues in understanding the sustainability scope of these systems, what items are implicitly prioritized, and how they can be transferred from one context to another.

A system should consist of well-defined credits and be quantifiable in specification-like language. Some credits have unclear requirements and subjective means to determine their accomplishment; therefore it might be difficult for assessors to provide a correct score. The results of twelve rating systems are presented in Table 3.14. Most systems consist of clear credits an objective means excluding CEEQUAL, STEED, and I-LAST. All twelve rating systems provide a clear project scope and most systems are designed to analyze a project in design and construction phase. The best practices of systems should 1) be consistent with current regulations, and 2) improve on current standards and regulations. Thus, some actions covered by existing regulations should not earn high scores in a rating system because they are already controlled by law. It was found that eight systems have related to existing regulation. Most systems attempt to improve current practice and give space for innovation.

A system should be described in an understandable way to show how it is developed, and how a credit contributes to sustainability. The reasons why this particular information and assumptions are used should be explained. Most systems are not transparent key decisions in regard to system development and how a credit varies from what it represents is not documented. The weighting

mechanism does not specifically describe what point values are based on. Thus, only a few systems, Greenroads, Envision, INVEST, and LEED-ND are transparent with their weighting and scoring logic. Each of the best practices of these systems is assigned a point value based on the impact of sustainability. Their documentation provides credits, criteria, action, checklists. However, most systems do not state the weaknesses and provide suggestions for strategies in each credit excluding Greenroads and INVEST_VicRoads. Greenroads offer supporting discussions on each credit including empirical evidence, strengths and weakness. INVEST_VicRoads provides strategies in each credit.

With regard to testing with actual road projects, based on available records, eight systems have already been tested in its pilot project phase in order to ensure accuracy, reliability, and consistent intended performance of systems. INVEST_VicRoads, I-LAST, Green Guide and STEED were not found in the records about testing in actual projects. Stakeholders need to be involved in decision-making processes in order to define indictor and suggest the best practices and to ensure systems address the full range of sustainability issues. Seven systems claim sort of evaluation by stakeholders of relevant industry.

CEEQUAL, Greenroads, INVEST_VicRoads, LEED-ND and Stars provide a third party certification. However, all systems can be used for self-evaluation by using material from the systems. I-LAST and STEED do not provide certification levels like other rating systems. I-LAST serves as a guidebook for road projects. Most systems are periodically updated and have the potential to release a new version of manual soon. Eight of them have released more than one version of their program except for I-LAST, Green Guide for Roads and STEED.

There are different levels of usability focus in design. Basically, most systems provide contact information such as phone numbers and emails excluding INVEST_VicRoads. User manuals are available on-line for public viewing. Only a few systems - CEEQUAL, IS, and Green Guide for Roads provide manuals for purchase.

Table 3.14: Evaluating Rating Systems Based on Assessment Criteria

Rating systems	CEEQUAL	ENVISION	GreenLITES	Greenroads	IS	INVEST	INVEST _VicRoads	LEED-ND	Green Guide for Roads	I-LAST	STARS	STEED
Sustainability Definition: presenting their definition	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Scope: providing a clear scope and which project stages are addressed	PDC	PDCO	DC	P*DCO*	CO	PDCO	DC	P	PDCO	PDCO	PDO	PDC
Validation: testing with actual projects.	Yes	Yes	Yes	Yes	Yes	Yes	Not found	Yes	Not found	Not found	Yes	Not found
Stakeholder Involvement: Stakeholders are engaged in the process of development	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No
Relation to Existing Regulations	20% of credits	17% of credits	15% of credits	8% of credits	0%	8% of credits	30% of credits	12% of credits	-	0%	0%	7% of credits
Weight and Scoring: weight and scoring framework are transparent.	No	Yes	No	Yes	No	Yes	No	Yes	No	No	No	No
Types of Evaluation: Independent third-party or self-evaluation	third-party	third-party	self-evaluation	third-party	Self-evaluation	self-evaluation	third-party	third-party	self-evaluation	self-evaluation	third-party	self-evaluation
Well-defined Credits and Actions: quantifiable in specification-like language	82 % total points meet this criterion	100%	100%	100%	100%	100%	100%	100%	-	91 % total points meet this criterion	100%	99 % total points meet this criterion
Substantiated Credits: offers the discussion in each credit.	No	No	No	Yes	No	No	Yes	No	-	No	No	No
Dynamic Nature of the System: A system is periodically updated.	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No
Usability: provides help and support functions/provide a free user manual	Provide support function/a purchase version	Provide support function/a free manual	Provide support function/a free manual	Provide support function/a free manual	Provide support function/a purchase version	Provide support function /a free manual	No support function/ a free manual	Provide support function/ / a free manual	Provide support function/a purchase version	No support function/ a free manual	Provide support function/ / a free manual	Provide support function// a free manual

P=Planning, D=Design, C=Construction, O=Operations and maintenance, * partially

3.3 Utility of a Framework

It is desired to establish sustainability rating systems for use internationally and develop new systems in different countries. There are two options for developing rating systems: 1) create one system that applies universally or 2) create a framework that allows for customization to fit the context. The second option is more suitable since an international rating system may not be suitable for applying to all countries due to differences in geographic regional conditions and requirements. Before proposing such rating systems, a framework to conceptualize between sustainability definition and transportation topics is need. However, sustainability definition is context sensitive which is based on different priorities and national conditions and in relation to location and with a time dimension (Brown et.al, 1987), (Todd & Geissler, 1999), (Liu et al., 2007), (Cole, 2005), (Cooper, 1999).

3.3.1 Different Location and Time Scales

Brown et al. (1987), Clark (1985), Kohler (1999), and Anderson (2008) agree that different location and time scales may lead to different meanings of sustainability based on diversity of such things as geography, climate, culture and historic value, economic, political systems, and natural resources. These differences can significantly influence priority issues to be addressed in the pursuit of more sustainable roads. For instance, in some regions potable water is a scarce resource, while in other regions it is not; using the example of limited water resources, less than 25% of countries in Asia and the Pacific have sufficient potable water resources (ADB, 2013). In contrast, the North America continent has 100 % of total population, which have high access to potable water resources (ADB, 2013). A time horizon is another key component of approaching to sustainability as a boundary condition such as concerning consequences, forecasting outcomes

and capturing both short-and long-term effects (Anderson, 2008). A system in different time scales may result in different impacts of the life cycle. Most rating systems lay the foundation based on their sustainability definition. Hence, context sensitive is important because it allows a rating system to differ from others by addressing different criteria depending on its region and time. This can mean that a sustainability rating system would have different elements in Japan than it would in the U.S. It can even mean that Texas would need different versions of a system than Washington. LEED has an attempt to recognize different regional priorities in the U.S. with its regional priority credits in LEED for new buildings.

3.3.2 Different Priorities and National Conditions

Amongst the two available options (universal systems, or several local systems), the several local systems are easier to implement and ultimately more effective. If a framework is used for developing and analyzing rating systems. The universal systems are essentially impossible because most rating tools are developed under their developers' priorities and reflect their developers' values and problems, leading to systems different in weightings and criteria. In some cases, each project needs its own system because they are all slightly different. However, it may be acceptable to have the same system for multiple projects at the national level because each country has some level of shared policies, priorities, and cultures. The comparison of developed and developing countries will be used as examples to point out the issues because they typically have different priorities in their goals and policies (Cole, 2005), (Gibberd, 2001).

3.3.2.1 *Developed Countries*

There are several ways to quantify the economic development of countries. The World Bank quantifies the economic development of countries by using per capita (per person) gross national income (GNI). The World Bank classifies the terms of "developed countries" that countries are

in upper middle income ($4,126-$12,745); and high-income economic ($12,746 or more) groups (World Bank, 2013). Thus, it means that environmental performance and social development are not included in the meaning of developed countries.

- Adequate access to basic needs and public transportation. United Nations Environment Program stated that the developed countries in the North American continent has 100 percent of total population, which can access freshwater and sanitation. People in most countries in North America and Europe have easy access to services (ADB, 2009). Thus, systems in developed countries focus on making services more efficient and affordable rather than providing access.
- Environmental aspect is their priority. The standard of living is generally high in developed countries. Due to wealthy countries having less social problems, concern about environment issues has been an important topic including climate change, energy consumption, and biodiversity. These countries tend to reduce greenhouse gas emission and promote renewable energy consumption and preserve biodiversity. Several rating systems were developed in these countries that mainly focus on environmental indicators and gave a high rating to environment aspects and less weight to social and economic aspects (AlWaer and Kirk, 2012).

3.3.2.2 *Developing Countries*

The World Bank classifies developing countries into two groups based on their GNI per capita: low income economies ($ 1,045 or less) and lower-middle-income economies ($1,046-$4,125) (World Bank, 2013). There are several different characteristics between developed and developing countries. Kumar (2004) gives the main characteristics of developing countries as illustrated: low gross domestic product (GDP) per capita, high rates of population growth,

predominance of agriculture, and low levels of industrialization, rapid urbanization, dominance of informal sector, underdeveloped labor, financial, and other markets, strong traditions of cooperative society, lack of infrastructure and service, high level of social inequality, low skill levels, institutional incapacity, weak governance, and an uncertain economic and environmental degradation (Kumar, 2004), (UNEP-IETC, 2002).

- Lacking accessibility to basic needs and public transportation. Most developing countries are concerned with social and economic dimensions more than developed countries with regard to increasing access, providing equal opportunities, reducing poverty, improving health and education, and boosting local economy due to a lower standard of living and a lack of basic needs (Cole, 2005), (Gibberd, 2001), (Kemmler & Spreng, 2007); for example, accessibility to basic needs and public transportation pose challenges in some developing countries especially in rural areas such as Haiti (Liang, 2012) ; about 98% of rural people in developing countries do not have adequate access to transport systems (World Bank, 2007). For example, Greenroads and INVEST do not address accessibility to basic needs and all-season accessibility, poverty alleviation, and quality of facilities. However, these criteria are very significant in developing countries such as Nepal and Chile (Lebo & Schelling, 2001). If people in the area have no access to clean water, people do not focus on porous pavement for helping the environment.
- Social and economic aspects are their priority. Economic crisis and poverty enduring in the developing countries can limit the nations' ability to improve environmental aspects, and cause environmental problems as well (Melchert, 2007). Furthermore low standards of living, high rates of unemployment, and high rates of population growth are characteristics of developing countries. Thus, they are giving social and economic aspects more significance than environmental aspects. These countries have a very different view

of what sustainable is, based on their context. For example, developing nations tend to rely more on local resources including natural, energy, and labor resources. In addition, due to a wide range of ethnic and religious diversity, cultural and historic preservation is important in their social aspects. Therefore, social and economic criteria are likely to be a priority in developing countries. However, rating systems in developed countries tend not to take these criteria into account. As mostly rating tools have emerged in developed countries and have been used in developed countries and developing countries, these important social and economic issues in developing countries have lower points than other issues or are not addressed in these tools. Thus, considering different sets of priorities and different regional conditions would be crucial to making rating systems reflect the national values, and even reflect differences within the same developed world or in a single country.

3.3.3 Advantages and Limitations of Describing Context in terms of National Boundaries

This research analyzes rating systems at a national scale because it is formally and clearly defined as having the same social, cultural, national governments, policies, and regulatory systems within its own boundary. It is convenient to reference because there is general agreement on most national boundaries. National boundaries are abstractions of the lines on the earth's surface or geographic boundaries, dividing the earth up into countries, which are used to identify socio-cultural, economical, ethical, and political classification (Clark, 1994). Sustainable development indicators define their scope in terms of contiguous geography and are used for comparing levels of sustainable development in different countries. However, there are limitations: no country is truly homogeneous within its own border. Fiala (2008) argues that

comparisons of the ecological footprint by using national boundaries are arbitrary. Further, some issues of sustainability are not within national boundaries but on a global scale such as climate change and pollution because they are distinguished on the basic principles of scientific research and international agreements and pollution cannot be isolated to individual countries. (Todd & Geissler, 1999). To use the one design to fit all projects in all countries may not be suitable because of the differences in climate, local conditions, and geographic features. Different locations have different sustainable solutions and these may impair the consistency of the results due to the fact that sustainable issues in one location might be less important in another. Sev (2011) agrees that the adaptability of any rating systems from other countries leads to a problematic issue because each is system based on the conditions and priorities of nations and regions.

3.3.4 International Systems Are Not Appropriate

Given these efforts, it is not appropriate to apply one rating system worldwide. This research proposes an alternative to the one system idea by using the international framework to develop regional rating systems. Even so, there is increasing interest to develop international sustainability rating systems. Several sustainability rating systems for buildings have been using globally; however, several countries have their own rating systems. For instance, among internationally sustainable building rating systems, LEED, BREEAM, and Green Globes are promoted for use as global sustainability tools (BREEAM, 2013), (USGBC, 2012), (Green Globes, 2013). One example, LEED International program's effort is currently implemented globally in 135 countries (USGBC, 2012). Nevertheless, many countries have still established their own rating systems over the past few years including CASBEE (Japan)(CASBEE,2013), Pearl Building Rating System (PBRS) (Abu Dhabi) (UPC, 2013), and other national rating

systems. LEED has been collaborating with other countries to develop LEED for use locally such as in India, Brazil, Canada, and Mexico (USGBC, 2012), and BREEAM Gulf and the European schemes have been developed to use for countries in the Middle East and in Europe respectively (BREEAM, 2013). In addition, there are efforts to adapt green building to their countries such as Madagascar and Tanzania, Egypt, Nigeria, Malaysia, South Africa, and Thailand because a single rating system did not work for them (Ozolins, 2010; Younan, 2011; Adegbile, 2012; Ismail, 2011; Green Building Council of South Africa.(n.d).;TGBI, 2011). In sum, most systems for developing countries are based on those for developed nations.

It appears that no universal framework exists in sustainable roadway rating systems. As many as 50 of sustainable infrastructure rating systems are intended for applying in developed countries such Australia, U.K., U.S., and Canada (Anderson, 2012). Only one infrastructure rating tool, CEEQUAL International, claims applicability for all international projects (CEEQUAL, 2012). On the other hand, there is an increasing number of sustainable infrastructure rating systems that are applicable to developing countries such as Sustainable Building Assessment Tool (SBT) (South Africa), TREES (Thailand), and PBRS (Abu Dhabi) (Gibberd, 2001; IGDB, 2008; TGBI, 2011; UPC, 2013). Some rating systems are developed by adopting or adapting from existing rating systems such as LEED and BREEAM. The adaptability may be a problem in practice because some systems are not suitable for regional characteristics and standard practices; they are not flexible for local adaptability; and they do not contain some significant issues with regard to road safety, workforce safety, rural access, and climate resilience. Ozolins (2010) confirms that several significant characteristics in sustainable construction in developing countries are not addressed in LEED including: (1) regional workers, (2) poverty alleviation, (3) local material resources, (4) social and cultural values, (5) adaptability and flexibility, (6) safety and security,

(7) equity, and (8) local technologies. Therefore, it should be noted that the one system might not be suitable for all countries and not fit in their particular context and that is why rating systems have recently been developed in many countries.

As borrowed sustainability rating systems are not suitable in a practical way, agencies have made efforts to develop new systems for their own countries that take into account the local context and regional differences. Most systems are typically created in the first place by adapting such systems from existing rating systems such as LEED and BREEAM.

3.4 Summary

- Most systems do not provide key ideas in the system development such as decision, reasoning and logic in the system, and does not provide weaknesses and suggestions how a credit relates to sustainability.
- Sustainability is context sensitive which bases on different priorities, and national conditions and in relation to location and with time scales.
- One system does not work because systems are not flexible in different context and are not represent local priorities and their standard.
- International rating systems are not appropriate because they do not address issues in developing countries such as accessing to basic need services, poverty alleviation and local resources.
- It is a good idea to propose an alternative to the one framework worldwide idea.

Chapter 4 An International Framework for Sustainable Roadway Rating Systems

As stated in Chapter 1, a rating system may not be appropriate to develop and apply everywhere. This chapter proposes an international framework for analyzing and developing sustainability rating systems for roadway projects. The components of the international framework comprise elements of sustainability and elements of existing sustainability rating systems as illustrated in Chapter 2 and Chapter 3. This chapter first reviews existing global metrics for selecting sustainability or components of sustainability. Sustainable Society Index (SSI) is selected as the foundation of the international framework.

Then, the development of the international framework for sustainable roadway rating systems is described. SSI sustainability indicators are mapped to roadway topics from the existing eleven infrastructure rating systems. Because there are four unmatched SSI-2012 indicators, twelve building rating systems are checked for providing a viable roadway topic. To emphasize the differences in focus between systems, the finished international framework (Table 4.4) is used to analyze eleven infrastructure rating systems. The international framework will be used for evaluating Greenroads in Chapter 5 and adapting Greenroads for Thailand in Chapter 6.

4.1 Review Existing Frameworks

This section reviews available global metrics with the purpose of choosing a pre-existing organization from which the international framework could be built; consequently, the Sustainable Society Index (SSI) was selected as the basis for the international framework because it was the only one addressing the required breadth of sustainability.

4.1.1 Background

An index is convenient because it tends to break a complex idea (such as happiness or human development) down into discrete and identifiable and often measureable components.
There is a large number of global indexes in use today such as Human Development Index (HDI), Ecology Footprint (EF), The Living Planet Index (LPI), Gross National Happiness Index (GNH), and SSI (United Nations Development Programme (UNDP), 2013), (WWF, 2012),(Ura et.al, 2012). Literature on international sustainability indexes was reviewed with the purpose of choosing a pre-existing basis from which the framework could be built.

The search focused on sustainability indexes (and not rating systems) because indexes typically pay close attention to the sustainability scope they address (Singh et al. 2012) rather than the nature of specific project-related actions. Most of them tend to address only one aspect of sustainability (e.g., human development, happiness, or environment). Only SSI accounts for all three parts (environmental, economic, and social), the expectations of humans, the long term perspective, and spatial consideration, all of which are consistent with the definition of sustainability used in this dissertation.

4.1.2 Choosing a Basis: The Sustainable Society Index (SSI)

Criteria for selection of an appropriate basis index were that the index should (1) represent all three dimensions of sustainability (human/social, environment, economic), (2) contain categories that subdivide these dimensions and are reasonably independent from one another, (3) be peer-reviewed, and (4) be readily available to the general public. Based on these criteria, the 2012 Sustainable Society Index (SSI-2012), (Van de Kerk & Manuel 2008; Saisana & Philipas, 2012) was selected as the basis for the proposed framework. The SSI-2012 contains three dimensions

(human, environmental, and economic "wellbeing" as the SSI terms them), which are subdivided into eight categories and 21 indicators (Table 4.1). The draft framework is developed by using SSI to set up dimensions, categories, and indicators as shown in Table 4.1.

In arriving at the SSI-2012 selection, 32 different indexes were considered including the original 11 considered by van de Kerk and Manuel (2008) as well as 21 more described by a later audit of the SSI, the Joint Research Centre of the European Commission (JRC) (Saisana & Philipas, 2012). Conclusions were similar to those made by (van de Kerk and Manuel 2008) in that most indexes address only one or two sustainability components and not all three. Specifically, there is a noticeable divide between indexes addressing environmental issues, and indexes addressing human development issues. The SSI-2012 index was chosen because of its comprehensive sustainability scope (all three sustainability dimensions are addressed), relatively independent set of categories (Saisana & Philipas 2012; Kaivo-oja 2013), its vetting via peer-reviewed articles (van de Kerk and Manuael 2008; Kaivo-oja 2013) and an independent audit (Saisana & Philipas 2012), and its publication on the Web as a periodically updated index (www.ssfindex.com). Relevant to this framework development, (Saisana & Philippas 2012) found the SSI-2012 to be "*conceptually coherent*" in that "*…the indicators are more correlated to their own category than to any other category; all correlations within a category are significant and positive; the same conclusions are drawn at the dimension level."* The SSI-2012 also matches reasonably well with United Nations sustainable development indicators (UN, 2007). While category and indicator selection is endlessly debatable, ultimately we agree with (Kaivo-oja et al. 2013) that the SSI-2012 *"…is a reasonably good and general measure of sustainability and it embodies much of the discussion, debate, and state-of-the-art on the measurement of sustainability.*"

4.1.3 Sustainable Society Index (SSI)

SSI was first published in 2006 by the Sustainable Society Foundation in the Netherlands (SSF, 2013). It addresses key aspects of sustainability and quality of life of a national society. There are three wellbeing dimensions (human, environmental, and economic "wellbeing" as the SSI terms them), which are subdivided into eight categories and 21 indicators using equal weights as shown in Table 4.1. The indicators relate to Economic Wellbeing, Environmental Wellbeing, and Human Wellbeing. Its scores range in value from 0 to 10, with a larger number signifying greater sustainability. It has been used to rank 151 countries in terms of sustainability (Van de Kerek & Manuel, 2008). The world map of SSI data in 2012 as illustrated in Figure 4.1 and 2, shows that the world average in 2012 is between the scores of 4 and 5; so indicating that many countries still need to improve to achieve full sustainability in terms of air quality, employment, renewable energy and organic farming. It produces some seemingly surprising results. For instance Thailand, a developing country by UN standards, scores a 5.6, while the U.S., a developed country by UN standards scores only a 4.2 because Thailand have higher scores in environmental well-being and Economic well-being dimensions such as employment, public debt, and national resources.

Table 4.1: The SSI-2012 Index (Saisana and Philipas, 2012)

Dimensions	Categories	Indicators	Index Description[a]
Human Wellbeing	Basic Needs	Sufficient Food	Fraction of population undernourished
		Sufficient to Drink	Fraction of population with sustainable access to an improved water source
		Safe Sanitation	Fraction of population with sustainable access to improved sanitation
	Health	Healthy Life	Life expectancy at birth in number of healthy life
		Clean Air	PM 2.5
		Clean Water	Surface water quality
	Personal & Social Development	Education	Combined enrolment for primary, secondary and tertiary schools
		Gender Equality	Gender gap index
		Income Distribution	Ratio of income of the richest 10% to the poorest 10% of population
		Good Governance	Average of six governance indicators of the World Bank
Environmental Wellbeing	Nature & Environment	Air Quality	Emissions of SO2
		Biodiversity	Size of protected areas
	Natural Resources	Renewable Water Resources	Annual water withdrawals as a fraction of renewable water resources
		Consumption	Ecological Footprint minus Carbon Footprint
	Climate & Energy	Renewable Energy	Renewable energy consumption as a fraction of total energy consumption
		GHG Emissions	Co2 emissions per capita
Economic Wellbeing	Transition	Organic Farming	Area of organic farming as a fraction of total agricultural area
		Genuine Savings	Adjusted net savings as a fraction of Gross National Income (GNI)
	Economy	Gross Domestic Product (GDP)	GDP per capita (purchasing power parity) in current international dollars
		Employment	Unemployment as fraction of labor force
		Public Debt	Public debt as a fraction of GDP

a. How the index is actually measured

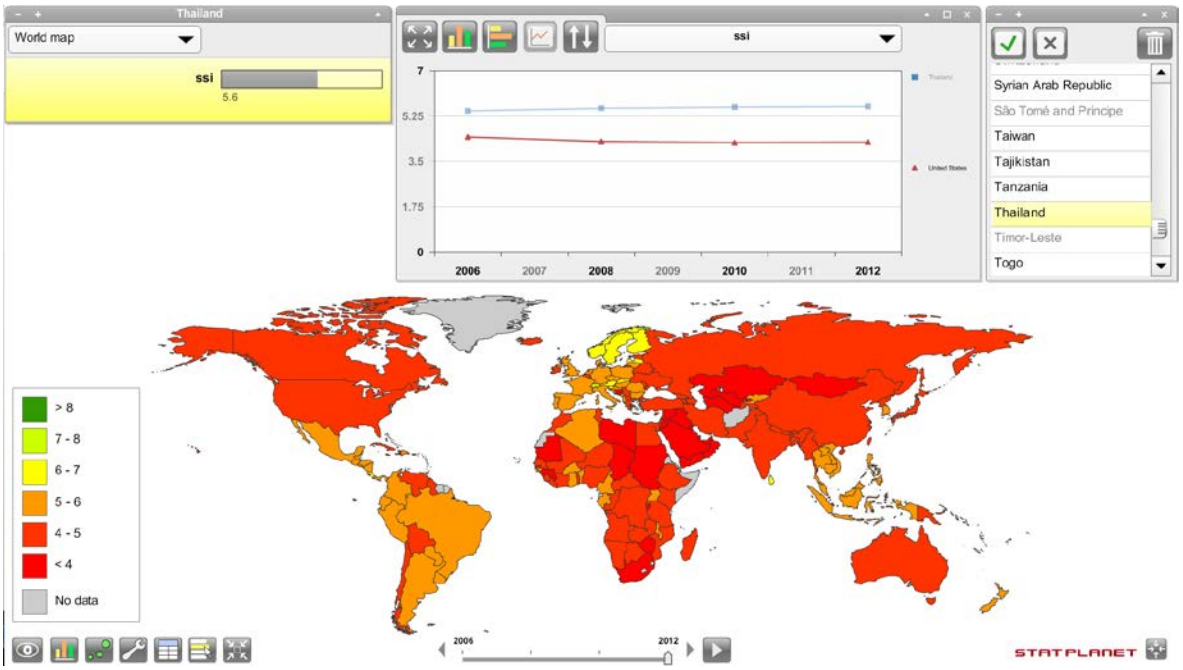


Figure 4.1: The Interactive World Map of SSI in 2012 (SSF, 2013)

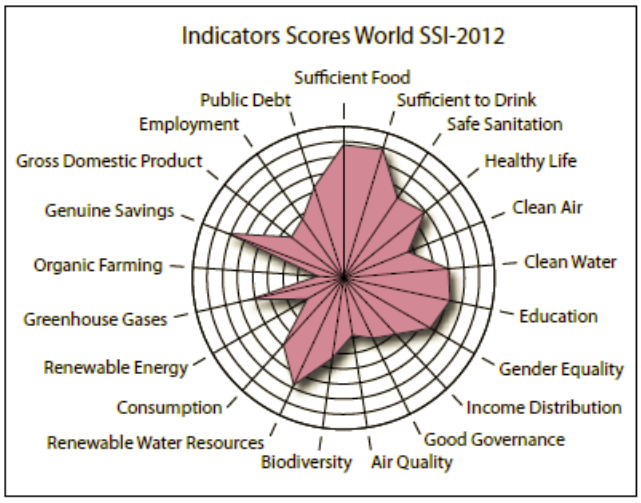


Figure 4.2: Indicators Scores World SSI in 2012 (SSF, 2013)

4.2 Establishing a Framework

This section explains how SSI sustainability indicators are mapped to specific roadway topics to create the framework. Starting with SSI indicators as the foundation. The existing eleven sustainability rating systems are analyzed and compared to determine common roadway topics that address each SSI sustainability indicator. The resulting framework can provide a broad sustainability scope and a sense of direction in the development of new rating systems. To assign credits, national regulations, standards, and priorities are used to determine which broad areas of credits to emphasize, but ultimately the specifics of each credit depend on the specific definition, goal and scope of the rating system.

4.2.1 Steps of Developing a Framework

This section describes, in a stepwise process, how the SSI-2012 is adapted from its form in Table 4.1 to a roadway rating system framework.

Step 1: Identify Roadway-related Rating Systems

The original twelve sustainability rating systems were reviewed in Chapter 3. However, there are eleven sustainability rating systems reviewed here. The Green Guide for Roads was eliminated because no available documentation could be found on its details. Eleven infrastructure sustainability rating systems were specifically identified as (1) being related to roadways (e.g., could be meaningfully applied to road projects – each of these systems has been applied to roadways on at least one occasion either in actual rating or testing), and (2) having adequate documentation (i.e., a manual or article that describes the system enough to allow analysis). Green Guide for Roads is not included to evaluate because it does not provide public any manuals online. These systems are hereafter identified as “roadway rating systems” even though they may not be solely or even primarily focused on roadways. Importantly, they have the

capacity to rate road projects in some form and have done so in the past. These systems are (country of origin and approximate year of inception following):

- Road-specific systems
    - GreenLITES: U.S., 2008
    - Greenroads: U.S., 2007
    - INVEST (FHWA): U.S., 2010
    - INVEST (VicRoads): Australia, 2011
    - I-LAST: U.S., 2009
    - STARS: U.S., 2008
    - STEED: U.S., 2008
- Civil infrastructure systems (these include but not limited to roads)
    - CEEQUAL, U.K., 2003
    - Envision: U.S., 2010
    - Infrastructure Sustainability: Australia, 2008
    - LEED-ND: U.S., 2007

Step 2: Generate Road Topics

The individual credits of these eleven systems were analyzed to determine the general roadway topics they address. This analysis made no judgment on the quality or rigor of an individual credit, but focused solely on its topic. This analysis produced 51 identifiable roadway topics. In some cases rating systems have multiple individual credits that address a single topic. For instance, Greenroads has 17 credits we believe address greenhouse gas emissions either directly or indirectly.

The specific characteristics transportation issues were selected according to various SSI indicators. For the selection process, the popularity of credits among those rating systems mostly based on Greenroads rating system were considered together with other rating systems. For example, the Material Recycling topic is being used in Greenroads (recycled materials), ENVISION (recycled materials), GreenLITES (recycled content), INVEST_VicRoads (the use of products and materials with greater environmental benefits), I-LAST (soil stabilization with cementations and recycled materials), STARS (evaluation of construction materials and methods: recycling), LEED ND (recycling and reused infrastructure), and CEEQUAL (responsible sourcing of materials). These topics are shown in Appendix A.

Appendix A shows the potential roadway topics in the fourth column and the right of the fourth column show credits of eleven rating systems addressing the same basic roadway topic. Each credit of existing rating system can be assigned to multiple topics or similar topics. For instance, the Earthwork Balance credit in Greenroads rating system is addressed in multiple topics including material transportation emission, land use, waste management, clean air for human, and LCCA and/or cost-benefit.

While many potential topic issues were identified for transportation topics, 51 roadway topics were picked and confirmed with eleven existing sustainability rating systems. A comparative analysis method was conducted to determine assessment topics. The comparative method is used to count number of systems of which credits cover each transport topic. If a topic is included in at least three of eleven systems, the topic will be selected as shown in Table 4.2.

Step 3: Match Roadway Topics to SSI Indicators

Each of the 51 roadway topics was then matched up with one or more SSI-2012 indicators (Table 4.2). This proved difficult since SSI-2012 indicators are constrained to only those metrics with available national aggregate data needed for their calculation, while roadway rating system topics can be much more specific, and only indirectly represent the roadway contribution to that indicator, or to a combination of several indicators. For instance, SSI-2012 calculates the "healthy life" index as the healthy life expectancy at birth (HALE) for a given country (Saisana and Philppas, 2012), while "healthy life" topics for roadway rating systems are all topics that would contribute to the SSI-2012 indicator: clear air, livability, noise reduction, worker safety, road user safety, infrastructure resilience, cultural preservation and outreach, historical preservation, scenic views, and aesthetics of earthwork and structures. Some notes on matching are:

- The SSI-2012 indicator "healthy life" is broadly construed to mean both physical and mental health including happiness.
- 4 SSI-2012 indicators had no roadway topic matches (income distribution, organic farming, genuine savings, and good governance (anti-corruption/collusion).
- Modal access was matched with 5 SSI-2012 indicators. A road's contribution to these indicators constitutes access to them.
- 4 roadway topics were not associated with any SSI-2012 indicator (contaminated soil – brownfield development, waste management/minimization, climate change adaptation, electric vehicle infrastructure). The first two were put in the Nature & Environment category, while the latter two were put in the Transition category.

- Because multiple credits from in individual rating system can be associated with one topic, the number of roadway topics associated with a SSI indicator may not be indicative of that indicator's priority within roadway rating systems.

Table 4.2: Matching Roadway Topics to SSI-2012 Indicators

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Systems[c]
Human Wellbeing	Basic Needs	Sufficient Food	Modal access (ped., bike, bus, HOV)	10
		Sufficient to Drink	Modal access (ped., bike, bus, HOV)	10
		Safe Sanitation	Modal access (ped., bike, bus, HOV)	10
	Health	Healthy Life	Modal access (ped., bike, bus, HOV) Livability Noise reduction Worker/jobsite safety Traffic/road user safety Cultural preservation and outreach Historical preservation Scenic views Aesthetics of earthwork & structures	10 9 8 3 7 7 7 7 6
		Clean Air	Construction Equipment Emissions Materials Transport Emissions Materials Production Emissions Traffic Emissions	7 5 4 4
		Clean Water	Clean water Stormwater runoff quality Groundwater quality	10 8 3
	Personal & Social Development	Education	Modal access (ped., bike, bus, HOV) Local employment Job training	10 4 4
		Gender Equality	Environmental justice/ gender diversity	4
		Income Distribution	(non)	(none)
		Good Governance	Context Sensitive Solutions (CSS)	10
Environmental Wellbeing	Nature & Environment	Air Quality	Construction Equipment Emissions Materials Transport Emissions Materials Production Emissions Traffic Emissions	7 5 4 4
		Biodiversity	Habitat creation Habitat preservation/conservation Wildlife conservation Stormwater runoff volume/flow Ecological connectivity Light pollution/reduction and glare Non-hazardous materials	4 10 10 8 7 8 2
			Contaminated soil - brownfield Waste Management/minimization	7 11
	Natural Resources	Renewable Water Resources	Water use Renewable water resources (potable water conservation)	6 5
		Consumption	Material reuse Material recycling Minimize materials Local materials Durable structures Quality control Reduce non-renewable energy use Fuel use	10 10 10 9 3 3 11 7

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Systems[c]
	Climate & Energy	Renewable Energy	Encourage renewable energy use	8
		GHG Emissions	Lifecycle assessment (LCA) Greenhouse gas emission	3 11
Economic Wellbeing	Transition	Organic Farming	(none)	(none)
		Genuine Savings	(none)	(none)
			Climate change adaptation Electric vehicle infrastructure	1 1
	Economy	Gross Domestic Product	Local economy	4
		Employment	Local employment	4
		Public Debt	Cost-benefit	4

Step 4: Address Indicators with No Related Roadway Topics

Further attempts were made to provide a viable roadway topic for the four unmatched SSI-2012 indicators. First, the more mature field of building sustainability rating was checked to determine if appropriate topics existed there that could be extended to roadways. In all, twelve building rating systems, representing a sampling of prominent international systems (country of origin in parentheses), were checked (Table 4.3):

- BREEAM (United Kingdom)
- CASBEE (Japan)
- LEED (U.S.)
- LEED India (India)
- Green Star (Australia)
- Green Star SA (South Africa)
- SBTool (International)
- Green Globes (U.S. and Canada)
- DGNB (Germany)
- World Green Building Council International Framework for Rating Tools (International)
- HK-Beam (Hong Kong)

- TREES Rating System (Thailand)

Table 4.3: Topics Sustainable Rating Systems for Building

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic[a]	Systems[b]
Human wellbeing	Basic Needs	Sufficient food	Modal access (ped., bike, bus, HOV)	11
		Sufficient to drink	Modal access (ped., bike, bus, HOV)	11
		Safe Sanitation	Modal access (ped., bike, bus, HOV)	11
	Health	Healthy life	Modal access (ped., bike, bus, HOV Livability Noise reduction Worker/jobsite safety Traffic/road user safety Cultural preservation and outreach Historical preservation Aesthetics of earthwork and structures	11 10 9 0 4 4 3 2
		Clean Air	Construction Equipment Emissions Materials Transport Emissions Materials Production Emissions Traffic Emissions	8 5 11 0
		Clean Water	Clean water Stormwater runoff quality Groundwater quality	11 9 1
	Personal & Social Development	Education	Modal access (ped., bike, bus, HOV) Local employment Job training	11 2 2
		Gender Equality	Environmental justice/ gender diversity	2
		Income Distribution	(none)	(none)
		Good Governance	Context Sensitive Solutions (CSS)	4
Environmental wellbeing	Nature & Environment	Air Quality	Construction Equipment Emissions Materials Transport Emissions Materials Production Emissions Traffic Emissions	8 5 11 (none)
		Biodiversity	Habitat creation Habitat preservation/conservation Wildlife conservation Stormwater runoff volume/flow Ecological connectivity Light pollution/reduction and glare Non-hazardous materials	0 6 1 9 7 10 8
			Contaminated soil - brownfield development Waste Management/minimization	6 11
	Natural Resources	Renewable Water Resources	Water use Renewable water resources (potable water conservation)	10 6
		Consumption	Material reuse Material recycling Minimize materials Local materials Durable structures Quality control Reduce non-renewable energy use Fuel use	11 11 11 3 (none) 4 11 11
		Renewable Energy	Encourage renewable energy use	8

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic[a]	Systems[b]
	Climate &Energy	GHG Emissions	Lifecycle assessment (LCA) Greenhouse gas emission	2 11
		Greenhouse gas emission	LCA Greenhouse gas emission	2 10
		Energy consumption	Encourage renewable energy use	11
Economic wellbeing	Transition	Material Consumption	Material reuse Material recycling Minimize materials Local materials	11 11 11 3
		Organic Farming	(none)	(none)
		Genuine Savings	(none)	(none)
			Climate change adaptation Electric vehicle infrastructure	4 1
	Economy	Gross Domestic Product	Local economy	1
		Employment	Local employment	2
		Public Debt	Cost-benefit	4

a. The roadway topics associated with the indicator as identified in the analysis of the 12 building rating systems.
b. The number of building rating systems out of the 12 analyzed that contained a credit addressing the associated roadway topic.

No new topics were found in these building rating systems; however, this building topic search did identify two topics (non-hazardous materials and infrastructure resiliency) that although poorly represented in roadway systems, were well represented in building rating systems. These topics were added to the framework.

Second, a literature search was conducted, which led to inclusion of the following roadway topics: anti-corruption (Transparency International 2013; GIACC; TI 2013), which was matched with Good Governance indicator, and prevailing wages (UNEP 2013), which was matched with Income Distribution indicator. The SSI-2012 indicators Organic Farming and Genuine Savings were left without roadway topics and were omitted from the framework.

- **Non-Hazardous Materials.** It was found that eight systems address non-hazardous materials including TREES_NC, BREEAM International, Green Star office, Green Star SA, LEED,

LEED 2011 for India-NC, Green Globe, and CASBEE for new construction 2010. The example of the details of Non- Hazardous Materials are as follows (LEED,2011):

Intent: To reduce concentrations of chemical contaminants that can damage air quality, human health, productivity, and the environment.

3 points. Minimizing use of hazardous materials including the volatile organic compounds (VOCs) or hazardous air pollutants (HAPs), heavy metals and other substances linked to health and safety considerations.

- **Natural Disaster** (flooding, hurricanes, earthquakes, etc.). Three building rating systems including TREES_NC, SBTOOL, and CASBEE, address this topic. In addition, adapting to climate change in BREEAM addresses this topic as well.

Infrastructure Resiliency (INVEST, SP-16, (FHWA, 2012))

Intent: To ensure the project is resilient to the current and future hazards including those associated with climate change (flooding, hurricanes, earthquakes, etc.)

2 Point. Hazard Identification
4 Points. Vulnerability Assessment
2 Points. Risk Assessment
5 Points. Develop and Implement Adaptation Strategies

- **Anti-corruption.** The American Society of Civil Engineers claims that corruption accounts for an estimated $ 340 billion of worldwide construction costs each year (Sohail and Cavill, 2008). The World Bank (1997) definition of corruption is the "the abuse of public office for private gain." The World Bank has identified corruption as "the single greatest obstacle to economic and social development." In extreme cases, corruption can lead to thousands of people being killed or injured because earthquake resistant construction requirements can be avoided by bribing government officials. Other evidence by Tanzi and Davoodi (1997)

shows that higher corruption is associated with higher public investment, lower government revenues, lower expenditures on operations and maintenance, and lower quality of public infrastructure including poor condition of roads.

Thus, anti-corruption should be implemented in the framework. The goal is to prevent and detect corruption on projects.

1 to 2 points. The project will be able to earn bonus points based on the Corruption Perception Index (CPI) 2014, a country or territory's score divided by 35 and then rounded up to the nearest whole number. Based on CPI 2014 scores, two-thirds of countries score below 50 and global average 43. The world map of CPI is shown in Figure 4.3 (IT, 2014).

Transparency International (TI) has developed the Corruption Perception Index (CPI) which ranks countries and territories in terms of the perceived levels of public sector corruption based on expert opinion including country experts, both residents and non-residents, and business leaders. The index is a "poll of polls" and calculated using data from 12 data sources as listed below by independent institutions (TI, 2014). It scores range between 100 (very clean) and 0 (highly corrupt). However, these are measures of corruption perceptions and not actual levels of corruption. The information used to determine the index comes from:

1. African Development Bank Governance Ratings 2013
2. Bertelsmann Foundation Sustainable Governance Indicators 2014
3. Bertelsmann Foundation Transformation Index 2014
4. Economist Intelligence Unit Country Risk Ratings 2014
5. Freedom House Nations in Transit 2013
6. Global Insight Country Risk Ratings 2014
7. IMD World Competitiveness Yearbook 2014
8. Political and Economic Risk Consultancy Asian Intelligence 2014
9. Political Risk Services International Country Risk guide 2014
10. World Bank – Country Policy and Institutional Assessment 2013
11. World Economic Forum Executive Opinion Survey (EOS) 2014

12. World Justice Project Rule of Law Index 2014

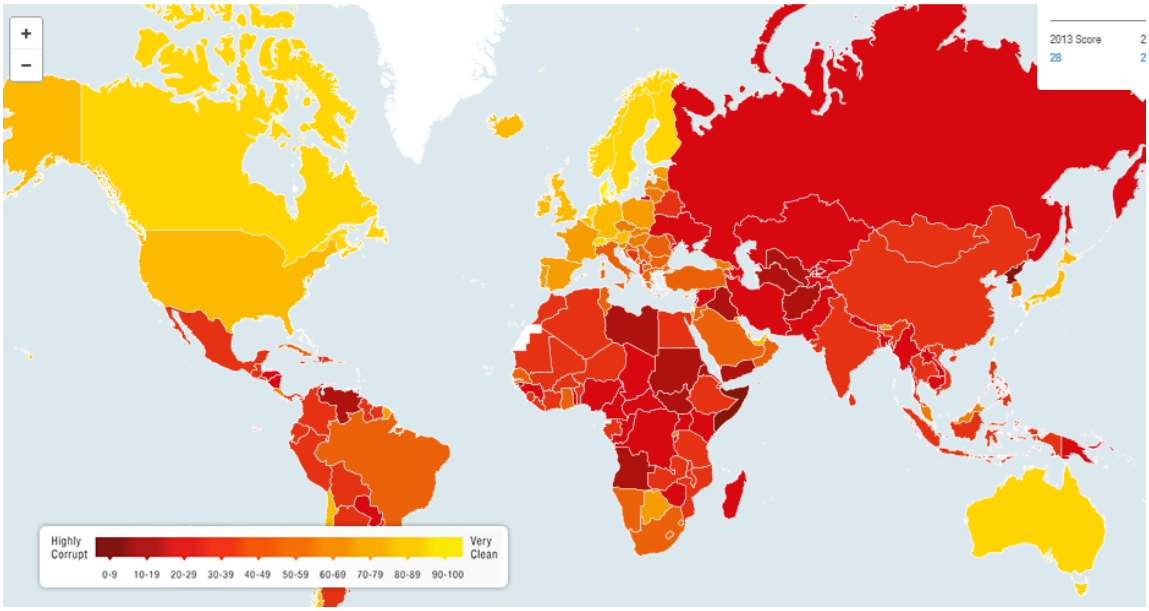


Figure 4.3: World Map of Corruption Perceptions Index 2014 (TI, 2014)

OR

2 Points. PACS has been implemented in projects.

The Project Anti-Corruption System (PACS) have been developed by (Global Infrastructure Anti-Corruption Center (GIACC) and Transparency International (TI) (UK) in order to prevent corruption. It comprises two sections: the PACS standards and PACS templates, which can be used to assist project participants in implementing anti-corruption measures on projects. It includes independent assessment, transparency, procurement, pre-contract disclosure, project anti-corruption commitments, funder anti-corruption commitments, government anti-corruption commitments, raising awareness, compliance, audit, reporting, and enforcement (TI, 2013). The PACS does not solve corruption because corruption is complicated and could apply to many standards and occur at any level of projects. However, the PACS may deter corruption ever so slightly in some instances. The use of PACS will

discourage corruption, reduce the opportunity for corruption, and increase the change of identifying corruption (Stansbury & Stansbury, 2008).

- **Prevailing Wages.** According to Social Life Cycle Assessment (S-LCA), fair wage means "a wage fairly and reasonably commensurate with the value of a particular service or class of service rendered, and, in establishing a minimum fair wage for such service or class of service" (UNEP, 2013).

  1 point. Workers get a fair salary. Comparison between lowest paid workers and country minimum wage and interview with directors or Human resources officer and workers.

Step 5: Adjust SSI-2012 Indicators

SSI-2012 indicators were adjusted to be more useful in a roadway specific framework in the following manner:

- **Combine**. SSI-2012 indicators that contained duplicate roadway topics were combined as follows: Sufficient Food + Sufficient Drink + Safe Sanitation = Modal Access, Clean Air + Air Quality = Clean Air. This eliminated double-counting roadway topics. While SSI-2012 counts air issues in both Human Wellbeing and Environmental Wellbeing, the framework indicator of Clean Air was placed in Environmental Wellbeing because it was felt that human air quality issues are a result of environmental air quality issues.
- **Relocate**. The Clean Water indicator was relocated from the Human Wellbeing Healthy Life category to the Environmental Wellbeing Nature & Environment category. It was felt that while clean water is certainly necessary for a healthy life, it is essentially an environmental issue; clean water can be created from polluted water directly through various drinking water treatments.

- **Expand.** The Healthy Life SSI-2012 indicator was broken apart to create 5 framework indicators (Healthy Life, Safety, Culture and History, Aesthetics, and Public Participation). All new indicators remain in the Personal Development category.
- **Add.** Land Quality was added as the associated indicator for the "contaminated soil – brownfield" and "waste management/minimization" roadway topics. Transition was added as the associated indicator for "climate change adaptation" and "electric vehicle infrastructure."
- **Rename.** 4 SSI-2012 indicators were renamed to a term that better reflects the associated roadway topics (e.g., "Public Debt" was renamed "Cost-Benefit").

Table 4.4 shows the completed international framework for sustainable roadway rating systems.

Table 4.4: The Framework for Creating Sustainability Rating Systems

Dimension	Category	Indicator	Topic[b]
Human	Basic Needs	*Access*	Modal access (ped, bike, bus, HOV)
	Health	Healthy Life	Livability Noise reduction
		Safety	Worker/jobsite safety Traffic/road user safety Infrastructure resiliency
		Culture and History	Cultural preservation and outreach Historical preservation
		Aesthetics	Scenic views Aesthetics of earthwork and structures
	Personal & Social Development	Education	Job training
		Equality	Environmental justice/ gender diversity
		Income Distribution	*Prevailing wages*
		Good Governance	Context Sensitive Solutions (CSS) *Anti-corruption/collusion*
Environment	Nature & Environment	*Clean Air*	Construction Equipment Emissions Materials Transport Emissions Materials Production Emissions Traffic Emissions
		Clean Water	Clean water Stormwater runoff quality Groundwater quality
		Clean Land	Contaminated soil - brownfield Waste Management/minimization
		Ecological Resources	Habitat creation Habitat preservation/conservation

Dimension	Category	Indicator	Topic[b]
			Wildlife conservation Stormwater runoff volume/flow Ecological connectivity Light pollution/reduction and glare Non-hazardous materials
	Natural Resources	*Water Resources*	Water use Renewable water resources (potable water conservation)
		Consumption	Material reuse Material recycling Minimize materials Local materials Durable structures Quality control Reduce non-renewable energy use Fuel use
	Climate & Energy	Renewable Energy	Encourage renewable energy use
		GHG Emissions	Lifecycle assessment (LCA) Greenhouse gas emissions
Economy	Transition	*Transition*	*Climate change adaptation* *Electric vehicles infrastructure*
	Economy	*Financial Impact*	Local economy
		Employment	Local employment
		Cost-Benefit	Cost-benefit

a. Titles in italics indicate a change from the wording of the SSI-2012.
b. The roadway topics associated with the indicator as identified in the analysis of the 11 roadway rating systems.
c. The number of roadway rating systems out of the 11 analyzed that contained a credit addressing the associated roadway topic.

4.2.2 Potential Use

There are two principal uses for this framework: (1) evaluating and reporting the sustainability scope of existing roadway rating systems, and (2) development of new or adaptation existing of rating systems for new contexts (e.g., states, countries, regions).

Evaluating the Sustainability Scope of Existing Roadway Rating Systems

Chapter 5 will evaluate and report the sustainability scope of Greenroads rating system. Grenroads version 1.5 is analyzed by using the international framework for roadway sustainability rating systems (in Table 4.4). As a case study to determine the sustainability, the dimensions and categories were emphasized within a rating system. The result will provide the

information for the users' decision to suitably select the rating systems for organizational or project sustainability goals. This evaluation also leads to some interesting insights about the implicit priorities of existing rating systems.

Developing or Adapting Rating Systems for New Contexts

Chapter 6 will adapt Greenroads version 1.5 for Thailand, as a case study in adapting a rating system for a new context. The study will determine the proper weighting of sustainability dimensions and categories in relation to the stated sustainability goals and priorities of an organization. Document and policy literature review of Thailand and SSI 2012 scores were analyzed to identify country priorities based on the international framework. Collectively, this information should make it possible to modify Greenroads v1.5. Therefore, it addresses Thailand's contextual interpretation of sustainability.

4.3 Discussion

The section discusses key observations from framework development about: (1) numbers of topics in each dimension, (2) blank indicators, (3) applicability to developing countries, and (4) eco-efficiency.

4.3.1 Numbers of Topics in Each Dimension

The environmental wellbeing dimension is the largest topics by number. There are 29 topics in the environmental wellbeing dimension compared to only 20 topics combined in both human wellbeing and economic wellbeing dimensions.

It should be noted that rating systems are weighted toward the environmental wellbeing dimension. Furthermore, rating systems rarely address the economic wellbeing dimension. None of the economy dimension topics are presented in more than four rating systems. This may be because the economy is either explicitly or implicitly outside the scope of most rating systems. Nonetheless, economic wellbeing dimension in sustainability dimension remains under-represented in roadway rating systems.

4.3.2 Blank Indicators

The process of matching roadway topics to SSI indicators (Step 3 in Section 4.2.1) found that there are four SSI-2012 indicators, which did not match roadway topics, including income distribution, organic farming, genuine savings, and good governance (anti-corruption/collusion). The reason, that these items are not included in rating systems, is that these features may not be relevant to sustainable roadway projects. These items focus more on social sustainability and relate to the national level, not tailored to roadway projects. Thus, the SSI-2012 indicators organic farming and genuine savings were left without roadway topics and were omitted from the framework because they are more difficult to apply to roadway projects. However, if we focus on these items at the project level, prevailing wages and anti-corruption/collusion indictors may be addressed in roadway projects. The authority needs to address these indictors and report truthfully to the project team, which may be difficult to deal with in real situations.

No rating system addressed all indicators in the international framework because each rating system is different in sustainability scopes in details. Specific items that are not addressed by any systems are: anti-corruption/collusion and prevailing wages because the author considers them as part of sustainability scopes.

4.3.3 Applicability to developing countries

Most of these topics are addressed from the standpoint of developed countries and represent high standards of practice in roadway projects. Since sustainability is context sensitive and the context in developing countries is markedly different than that in developed countries such as accessibility to transportation and the priority on sustainability scopes as described in Section3.3.2. Therefore, rating systems for developed countries may not address important issues for developing. If they are used for creating a rating system in developing countries, they can mean different things than in developed countries. For example, the "Access" topic means to promote the use of public transportation or upgrade the existing facilities so that they become more effective from environmental perspectives. It can mean to provide mobility since they already have accessibility. People can transport faster and with more convenience. All tools address access in terms of pedestrian access, bicycle access, and transit HOV access. In contrast, the "Access" topic in developing countries would mean to provide physical access for rural populations to school due to the lack of rural access or year-round access.

4.3.4 Eco-efficiency

Rating systems promote eco-efficiency. A term coined by Schmidheiny (1992), "eco-efficiency," describes the concept of producing goods and services using fewer resources while producing less pollution and waste. While eco-efficiency represents a step towards sustainability, it does not provide a viable long-term strategy because reducing the rate of environmental degradation delays but does not change the ultimate result (McDonough and Braungart, 2002). Of the 29 roadway topics in the Environment dimension, eighteen represent this idea (generally characterized by the idea of reducing negative consequences, reducing waste, or being more

efficient in a process). Only two roadway topics “encourage renewable energy use” and “habitat creation” could be categorized as “upcycle” (McDonough and Braungart, 2013) topics that encourage a rethinking of the process and emphasize designing for abundance. This emphasis on eco-efficiency reinforces the idea that current rating systems tend to require users to go just beyond existing practice/regulation, but do not articulate the desired sustainable end-state. Thus, rating systems must continue to be updated if they are to drive users towards an as yet unarticulated desired end-state.

4.4 Summary

The chapter developed the international framework (Table 4.4) that is based on the SSI-2012 structure and is built based on a review of eleven existing roadway or infrastructure sustainability rating systems and their included topics. The summary is:

- The framework presented here can be helpful in (1) evaluating and comparing the sustainability scope of existing roadway systems, and (2) developing or adapting rating systems for other countries.
- Regarding the scope of the presently developed sustainability rating systems, the tools in use today tends to emphasize environmental impacts and depletion of natural resources rather than economic and social issues of sustainability. Systems do not address economic and social indicators with the same emphasis as environmental indicators.
- No single sustainability rating system addresses all indictors in the international framework because of difference in sustainability scopes.
- The application of rating systems without modification is not appropriate for developing countries because of the differences between developed and developing countries.

- Rating systems promote eco-efficiency. Using fewer resources and producing less waste is the state-of-practice for sustainability efforts in roadways.

Chapter 5 An Analysis of Greenroads by Using the Framework

This chapter analyzes Greenroads version 1.5 using the international framework for roadway sustainability rating systems (in Table 4.4 in Chapter 4) as a case study to determine the scope of sustainability it addresses and the priorities it sets.

The results present the sustainability scope breakdown for Greenroads rating system by dimension and category, and a breakdown of indicator influence for Greenroads. The analysis concludes that 1) Greenroads favors the environmental dimension the most, and 2) Greenroads in its current unaltered version may not be appropriate for developing countries. Therefore, Thailand will be used as a case study for adapting Greenroads for developing countries as described in Chapter 6. Ultimately, the analysis provides a clearer understanding of how Greenroads' priorities are attempting to influence behavior and the expected outcomes of their use.

5.1 Method

5.1.1 Training Analysts and Aggregating Their Results

The international framework for sustainable roadway systems (Table 4.4) is used to analyze Greenroads rating system for sustainability scope. A standard process is used to allow multiple analysts to associate Greenroads credits with specific international framework indicators, with minimal subjectivity. Points associated with all credits that are assigned to an indicator are totaled and used to represent the influence of that indicator on the overall Greenroads Rating

System. This section describes the methods used in the analysis. Training Analysts and Aggregating Their Results

Assigning particular credits to sustainability indicators is somewhat subjective. To investigate the nature of this subjectivity, five different analysts were given scoring training and then asked to independently score Greenroads. The process for developing a final set of scores for Greenroads based on the aggregate of all five researcher score sets follows.

Step 1. Train all analysts in scoring technique. This training was about one hour long and consisted of (1) introducing the concept of sustainability, (2) introducing the international framework (Table 4.4) and indicator linkages (Table 5.1), and reviewing an example of scoring the Greenroads PR-6 Waste Management which is a project requirement.

Step 2. Each analyst scores the rating system.

Step 3. Aggregate analyst scores into one master list of scores. For each credit in the sustainability rating system, we selected for inclusion in the master list all indicators that were selected by at least three researchers. Results are reported based on the master list only (see Appendix B).

5.1.2 Scoring Process for Each Analyst

This section describes how the five analysts evaluated (termed “scored”) the rating system for sustainability scope.

Step 1: Determine the International Framework Indicator(s) Addressed by Each Greenroads Credit.

This step was thought likely to be the most subjective so procedures were developed to make it objective as possible. Importantly, this determination only considers primary and secondary indicators, but not lower level indicators. These are defined as:

- Primary indicator: addressed as a direct result of achieving the Greenroads credit. For instance, a Greenroads credit for recycled materials would directly address the consumption indicator. Greenroads credits may address more than one primary indicator.
- Secondary indicator: addressed by a primary indicator. For instance, a recycled materials credit would directly address consumption indicator. This could have other benefits by lowering GHG emissions and resulting in a net financial benefit. Therefore it addresses GHG emissions indicator, and cost-benefit indicator. Credits may address more than one secondary indicator.
- Lower level indicators: addressed by a secondary indicator. For instance, it could be argued that an action that reduces consumption and therefore reduces GHG emissions may also reduce air pollution. Therefore, the GHG emissions indicator addresses clean air. Ultimately all indicators could be argued as relevant since they all address sustainability. However, the boundaries for this analysis exclude those beyond secondary indicators.

Indicator Relationships. A list of indicator relationships (Table 5.1) was developed to assist in 40 identifying secondary indicators addressed by each Greenroads credit and to ensure consistency across different analysts. The relationships in Table 5.1 add robustness to the analyst assignment of primary indicators, i.e., even if different analysts select different primary indicators it is likely that each will list the other as a secondary indicator such that the final list of

addressed indicators (both primary and secondary) from each analyst will be a more complete match.

Table 5.1: International Framework Indicator Linkages (developed by Heta Kosonen, Ph.d. student, University of Washington)

Primary Indicator	Secondary indicators			
Access	Healthy life			
Healthy Life	(None)			
Safety	Healthy life			
Culture and History	Healthy life	Aesthetics		
Aesthetics	Healthy life			
Education	Healthy life			
Equality	Healthy life	Access		
Income Distribution	Healthy life			
Good Governance	Equality			
Clean Air	Healthy life	Ecological resources	Clean water	
Clean Water	Healthy life	Ecological resources	Water resources	
Clean Land	Clean water	Ecological resources	Healthy life	
Ecological Resources	GHG emissions	Consumption	Healthy life	Water resources
Water Resources	Ecological resources			
Consumption	GHG emissions	Cost-benefit		
Renewable Energy	GHG emissions	Consumption		
GHG Emissions	Clean air	Ecological resources		
Transition	(None)			
Financial Impact	Cost-benefit			
Employment	Healthy life			
Cost-Benefit	Consumption			

The users' manual is used to help assign Greenroads credits to the international indicators. In general, specific sections are identified in a manual that provide the best information on what international framework indicators should be assigned for each Greenroads credit. If no determination can be made using these specific sections, general credit text is used. This method works well for identifying related indicators, but is only marginally effective at identifying whether an indicator is primary or secondary. The users' manual contains (1) a "Goal" statement

that states what the Greenroads credit is intended to address, and (2) a list of benefits realized by achieving the Greenroads credit. A subset of a comprehensive list of benefits is described in Muench et al., 2011, which, in most cases align well with the international framework indicators. Greenroads' list of benefits includes tertiary and beyond indicators (not considered in this analysis), which are:

Primarily Eco-centric Benefits	**Primarily Anthropocentric Benefits**
Reduces Raw Materials Use	Improves Access
Reduces Fossil Fuel Use	Improves Mobility
Creates Energy	Increase Service Life
Reduces Water Use	Improves Human Health & Safety
Reduces Air Emissions	Improves Local Economies
Reduces Greenhouse Gas	Reduces First Costs
Reduces Water Pollution	Reduces Lifecycle Costs
Reduces Solid Waste	Improves Accountability
Restores Habitat	Increase Awareness
Creates Habitat	Increase Aesthetics
Reduces Manmade Footprint	Creates New Information

The roadway sustainability rating system topics in the international framework were used to help assign Greenroads credits to the international framework indicators (see the last column in Table 4.4). The analyst can identify the roadway system topic addressed by a Greenroads credit then look up this topic in Table 4.4 and select the associated indicator.

Step 2: Assign Points to Each Indicator

If a Greenroads credit addresses an indicator, the maximum possible points for that Greenroads credit are assigned to that indicator. In Greenroads, Project Requirements (PR), which have no point value in the rating system but must be achieved for certification, are assigned a point value of five, which is equal to the highest point value of any credit in the Greenroads system.

Step 3: Sum up the Total Points Assigned to Each Indicator

After all Greenroads credits are analyzed, the total point value associated with each indicator is summed across all credits. Since credits are frequently associated with more than one indicator, the total points summed for this analysis step will be substantially more than the publicized total of points available in a given rating system.

Scoring Example: Greenroads Energy Efficiency (MR-6) Credit

This section provides an example of how the first three steps are used to assign points to indicators for a particular credit in the Greenroads rating system.

Step 1. The Greenroads rating system version 1.5 manual (Muench et al., 2011) is used to identify the international framework indictors that are addressed by each Greenroads credit.

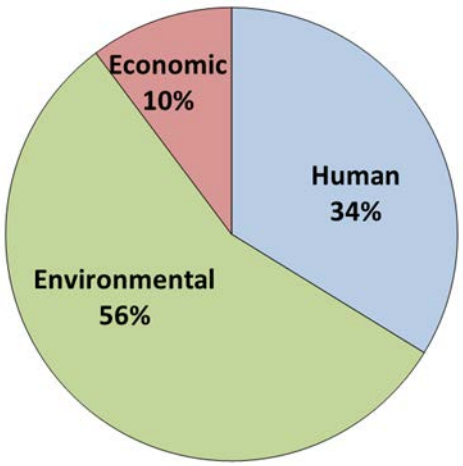
Step 2. The MR-6 credit goal is stated as, “Reduce lifetime energy consumption of lighting systems for roadways.” Benefits are listed as “reduces fossil fuel use, reduces air emissions, reduces greenhouse gases, increases service life and reduces lifecycle costs.” Based on this, the primary indicator of consumption is chosen which is associated with GHG emissions and cost-benefit indicators. “Reduces air emissions” and “increases service life” are interpreted as beyond secondary indicators. For corroboration Table 4.4 also shows that “reduce non-renewable energy use” is typical roadway rating system topics associated with consumption.

Step 3. The maximum point value associated with Greenroads credit MR-6, 5 points, is assigned to the consumption, GHG emissions, and cost-benefit indicators.

5.2 Results

This section presents (1) the sustainability scope breakdown for Greenroads rating system by dimension and category (see Figure 5.1); (2) a breakdown of indicator influence for Greenroads (see Table 5.2); (3) points awarded by analysts (see Table 5.3).

A Breakdown Greenroads Credits with SSI Dimensions



A Breakdown Greenroads Credits with SSI Categories

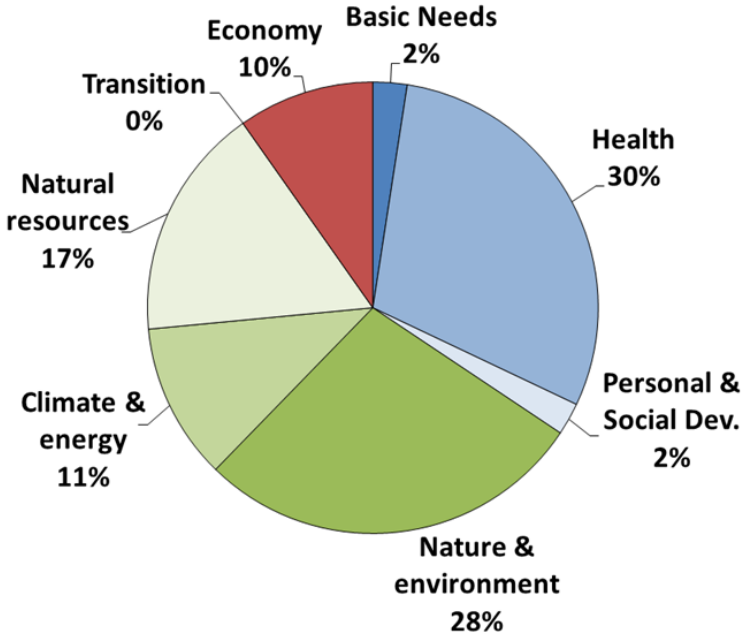


Figure 5.1: Sustainability Breakdown by Dimension and Category Levels for Greenroads

Table 5.2: Most and Least Influential International Framework Indicators[a,b]

Healthy Life	15%
Consumption	12%
GHG Emissions	11%
Clean Air	9%
Cost-Benefit	9%
Clean Land	7%
Ecological Resources	7 %
Safety	6 %
Aesthetics	6 %
Clean Water	5 %
Water Resources	4 %
Access	2 %
Culture and History	2 %
Good Governance	1 %
Education	< 1%
Financial Impact	< 1%
Equality	< 1%
Income Distribution	0 %
Renewable Energy	0 %
Transition	0 %
Employment	0 %
Mean:	4.8%
Median:	4.0%

Notes:

a. Color legend: Dark Green => 10%, light green => 5% and < 10%, light red =<1%., dark read =0%

b. Bar legend: First dark bar = sum of indicators above line constitute > 50% of rating system, second dark line = indicators below make up <1% of rating system, third dark line = indicators below are not represented in rating system.

Table 5.3: Points Awarded by Analysts

SSI Dimensions	Points Awarded by Analysts (Number in parentheses indicates a dimension's fraction of the total)										Final Values	
	A		B		C		D		E			
Total	783		850		786		886		757		777	
Human	224	(29%)	356	(42%)	305	(39%)	261	(29%)	216	(29%)	267	(34%)
Environment	463	(59%)	414	(49%)	390	(50%)	518	(58%)	437	(58%)	434	(56%)
Economy	96	(12%)	80	(9%)	91	(12%)	107	(12%)	104	(14%)	76	(10%)

5.3 Discussion

5.3.1 Analyst Scoring Comparison

All five analysts agreed on the order of the three dimensions (human, environment, economy). The assignment of indicators for each Greenroads credit was significantly affected by each analyst's individual preferences and point-of-view. Therefore, the international framework category and indicator level of analysis revealed greater differences. For instance, some analysts consistently emphasized human health aspects of Greenroads credits whereas others put more emphasis on nature and environment (see Table 5.3). The total number of the assigned indicators for each Greenroads credit was dependent on analysts' personal scoring methods. For example, some analysts always chose at least one indicator for each Greenroads credit whereas others left some Greenroads credits without any assigned indicators. The subjectivity of the evaluation was the most visible within credits that addressed multiple sustainability dimensions or that were vaguely described in their respective manuals.

As the analyst group had a diversity of backgrounds and different levels of expertise in the field, variability in scoring was expected. However variability could have been reduced with more comprehensive training and more detailed rating guidelines. For example, variability could have been reduced by (1) setting a minimum of one assigned indicator for all Greenroads credits, and (2) giving analysts more detailed descriptions of the road topics associated with different indicators (Table 5.1). Overall, despite any issues, analysts were in agreement on the dimension level lending confidence that the procedure described in this chapter could be repeated with similar results.

5.3.2 Greenroads Sustainability Scope

The sustainability scope of Greenroads emphasizes the environment more than the human and economic dimensions.

Figure 5.1 shows percentage of Greenroads sustainability scope at the dimension and category level: It favors the environmental dimension more than the human and economic dimensions combined.

There are two ways to explain Greenroads' sustainability scope. It may be a reflection of the sustainability goals and priorities of U.S. roadways projects that reflect U.S. status as a high-income country. Being so, its concept of sustainability may be skewed towards the environment because major social issues (e.g., inequity, poverty, average wage) are not as pressing as they are in low- income countries. Users might expect a rating system to reflect these values and indeed Greenroads does; (2) the meaning of sustainability may just be intrinsically more focused on the environment dimension, with the human well-being dimension (and economic dimension) functioning as a subsystem within a fully-functioning ecosystem. Therefore, as many of Greenroads credits suggest, if environmental well-being is improved a byproduct is human well-being (and economic well-being).

5.3.3 Influence of Sustainability Indicators

The "influence" of an indicator refers to the fraction of total points assigned in the analysis of a rating system that is attributed to that indicator. All discussion here refers to results as shown in Table 5.2. Over 50% of the points for a system are attributed to the top five indicators alone. Seven indicators contribute point totals less than 1% of the system total, making them essentially irrelevant.

Most Influential Indicators

Greenroads has healthy life, consumption, and GHG emissions within its top three most influential indicators (i.e., more points were assigned to these indicators than any other). Possible explanations follow.

- Healthy life is the indicator associated with livability (a broad term used to describe human health and happiness as influenced by infrastructure quality, location, and affordability), which is often linked as a secondary indicator (Table 5.1).
- Consumption contains five extremely common roadway rating systems topics (materials reuse, materials recycling, minimize materials, and reducing non-renewable energy use). In short, reducing materials consumption is a common sustainability topic.
- GHG emissions is linked to consumption as a secondary indicator (Table 5.1) so it is selected whenever consumption is, and GHG emissions are also a common stand-alone sustainability topic given their global popularity (e.g., (IPCC, 2014)).

Least Influential Indicators

No points are attributable to employment, renewable energy, transition, and income distribution, while education, financial impact, and equality were < 1%. Additionally, good governance did not account for more than 2%. None of these indicators has significant influence perhaps because (1) they are not deemed part of sustainability by these systems, or (2) these systems believe roads have a negligible effect on these indicators. This is somewhat surprising given the general political importance of equality, employment, education, and the economy.

5.4 Summary

This chapter analyzed the sustainability scope of Greenroads against the standard sustainability international framework for roadway sustainability rating systems (in Table 4.4 in Chapter 4), with minimal subjectivity, in order to comprehend regional and culture contexts and compound all elements that address the breadth and context of sustainable roadway construction. The method identifies the international framework indicators addressed by a Greenroads credit, then assigns points to each indicator, and sums up the total points assigned to each indicator. A list of indicator relationships (see Table 5.1), and the international framework topics, are prepared to assist in selecting the associated indicators of the international framework addressed by each Greenroads credit. Analysis of Greenroads shows:

- It has sustainability scopes that favor the Environmental dimension the most (56%), followed by the Human dimension (34%), and the Economic dimension (10%). This may be because it originated in the U.S. where sustainability concerns are on environmental issues and social and economic aspects are in a good condition, by most high-income countries (as classified by GNI per capita by the World Bank). According to Human Development Index (HDI), the U.S. ranks third in the word with a 2012 HDI of 0.937 (UNDP, 2013), which means addressing social issues may be a relatively minor concern. However, the U.S. ranks as the fifth highest ecological footprint in the world (at about seven global hectares/person) showing that environment may be a more pressing priority (Global Footprint Network, 2012).
- Greenroads is dominated by a short list of indicators: healthy life, consumption, and GHG emissions are within its top three. Healthy life and GHG emissions are often secondary indicators with GHG emissions almost always linked to consumption.

- Seven indicators (income distribution, transition, renewable energy, employment, equality, financial impact, and education) are relatively insignificant. None of these indicators account for over 2% of the points assigned in any rating system rendering them insignificant as behavior modifiers. This is somewhat puzzling since many of these indicators represent important political issues (e.g., economy, employment, education) or sustainability issues (e.g., renewable energy). It could be that roads are deemed unable to address these issues or it could be that these issues, despite their inclusion in broad descriptions of sustainability, are not yet in the industry's sustainability lexicon.
- Greenroads usually only gives points for actions that are beyond regulatory requirements or common practice, e.g., the Clean Water Act, Clean Air Act, National Historical Preservation Act, Americans with Disabilities Act (ADA), Occupational Safety and Health Administration (OSHA), etc.
- A portion of Greenroads weighting is based on life cycle assessment (LCA), which tends to emphasize GHG emissions and energy use. However, Greenroads does not consider social life cycle assessment (S-LCA), which is a tool for assessing social and socio-economic impact related to projects' life cycles such as worker, users, local community, and society (UNEP/SETAC, 2009). This may result in less attention to social impacts in Greenroads.
- Greenroads was originally developed based on the LEED system for buildings. If we look back at when the first LEED was developed, its priority was to improve the environment. Its main aims are to minimize environmental impact and minimize natural resource consumption and energy consumption, ignoring the social and cultural aspects. Though it is concerned with equity that is all about human health and context sensitive solutions, these sections had the lowest weighting (Söderlund, 2007).

- The evaluation method can apply to evaluate other existing sustainability rating systems for infrastructure. The results from evaluation can help us understand which of their credits are useful or which credits have been overlooked, and understand how they address the scope of sustainability, what they implicitly prioritize, and how they can be transferred from one context to another based on the local conditions.

Chapter 6 Thailand Rating System

6.1 Introduction

Chapter 2 provided the details why sustainability is context sensitive (see Chapter 2). This chapter presents an outline of a potential sustainability rating system for Thailand adapted from Greenroads version 1.5 as a case study in contextualizing an existing rating system for a different country.

The first sections of this chapter present methodology for identifying a country's sustainability priorities and categorizing them based on the Chapter 4 international framework. Two different methods of defining the Thai context are explored and compared: (1) an extended document and policy literature review method, and (2) a quick method based on SSI 2012 scores. Regardless of the method, the information gathered on the Thai context should make it possible to modify Greenroads version 1.5 for Thailand, which is done in the latter sections of this chapter.

Thailand was chosen as the specific country for the case study because: (1) it represents a common challenge in adapting developed world rating systems for use in the developing world, and (2), being Thai, I am familiar with the context, can read documents published in Thai, and have a familiarity with the Thai transportation system that will help me in this effort.

6.2 Description of the Study Area

Thailand is located in the center of Southeast Asia, bordered by Laos People's Democratic Republic and Myanmar to the north. Cambodia and the Gulf of Thailand are to the east,

Myanmar and the Indian Ocean to the west, and Malaysia to the south the Gulf of Thailand as shown in Figure 6.1. Thailand is approximately 198,457 square miles, about the size of France or Texas. In 2014, Thailand's population was approximately 67 million, 33 % living in urban areas, and 13.2 % living in poverty (living on less than $2.00 a day).

Thailand's climate is tropical, generally hot and humid across most of the country with three types of seasons: cool season (November- February), hot and humid season (March-June), and rainy season (July-October) with high humidity and rain, which is dominated by the southwest monsoon. The southern part is always hot and humid. The average low temperature is 20 degrees Celsius and average high temperature is 37 degree Celsius (Tourism Authority of Thailand, 2014).

Figure 6.1: Thailand Map (Utexas, 2013)**)**

Some key statistics for Thailand are:

2013 GDP Total	387.3 billion USD
2013 GDP Per Capita	5,779 USD
Income Group (The World Bank classification)	Upper middle income
Population Size	66,785,500
Poverty	88% of the country's 5.4 million poor living in rural areas.
2012 Sustainability Society Index	18th out of 151 countries (score of 5.60)
2012 Democracy Index Rank	58th/167 (Flawed democracy)
2014 Global Peace Index Rank	126th/162 (Medium)
2014 Environmental Performance Index	78th out of 178
2013 Corruption Perception Index (CPI)	102th /177 (score of 35)

Source: (World Bank, 2015 UNDP, 2014a; SSI, 2013; Economist Intelligence Unit, 2013; The Institute for Economics and Peace, 2014; YCELP & CIESIN, 2014; TI,2013)

6.2.1 About Road Transportation in Thailand

According to the Highway Act of 2006, highways in Thailand are divided into 5 types: special, national, concession, rural, and local. The following road networks are under the responsibility of the following organizations: approximately 41,565 miles (66,940 km.) of road under Department of Highway, 29,774 miles (47,916 km.) of roads under the Department of Rural Roads, and 218,820 miles (352,157 km.) under the Sub-District Administration organizations constructing and maintaining local roads (OTP, 2014).

Road transportation in Thailand:

- Road transport (roads, railroads, ports and air transports) is a major mode of transportation for four- and two-wheel vehicles in Thailand (87.50 percent) (OTP, The Study on Transport and Traffic Development Master Plan, 2011). Also, road transport is

the main type of freight transportation across the country since there is no well-developed rail network.

- Road transport in Thailand has a very high energy use and the highest CO_2 emission out of major modes of transportation, amounting to 97% of the total transport emission base on National Greenhouse Gas Listing (National Greenhouse Gas list, 2011).
- The quality of highway networks in Thailand might be considered “fair”. In 2014 Thailand ranked 50th out of 144 countries and rated a 4.5 points in the quality of roads indicator within the World Economic Forum Global Competitiveness Report (1= extremely undeveloped; 7 = extensive and efficient by international standards) (World Economic Forum, 2014).
- Wheelchair ramps, audible accessible pedestrian signals, and bike lanes are not common in Thailand. However, the government has offered plans to construct them in recent years (BMA, 2013).

6.3 Methods for Determining the Context

Two methods are used to describe the Thai context:

- Document and policy literature review. A review of key Thai documents and policies is used in order to extract common strategic goals. This method is somewhat subjective (based on which documents are reviewed and the author’s interpretation of strategic goals), but offers a more in-depth technique of determining context.
- SSI Scores. The SSI-2012 scores are used to identify areas of strength and improvement. This method is more straightforward and objective, but it cannot identify any details or subtleties not contained in the 22 SSI indicators.

Triangulation and audit trail methods are chosen to ensure validity and reliability:

- Triangulation. Multiple investigators, sources of data, or data collection methods are used to confirm emerging findings (Yin, 2009; Merriam, 2009). The aim is to corroborate the same fact or phenomenon from different sources (Yin 2009). This research uses two methods to compare which are using document and policy literature review and SSI scores.
- Audit Trail. The research design is set up in a rigorous manner and transparently described. This is a detailed account of the methods, procedures, and decision points in carrying out the study (Merriam, 2009). This Chapter presents the process to adopt Greenroads using the international framework in Thailand as a case study and the process presented herein could be applied to any country.

6.4 Document and Policy Literature Review

In this method, key Thai documents (to include government publications, refereed journal articles, and building rating systems) are reviewed in an attempt to capture (1) stated strategic goals, and (2) how those goals are translated into sustainability values based on the international framework.

Step 1: Collecting and reviewing documents and policies about sustainable transportation in Thailand are described in section 6.4.1- 6.4.2 Documents examined are:

- Major sustainable policies in Thailand;
- National Transport Development Strategy B.E. 2554-2558 (2012-2016);

- The Enhancement and Conservation of the National Environmental Quality Act B.E. 2535 (NEQA 1992);
- National Economic and Social Development Act No. 11 B.E. 2555-2559 (2012-2016);
- Transport Sector Assessment, Strategy, and Road Map, Asia Development Bank;
- Strategic Plan of Department of Highway;
- Strategy of Department of Rural Roads;
- Bangkok Declaration Sustainable Transport Goals for 2010-2020 (UNCRD);
- EIA Thailand;
- OSHA Thailand 2009;
- Thailand Human Development Report 2014;
- Theses and peer-reviewed journals about sustainable road construction in Thailand;
- Building rating systems in Thailand

Step 2: Matching content of documentation with indicators from the international framework is described in Table 6.3. Indictors were selected because they are most often addressed in the strategic goals of governance documentation from step 1. The criteria for selection topics are described below. The resulting Thai context, represented by key priority topics found in this literature review, is show in section 6.3.5.

Criteria for Selection of Appropriate Priority Topics Are:

1. Indicators are addressed in National Economic and Social Development Act No. 11 B.E. 2555-2559 (2012-2016).

2. Indicators are related with strategic plans of several transport sectors as in Table 6.3.

3. OSHA Thailand 2009 for worker safety and road safety audit standards should be integrated into priority topics because Thai standards are still below other countries, the standards are still unclear for descriptions, and the standards are not required to enforce the practice on all types of road projects (Teerananon, et al., 2003; Sutthamongkhol, 2011).

6.4.1 Sustainability Policies and Transportation Plan

6.4.1.1 *Major Sustainability Policies in Thailand*

The philosophy of the Sufficiency Economy (SE) is a model for sustainable development in Thailand. It was proposed by His Majesty King Bhumibol Adulyadej of Thailand in 1974. The philosophy mentions the "middle path" idea that people shall consume only what they really need and avoid unnecessary excess. It also encourages them to be aware of the consequences of their actions to others while minimizing resources and energy. The principle can be conducted by people at all levels in order to encourage themselves to live a reasonably comfortable life which is neither too lavish nor too frugal. Nowadays, the King's concept has become a key foundation of Thai society and influenced the implementation of the country's development strategies. After the Economic Crisis in 1997, the SE was initially implemented in the Eighth Thailand National Economic and Social Development Plan (1997-2001) (UNDP, 2007).

The principle of the SE has three components: moderation, reasonableness, and self-immunity from impacts arising from internal and external changes (see Figure 6.2). The three elements are defined as:

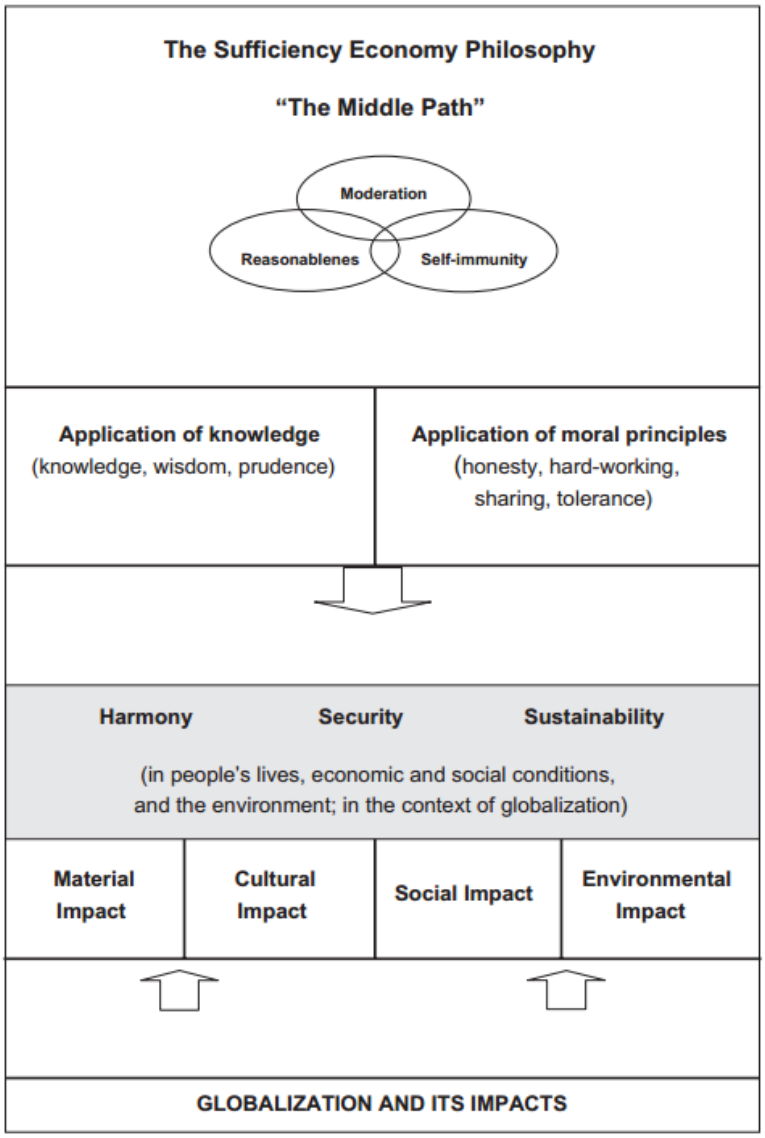
- **"Moderation** is closely linked to the idea of sufficiency. Like in English, the word for sufficiency (pho phiang) in Thai has two meanings: enough in the

sense of not too little, and enough in the sense of not too much. It conveys the idea of a middle way between want and extravagance, between backwardness and impossible dreams. It implies both self-reliance and frugality (Take a middle path and avoid extremes).

- **Reasonableness** means both evaluating the reasons for any action, an understanding its full consequences not only on oneself, but on others, the society, and the environment; and not only in the short term, but also in the long run. This idea of reasonableness thus includes accumulated knowledge and experience, along with the analytical capability, self-awareness, foresight, compassion and empathy (Be sensible and insightful when making decisions).
- **Self-immunity** means having built-in resilience, and the ability to withstand shocks, to adjust to external change, and to cope with events that are unpredictable or uncontrollable. It implies a foundation of self-reliance, as well as self-discipline (Build protection against shocks)." (UNDP, 2007)

Besides these three components, there are two other conditions: knowledge and integrity, which are part of the philosophy of the SE.

- **"Knowledge** means something close to wisdom in English as it encompasses accumulating information with the insight to understand its meaning and the care or prudence needed to put it to use (know what you are doing).
- **Integrity** means virtue, ethical behavior, honesty and straight –forwardness, but also tolerance, perseverance, a readiness to work hard and a refusal to exploit others (Be honest and persevere)." (UNDP, 2007)



Source: (Thongpakde, 2005)

Figure 6.2: The Philosophy of Sufficiency Economy Framework

6.4.1.2 *National Economic and Social Development Plan (NESDP)*

The Royal Thai Government has prepared a 5-year National Economic and Social Development Plan to guide national social and economic development since 1961. Thailand is currently using the Eleventh National Economic and Social Development Plan (NESDP) (2012-2016).

The Eleventh Plan (2012-2016) continues to implement the key elements of the SE and put into action a new model of holistic "people-centered development" by collaboration between stakeholders, such as civil society, the private sector, and academia, to participate in national development. The philosophy of the SE also has been implemented in order to manage impacts from internal and global changes and fluctuations by development of the country's self-reliance and resilience to external factors. The vision is "A happy society with equity, fairness and resilience." The Eleventh Plan highlights inclusive growth, regional equity, human resources and private sector development, transport and energy connectivity, regional cooperation, environmentally sustainable development, resilience against natural disaster, and good governance (NESDB, 2011). Key development strategies and details, which are related to transportation, are as follows (NESDB, 2011):

1. Creation of a just society, good governance and social security: Thai society has equitable access to quality services, resources, and basic infrastructure. People actively participate in the development process under good governance.
2. Development of a lifelong learning society.
3. Strengthening of the agricultural sector and security of food and energy: Transportation can help to protect and improve productive agricultural land.

4. Restructuring the economy toward quality growth and sustainability: The development of infrastructure and logistical systems should utilize energy sources efficiently and should be integrated into multimodal transportation management systems. The public transportation network should be increased.
5. Create regional connectivity for economic stability: Transport and logistics systems should be developed through sub-regional cooperation supported by reforming laws and regulations regarding transportation of passengers and goods.
6. Managing natural resources and environment toward sustainability: Increase energy efficiency in the transport sector to reduce greenhouse gas emission, renewable energy such as biofuel and natural gas.

6.4.1.3 *Transportation Organizations' Strategic Plans*

Regarding roads and highways in Thailand, the Department of Highways and the Department of Rural Roads, under the Ministry of Transport, are responsible for construction, maintenance, and operation of the national road and highway networks. The following strategic plans were established to guide government agencies, which are related with road projects and transportation in each organization.

The Ministry of Transport

Goals of this strategic plan (2011-2015) are (MOT, 2011):

1. Increase the capacity for infrastructure system and efficient transport service to comply with the integrated strategy for development;

2. Develop the extensive networks of mass transit systems and public transport services for both passengers and goods, to offer equal opportunities to travel to the public and to act as a catalyst for the sustainable development of the country;
3. Streamline the existing transport network;
4. Ensure public safety of transport systems, lessen their environmental impact, enhance the quality of life of people, and minimize the economic loss;
5. Maximize the potential of good governance and systematic monitoring with public participation in making and inspecting so as to raise the quality of public transport services.

Department of Highways Strategic Plan (2012-2016)

The Department of Highways (DOH) is responsible for constructing highway infrastructure throughout the country as well as linking it with international highways and maintaining highways of more than 50,000 kilometers. The strategic plan goals are (DOH, 2010):

1. Develop the highway network system to support transportation logistics;
2. Develop the highway network system to connect ASEAN Economic Communities;
3. Construct and maintain the highway network throughout the country;
4. Develop the highway network to promote road safety;
5. Manage organization efficiently to support society and preserve environment according to good governance.

Department of Rural Roads Strategic Plan

The Department of Rural Roads is responsible for developing and upgrading rural roads to support transport, tourism, and frontier and city development, to solve traffic problems by constructing missing routes (DRR, 2012). The strategic plan is:

1. Develop the road network system in order to improve and upgrade quality of life;
2. Integrate holistic approach to road infrastructure development and transport services;
3. Maintain the road network system in sustainable way;
4. Increase strengthening of local administrative organization for developing and maintaining local roads.

Transportation Infrastructure Development's Strategic Plan (2015-2022)

The strategy concentrates on four supporting areas (OTP, 2014):

1. Create stabilities and securities in transportation including sustainable and environmentally friendly development;
2. Create economic securities by reducing transportation costs, decreasing travel time, and urging production investment;
3. Ensure social securities by improving quality of life;
4. Create opportunities in competition and to get maximum benefits from being part of the ASEAN Community.

Transport and Traffic Policy and Planning Plan for Road Transportation (2011-2020)

In order to enable sustainable transport, there are six goals as follows (OTP, 2011):

1. Promote economic activities along the economic corridors;

2. Link road transport between economic zones;
3. Ensure road transport safety;
4. Make road transport environmentally friendly and reduce energy consumption;
5. Provide good quality of public road transport;
6. Ensure fast and convenient road transport.

The Master Plan for Sustainable Transport System and Mitigation of Climate Change Impacts

The vision is "An efficient transport model that is environmentally friendly, appropriate for the development of sufficient and sustainable socio-economic infrastructure for Thailand." The relationship between five instruments and six strategies is as shown in Figure 6.3 (Uabharadorn, 2013):

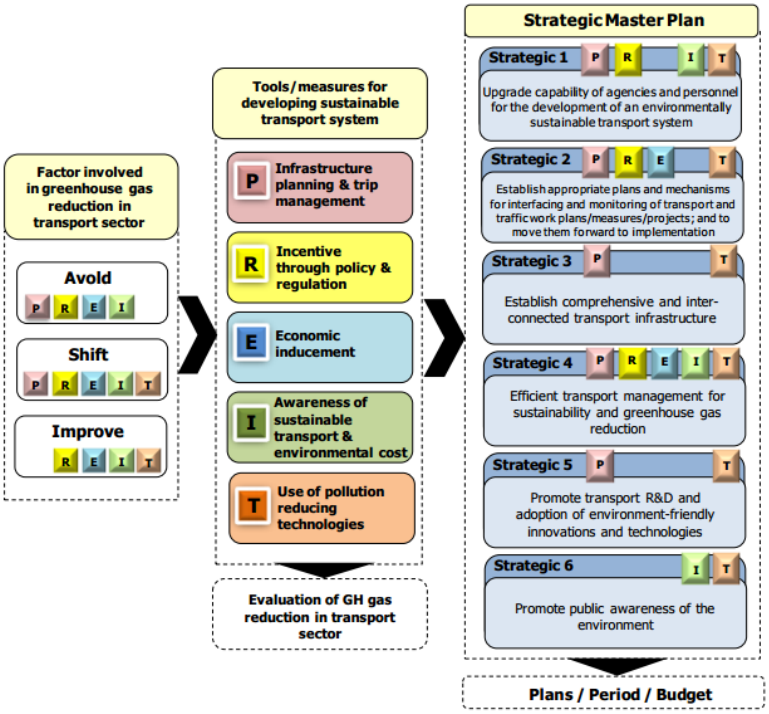


Figure 6.3: Relationship of Shift-Avoid-Improve, 5 Instruments and 6 Strategies of the Master Plan (Uabharadorn, 2013)

Bangkok Declaration on Sustainable Transport Goals for 2010-2020

The Bangkok 2020 Declaration: Sustainable Transport Goals for 2010-2020 was agreed upon at the Fifth Regional Environmental Sustainable Transportation (EST) Forum in August 2010 which was attended by approximately 200 participants from twenty-two Asian countries (UNCRD, 2010). Next, strategic plans which are related on sustainable transport will follow these goals. In order to achieve sustainable transport goals, the topics that will be integrated in Bangkok's plan are as follows (UNCRD, 2010):

1. Strategies to Avoid unnecessary travel and reduce trip distances
    - Land-use and transport planning
    - Mixed-use development
    - Information and communications technologies
2. Strategies to Shift towards more sustainable modes
    - Non-motorized transport
    - Public transport
    - Transportation Demand Management
    - Inter-city passenger and goods transport
3. Strategies to Improve transport practices and technologies
    - Transport fuels and technologies
    - Standards
    - Inspection and maintenance
    - Intelligent Transportation systems
    - Freight transport
4. Cross-cutting strategies
    - Safety
    - Health
    - Air quality and noise
    - Global climate change and energy security
    - Social equity

- Financing
- Information and awareness
- Institutions and good governance

Asian Development Bank (ADB) Strategy 2020 (ADB) for Thailand

The long-term strategic framework for Thailand focuses on the land transport subsectors of rail, motorways, and urban mass transport in Bangkok Metropolitan Region. The strategy concentrates on four support areas (ADB, 2011):

1. Railway modernization;
2. Expansion of the motorway network;
3. Support for the urban mass rapid transit (MRT) network in the BMR;
4. Advisory capacity development in procurement, private partnership (PPPs) and good governance.

In sum, all these strategic plans tend to reflect the 11th National Economic and Social Development Plan and the five parts of the middle path. Transport organizations developed their strategic plans based on the current 11th plan. It means that strategic plans in each organization are related to each other but they develop different strategies based on each objective and mission. After reviewing these strategies, it was found that road safety, social equity, connectivity, energy, and good governance are main strategies among organizations as shown in Table 6.1.

Table 6.1: Summary of Transportation and Related Strategic Plans

National Economic and Social Development (NESDP)	Details (related in transportation sections)	MOT	DOH	DRR	Infrastructure	Traffic policy	Master Plan	Bangkok	ADB for Bangkok
1. Creation of the just society	Adequate Access to basic needs, mobility			x	x	x	x	x	
	Good governance and participation	x	x	x			x	x	x
	Safety increase and accident reduction	x	x			x		x	
2. Development of the lifelong learning society	Education						x		
3. Strengthening of the agricultural section and security of food and energy	Increase accessibly and mobility food supplies								
4. Restructuring the economy toward quality growth and sustainability	Multimodal transportation and public transportation	x					x	x	x
5. Create regional connectivity for economic stability	Providing connection, infrastructure and logistics systems along border areas	x	x		x	x		x	x
6. Managing natural resources and environment toward sustainability	Reduce greenhouse gas emission		x		x	x	x	x	
	Utilize energy sources efficiently, and renewable energy	x				x	x	x	

Environmental Impact Statements (EIS)

Environmental Impact Statements (EIS) in Thailand have been used to evaluate direct and indirect, short and long term, impacts from projects or significant activities. Thailand's EIS is similar to National Environmental Policy Act of 1971 in the U.S. However, enforcement of the EIS requirements in Thailand may be different. The guidelines of environmental resources and values are studied in EIS are as in Table 6.2. The EIS report describes environmental impacts

from the project in question during the construction and operation phases. The EIS report helps to prevent and minimize impacts on the environment, to compensate for the damage incurred, to find alternative ways to develop the project, and to monitor the program.

Table 6.2: Specific Substantive Environmental Concerns in EIS Process in Thailand (ONEP, 2012)

Topic	**Issues of Environmental Concern**
Geomorphology	Topography Elevation Unique physical feature e.g. island, cliff, etc.
Soil	Earth movement and slope failures Soil erosion Sedimentation of roadside, water bodies, and drains Soil contamination
Water	Water sources, quantity, quality and flow rate Changes in flow of surface water and groundwater Water quality degradation by waste materials, equipment lubricants, fuels, and detergents Sedimentation of surface water bodies
Air	Degradation of air Generation of pollutants and dust
Noise	Intensity and frequency
Vibration	Intensity and frequency
Animal/plant	Damage of ecology, species, biodiversity, and forest Number distribution Damage of reproduction and food zone for fish, aquatic and migratory birds Disintegration of wildlife habitat by physically divided community
Land use	Existing land use Damage to vegetable and trees

Topic	Issues of Environmental Concern
Cultural Heritage	Damage of sites, structures and remains of archaeological, historical, religious and cultural values
Drinking/domestic water	Sources, quality and quality and adequacy
Transport	Disruption of traditional modes of transport
Socio-economic	Disintegration of social activities caused by physically divided community Disintegration of social activities Loss of roadside community business
Health and Safety	Degradation of living environment due to pollution of air and water, noise and vibration Road accidents

The following road and highway development projects require an EIS in Thailand (ONEP, 2012):

1. All sizes of expressways as defined by the Expressway and Rapid Transit Authority of Thailand Act or other projects alike;
2. All sizes of highway and road as defined by the Highway Act, passing through the following areas:
    - Wildlife Sanctuaries and Wildlife non-hunting areas defined by Wildlife Conservation and Protection Act;
    - National park as defined by National park Act;
    - Watershed area classified as class 2 by the cabinet resolution;
    - Mangrove forests designated by National Forest Reserve;
    - Coastal area within 50 meters at the highest sea level;

- Areas located next to RAMSAR sites or World Heritage Sites inscribed in World Heritage List according to World Heritage Conservation within 2 kilometer distance (1.3 miles);
- Areas located next to Ancient Remains, Archaeological Resources, Historical Sources or Parks regulated by Ancient Monuments, Antiques and National Museum Act or World Heritage Sites inscribed in World Heritage List according to World Heritage Convention within 2 Kilometer distance (1.3 miles).

The Occupational Safety and Health Act

Thailand's Occupational Safety and Health Act, in effect since 2008, provides for workplace safety regulation related with infrastructure construction (OSHThai, 2014) and (SHAWPAT, 2014). Key requirements include:

- Construction contractors must submit a "Safety management program in construction"; if projects are:
    - Bridge with a span length of more than 30 meters (98.4 ft.), bridge crossing, flyovers, U-turn bridge and interchange;
    - Excavation, or repairing or razing an infrastructure system deeper than 3 meters (9.8 ft.);
    - Tunnel and underpasses.
- Safety management plans requires:
    - General safety and health provisions;
    - Safety training and education;
    - Campaign to promote safety in the workplace;

- Employee emergency action plans;
- Recording and reporting of injuries.

It should be noted that Thailand's Occupational Safety and Health Act seems to be emphasized very little in Thailand. Owners and workers ignore regulations because laws and standards are not effective and enforcement is weak (Aksorn & Hadikusumo, 2007).

6.4.2 Example Rating Systems in Thailand

At present, there is no infrastructure rating system in Thailand. However, in regard to sustainability building rating systems, TREES-NC and DGNB International have been created mainly for use in Thailand. Thus, documents of these systems are reviewed.

- **TREES-NC:** Thai Green Building Institute (TGBI) has developed a green building rating system for rating purposes in Thailand, called the Thai Rating of Energy and Environmental Sustainability for New Construction and Major Renovation (TREES-NC). TGBI has partially adopted the LEED rating system with modification for the Thai initial framework. Only 30% of LEED credits have been adapted for Thailand rating system. The other 70% were created from local environmental conditions, natural resources, especially for flooding prevention, and local materials (Manager, 2012). There are 20 applications under review and one certified project in 2013 (OBG, 2012).

- **DGNB International:** The Thailand Association for Sustainable Construction (TASC) and the German Sustainable Business Council (DGNB) were working together to develop the international DGNB system for Thailand (OBG, 2012). The DGNB system consists of key aspects of sustainable building, including: environmental, economic, sociocultural and functional aspects, technology, processes, and sites. There are three levels of

certification which are Bronze: 35%-50%, Silver: 50%-65%, and Gold: 65%-80%. There is only one certified project by DGNB in Phuket, Thailand: Gold (80.1%) (DGNB, 2013).

6.4.3 Results: Key Priorities in Thai Context Based on This Method

This section presents key sustainability priorities in Thailand as determined by a document and policy literature review. Table 6.3 summarizes findings from the literature review and Table 6.4 presents the key sustainability priorities interpreted from these finds. To be selected as a key sustainability priority an indicator had to be addressed in at least three of the documents reviewed.

The results, on key sustainability priorities in Thailand based on this method, are:

- Accessibility to basic needs services;
- Connection to regional support and ASESN economic communities;
- Road safety improvement;
- Good governance;
- Clean air;
- Greenhouse gas emission and saving energy;
- Logistics (freight access).

Logistics in terms of freight access is added in key priorities in a Thai context because it is addressed in most strategic plans, in terms of expansion of the road network and creation of connections.

Table 6.3 The International Framework with Stratgic Plans

Dimension	Category	Indicator	NESDP	MOT	DOH	DRR	Infrastructure	Traffic	Master Plan	Bangkok	ADB	Topic
Human	Basic Needs	Access	x			x	x	x	x	x	x	Modal access (ped, bike, bus, HOV)
	Health	Healthy Life										Livability Noise reduction
		Safety	x	x				x		x		Worker/jobsite safety Traffic/road user safety Infrastructure resiliency
		Culture and History										Cultural preservation and outreach Historical preservation
		Aesthetics										Scenic views Aesthetics of earthwork and structures
	Personal & Social Development	Education	x						x			Job training
		Equality										Environmental justice/ gender diversity
		Income Distribution										*Prevailing wages*
		Good Governance	x	x	x	x			x	x	x	Context Sensitive Solutions (CSS) *Anti-corruption/collusion*
Environment	Nature & Environment	Clean Air	x		x		x	x	x	x		Construction Equipment Emissions Materials Transport Emissions Materials Production Emissions Traffic Emissions

Dimension	Category	Indicator	NESDP	MOT	DOH	DRR	Infrastructure	Traffic	Master Plan	Bangkok	ADB	Topic
		Clean Water										Clean water Stormwater runoff quality Groundwater quality
		Clean Land										Contaminated soil - brownfield Waste Management/minimization
		Ecological Resources										Habitat creation Habitat preservation/conservation Wildlife conservation Stormwater runoff volume/flow Ecological connectivity Light pollution/reduction and glare Non-hazardous materials
	Natural Resources	Water Resources										Water use Renewable water resources (potable water conservation)
		Consumption	x	x				x		x		Material reuse Material recycling Minimize materials Local materials Durable structures Quality control Reduce non-renewable energy use Fuel use
	Climate & Energy	Renewable Energy	x						x			Encourage renewable energy use

Dimension	Category	Indicator	NESDP	MOT	DOH	DRR	Infrastructure	Traffic	Master Plan	Bangkok	ADB	Topic
		GHG Emissions	x		x		x	x	x	x		Lifecycle assessment (LCA) Greenhouse gas emissions
Economy	Transition	Transition										*Climate change adaptation* *Electric vehicles infrastructure*
	Economy	Financial Impact	x	x	x		x	x	x	x		Local economy
		Employment										Local employment
		Cost-Benefit										Cost-benefit

Table 6.4: The Priorities of Thailand of Roadway Projects

Dimension	Category	Indicators[a]	Details from Strategic plans
Human	Basic Needs	Access	Accessibility, connectivity
		Safety	Worker safety, road user safety, flooding
	Personal Social Development	Good governance	Good management, Anti-corruption and public participation
Environment	Nature & Environment	Clean Air	Clean Air
	Natural resources	Consumption	Save energy and fuel
	Climate & Energy	Greenhouse gas emission	Greenhouse gas emission
Economy	Economy	Financial Impact	Logistics, Fright Access

a. Indicators are addressed more than three strategic plans.

6.4.4 Discussion

This section explains why key indicators in Table 6.4 are important in Thailand.

- Accessibility: There are two different forms of access. The first one is access to basic needs services such as food, sanitation and medical care. While more than 99% of the U.S. population has access to basic needs services (UNDP, 2013), Thailand still needs access to basic needs. The second is upgrading road facility to serve multiple modes of transportation and varying mobility levels (e.g. wheelchairs, bike lanes). For example, the Thai government has plans to develop all facilities in the next few years. The Bangkok Metropolitan revealed one project for adding 350 wheelchair ramps in 2015, and setting up 220 audible accessible pedestrian signals (BMA, 2013), and bike lanes have been promoted and developed a few years ago. Prime Minister General promotes cyclists in Thailand by supporting the creation safe bike lanes in all regions and protection of bike lanes from misuse since the end of 2014 (NNT, 2014).
- Road Safety: Motor vehicle crashes can cause not only fatalities and injuries, but also vital social and economic problems. In Thailand, approximately 13,000 people were killed annually due to road accidents leading to a national loss around 243,000 million Baht (US$7490 million) or about 2.8 percent of the country's GDP in 2007. In 2007-2010, roadside crashes on national highways averaged 44 percent of the total road crashes on the DOH highway (Bureau of Highway Safety, 2011). Thailand is ranked 3rd in ASEAN and 6th the world in terms of roads mortality rate based on the study of Asian Development Bank (ADB). Motorcycles remain a major safety challenge. Road safety is one of the first selected priority programs of WHO strategic agenda in Thailand (2012-2016) (WHO,2011)

- Workforce Safety: Health and safety of workers receive the least attention in existing rating systems. According to researchers in Thailand about work zone safety, work zone *safety has become an important issue for Thailand; though Thailand has developed the* work zone standards (Teerananon, et al., 2003) (Sutthamongkhol, 2011). A number of factors may contribute to safety issues in road construction zones are summarized below:
    - Inadequate safeguards at work sites;
    - Unforgiving roadside features, large pole deep trenches, damaged or incorrectly installed guardrails;
    - Insufficient traffic signs, inconsistent signs, installed at inappropriate locations, and poor road markings;
    - Enter and exit work zones;
    - Dust and other debris on carriageways;
    - Forcing pedestrians to stray onto the road;
    - Speed control in construction areas;
    - Lighting;
    - The transition area

  There is very limited emphasis in Thailand. Therefore, the workforce safety credit is included in Greenroads Thailand version by providing a plan for training and monitoring workers to strengthen the recognition of law and safety in work zones.

- Good Government: Corruption and government instability indicators are the most problematic factors for doing business based on the Global Competitiveness Report 2014-2015 which assesses national competitiveness worldwide in twelve different aspects over 100 indictors, and 144 countries (World Economic Forum, 2014). Corruption also remains a

major challenge. Transparency International's 2013 Corruption Perception Index (CPI) ranked Thailand 102 among 177 countries with a score of 35. Thailand's CPI ranking has deteriorated since 2010, when the ranking was 78 with a score of 35.

- Climate Change: It remains a serious hazard. Thailand emitted 4.4 tons of carbon dioxide into the atmosphere per person per year in 2010. The effects of climate change have elevated risk of natural and man-made disasters, droughts, extreme weather patterns and sea level rise, and threatening economic development and community livelihoods (UNDP, 2014a). Thailand faces flooding every year, 2011 flood crisis in Bangkok and other major provinces was a devastating natural disaster. The total damage and losses from the 2011 floods in Thailand approximated USD 46.5 billion. It damaged rural roads and bridges; consequently, it would limit access to basic needs of people in the areas (GFDRR, 2011). Flooding has become increasingly frequent in urban areas in wet season.

- Clean Air: Air pollution has become one of the top environmental concerns in Bangkok Metropolitan Administration (BMA), and other big cities, which mainly comes from vehicle emissions resulting in health impacts. Road transport in Thailand has the highest CO_2 emission, amounting to 97% of the total transport emission (National Greenhouse Gas list, 2011). Major sources of PM10 and PM 2.5 in Bangkok are automobile emissions (Chuersuwana et al., 2008). It should be noted that Thailand needs to reduce emissions from vehicular traffic and construction activities, which are major contributors of air pollution.

- Consumption: Thailand consumes fuel (oil and natural gas) for transportation uses particularly road transportation, about 78% of the total energy consumption in transport section, resulting in increased greenhouse gas emissions (Nicha, Kamphol, & Bundit, 2014). Thailand government has implemented several plans to reduce fuel consumption by

promoting using renewable energy sources. Furthermore, the government promotes public transportation, biking, and walking instead of private vehicles. They are important strategies to reduce fuel consumption and greenhouse gas emissions (NESDB, 2011).

- Freight Access: Improving freight transport by increasing mobility is the main factor in order to prepare for ASEAN Economic Community. In 2015 Thailand, a leading country in the ASEAN Economic Community (AEC), will propose a “single market and production base” to boost competitiveness among ten Southeast Asian nations. By 2020, the volume of road transport and freight transport will increase by 21.84 percent. Therefore, Thailand’s logistics for goods and services has to develop beside its education, tourism, investment, and skilled labor in order to support ASEAN Economic Community (UNDP, 2014b).

6.4.5 Method Evaluation

The literature review method has strengths and limitations as follows:

The strengths of this method are:

- More in-depth analysis is possible and greater detail than using SSI scores. Results can be more specific to sustainable transportation.
- This method could work at varying scales: statewide, provincial, or organizational.
- Easily accessible from the secondary sources that have already been published.

The limitations of this method are:

- The results are somewhat subjective. The reviewer introduces bias by picking the documents selectively, while document availability can also introduce bias as some useful documents may not be readily viewable.
- Some documents are unavailable to public access or are not published in English.

- More time-consuming than using SSI scores.

6.5 SSI Scores

The second method uses the 2012 Sustainable Society Index (SSI-2012) (http://www.ssfindex.com/data/) for identification of the priority topics in Thailand. This method is much simpler and represents the quickest option in terms of developing the tool for use. This section presents the formulas for weighting the SSI dimensions to adjust the ratios of three dimensions of rating systems. The method for how to choose priority indicators in Thailand is that SSI 2012 indicator scores, below 5 points, will be chosen.

6.5.1 Natural of SSI Scores

Table 6.5 describes overall SSI scoring for the world:

Table 6.5: World Totals SSI-2012, score range from 1-10, (SSF, 2013)

SSI-2012	Mean	Median	Standard Deviation	Min	Max
Human Wellbeing	6.2	6.6	1.57	3.6	9.5
Environmental Wellbeing	4.5	4.1	1.87	1.2	8.4
Economic Wellbeing	3.8	3.7	1.60	1.28	8.6
World scores SSI-2012	4.7	4.8	0.78	3.0	7.4

General observation for SSI 2012:

1. The level of human wellbeing is the highest score of three dimensions. The basic needs category achieves the highest score of which average per country is 8.09. The mean and median of human wellbeing is the highest as well.
2. Renewable energy in environmental wellbeing achieves very low score of which average per country is 3.58 considering hydro, geothermal, solar photovoltaic, solar thermal, tide,

wave, ocean, wind, solid biomass, gases from biomass, liquid biomass, and renewable municipal waste according to IEA's definition.

3. Most countries have very low score in organic farming. Average points of organic farming per country are 2.5. It was found that only Europe shows high scores for organic farming. Thus, it may be one reason that economic wellbeing has low scores.

6.5.2 Weighting the Dimensions

Calculating of weighting the dimensions. The formulas for calculation of weighting dimensions of SSI 2012 scores are given below:

Step 1: Determine the distance of a score from the maximum possible score (10.0) for each wellbeing dimension:

$$\text{Human wellbeing} = 10.00 - \text{Score}_{HW} = \text{Dis10}_{HW} \quad (6.1)$$

$$\text{Environmental wellbeing} = 10.00\text{-Score}_{EW} = \text{Dis10}_{EW} \quad (6.2)$$

$$\text{Economic wellbeing} = 10.00\text{-Score}_{ECW} = \text{Dis10}_{ECW} \quad (6.3)$$

Step 2: Choose the lowest result from step 1 and divide each score by this lowest result to get weighting by the following expression:

$$\text{The lowest result (LOW)} = \text{MIN}\ (\text{Dis10}_{HW}, \text{Dis10}_{EW,}\ \text{Dis10}_{ECW}) \quad (6.4)$$

$$\text{Final}_{HW} = \text{Dis10}_{HW} / \text{LOW} \quad (6.5)$$

$$\text{Final}_{EW} = \text{Dis10}_{EW}/\text{LOW} \quad (6.6)$$

$$\text{Fianl}_{ECW} = \text{Dis10}_{ECW}/\text{LOW} \quad (6.7)$$

Calculating Example: Thailand SSI 2012 Scores

This section shows how these calculations for Thailand (Table 6.6).

Table 6.6: Thailand SSI 2012 Scores (SSF, 2013)

SSI Dimension	Human wellbeing	Environmental wellbeing	Economic wellbeing
SSI_2012 Scores	6.8	5.22	4.68

Step 1: Determine the distance of a score from the maximum possible score (10.0) for each wellbeing dimension:

Human wellbeing: 10.00-6.80 = 3.20 (6.8)

Environmental wellbeing: 10.00-5.22 = 4.78 (6.9)

Economic wellbeing: 10.00-4.68 =5.32 (6.10)

Step 2: Choose the lowest result from step 1 and divide each score by this lowest result to get weighting:

The lowest result (LOW) = 3.20 (6.11)

Then, divide each by the lowest number to get weighting:

FinalHW: 3.20/3.20 =1.00 (6.12)

FinalEW: 4.78/3.20 = 1.49 (6.13)

FianlECW: 5.32/3.20 = 1.66 (6.14)

The results of weighting the dimensions of Thailand SSI 2012 data are HW: EW: ECW = 1.00:1.49:1.66. The environmental wellbeing and economic wellbeing are higher than human wellbeing scores. This means that Thailand should improve in human wellbeing more than other dimensions.

Weighting Dimension of World Totals SSI -2012

The average per country of weighting ratios is 1:3:3 as shown in Table 6.7. The calculation of SSI 2012 shows that the maximum number for environmental wellbeing and economic wellbeing are higher than human wellbeing scores. The results of SSI 2012 data of 151 countries list in Appendix C.

Table 6.7: The Weighting Dimension of World Totals SSI-2012

Weighting Dimensions	Human Wellbeing	Environmental Wellbeing	Economic Wellbeing
Max	3	11	14
Average per country	1	3	3
Min	1	1	1

The weighting of the dimensions provides reasonable results for most countries. The following describes the range of results for all countries:

- Sweden, Norway, Iceland, and Finland achieve nearly perfect 10 scores for human wellbeing but they have environmental wellbeing scores lower than the average. This leads to a very high weighting for environmental wellbeing of around 11. The pattern of weighting is 1:11:3 (human, environmental, economic) excluding Iceland, which has a very low score of economic wellbeing. Iceland weighting is 1:11:14.
- Some countries have higher human wellbeing, but lower environmental wellbeing and economic wellbeing scores, such as Poland, Spain, and Italy. Therefore the weighting of three dimensions is 1:4:3.

- Some countries have lower human wellbeing and economic wellbeing scores but higher environmental wellbeing scores such as Ghana, Uganda, and Zambia. Therefore the weighting is 2:1:2.
- Some countries have high human wellbeing scores and also have high environmental wellbeing scores such as Jamaica, Venezuela, and Malaysia: so, the weighting system is 1:2:2.

6.5.2.1 Weighting the Dimensions Modification in SSI Scores Method

The results from weighting the dimensions concluded that there are differences in the ratios of dimensions in each country. Thus, it confirmed that one rating system should not be applied worldwide. If countries would like to apply rating systems from other countries to their own, point value modifications should be conducted in order to adjust weighting the dimensions of rating systems in order to be consistent with countries' weighting of the dimensions. Therefore, the weighting ratios between dimensions will be modified based on results from Section 6.5.2.

Weighting the Dimensions Modification for Other Countries

This section describes how to adjust the weighting of dimension ratios within Greenroads (U.S.) based on the results from Section 6.5.2, to respond to the weighting ratios of other countries (Thailand as an example). The following method shows how to change the weighting ratios of dimensions, by trial and error:

Method: Adjust maximum point values of Greenroads credits by comparing them with the weighting ratios of countries in each dimension in order to change the weighting ratio based on results from Section 6.5.2. Three scenarios are:

Scenario 1: Adjust Maximum point values of Greenroads credits. If the Greenroad's weighting ratio is lower than the weighting ratio of a country, maximum point values of Greenroads credits will be increased up to a maximum of 5 points in each dimension.

Scenario 2: Multiple maximum point values of Greenroads credits in lower dimensions by a factor in order to increase the Greenroasds' weighing ratio to respond to the weighting ratios of other countries.

Scenario 3: Add Greenroads custom credits and new custom credits, designed 5 points, to the dimensions that have weighting ratios lower than a country.

Weighting the Dimensions Modification Example: Thailand Case Study

Comparing the weighing ratio of Greenroads (U.S.) with the weighing ratio of Thailand, Greenroads (U.S.) has lower weighting for economic wellbeing and higher for environmental wellbeing dimension than the weight ratio of Thailand. Therefore, the intended process is that Greenroads' weighting ratio of economic wellbeing dimension will be adjusted to increase and the weighting ratios of environmental wellbeing will be decreased.

Table 6.8: The Weighting Dimension of Greenroads and Thailand

Country	**Weighting Ratios**		
	Human	**Environmental**	**Economic**
Greenroads	34% (1.5)	56% (3)	10% (0.5)
Thailand	1	2	2

Method: Adjust maximum point values of Greenroads credits by comparing them with the weighting ratio of Thailand in each dimension and changing the weighting ratio based on

Thailand's ratios (Table 6.8). The following scenarios show how to modify the weighting ratios of dimensions:

Scenario 1: Adjust Maximum point values of Greenroads credits. If the Greenroad's weighting ratio is lower than the weighting ratio of Thailand, maximum point values of Greenroads credits will be increased up to a maximum of 5 points in each dimension.

In this case, the Greenroads' weighting ratio in the economic wellbeing dimension is lower than Thailand's weighting ratio. To equalize the weighting ratio of Greenroads to Thailand ratio, an adjustment was made by increasing point values of Greenroads credits, associated with the economic wellbeing dimension, up to a maximum of 5 points. The result of scenario 1 shows that the weighting ration of Thailand did not changed from the original Greenroads (U.S) (Table 6.9).

Table 6.9: The Results of Weighting Ratios of Scenario 1

Greenroads	**Weighting Ratios in Percentage (Point values)**		
	Human	**Environmental**	**Economic**
Original	34% (267)	56% (434)	10% (76)
Scenario 1	34% (292)	56% (517)	10% (105)

Scenario 2: Multiple maximum point values of Greenroads credits in lower dimensions by a factor in order to increase the Greenroasds' weighing ratio to respond to the weighting ratios of Thailand.

The adjustment was made by multiplying maximum point values of Greenroads credits by the factor, which is 2, in the economic wellbeing dimension. If the factor is more than 2 the maximum points values of Greenroads will more than 10 points, which are too high. The result

in scenario 2 shows that the ratios of the economic wellbeing and human wellbeing are able to change slightly; but, the ratio of the environmental wellbeing is still the same (Table 6.10).

Table 6.10: The Results of Weighting Ratios in Scenario 2

Greenroads		**Weighting Ratios in Percentage (Point values)**		
	Factor	**Human**	**Environmental**	**Economic**
Original	1	34% (267)	56% (434)	10% (76)
Scenario 2.1	2	31% (352)	56% (651)	13% (152)

Scenario 3: Add Greenroads custom credits and new custom credits, designed 5 points, to the dimensions that have weighting ratios lower than the U.S.

In this case, Greenroads custom credits and new custom credits related to the economic wellbeing dimension were added including pavement smoothness (5 points), electric vehicle infrastructure (5 points), design for disassembly (5 points), regional employment (5 points) anti-corruption (5 points), prevailing wages (5 points), and year-round access (5 points) to adjust the points of Greenroads in correspondence with the weighing ratio of Thailand. The result in scenario 3 is similar with the result in scenario 2. The ratios of the economic wellbeing and human wellbeing were able to change slightly; but, the ratio of the environmental wellbeing is still the same (Table 6.10).

Table 6.11: The Results of Weighting Ratios in Scenario 3

Greenroads	**Weighting Ratios in Percentage (Point values)**		
	Human	**Environmental**	**Economic**
Original	34% (267)	56% (434)	10% (76)
Scenario 3	32% (272)	56% (484)	12% (106)

In manipulating values by trial and error, it was found that when point values for economic wellbeing was increased, then point values of the human wellbeing and environmental wellbeing correspondingly increased. This is because most credits address more than one indicator and frequently address indicators in more than one dimension (e.g. human wellbeing and environmental wellbeing, see Table 5.1) as the following example. As a result, it was impossible to change these weighting ratios between dimensions by adjusting point values of existing credits or adding new credits.

Example: Recycled Material (MR-4) Credit

Greenroads credit MR-4 addresses healthy life, clean air, ecological resources, greenhouse gas, consumption, and cost-benefit indicators. If Greenroads credit MR-4 increased points, all these dimensions would be increased as well. Other prominent indicators (e.g., GHG emissions indicator) are directly tied to overall consumption. Credits in the environmental wellbeing dimension, some fairly prominent, tend to focus on secondary benefits of other dimensions.

In conclusion, the weighting of the dimensions modification does not work to adjust the weighting ratios because each credit relates to more than one indicator, which increases in more than one dimension.

6.5.3 Selecting Priority Indicators from SSI Indicators

Since the weighting the dimensions modification does not work, this section presents an alternate method based on a country's SSI 2012 indicator scores. The criterion required in selection of country sustainability priority indicators is "SSI indicators scoring lower than 5 points".

Indicators that score below 5 points, the midpoint in the 1-10 SSI 2012 scale, are interpreted as topics that are poor performers that should be addressed as a priority in a rating system.

In this step, the result of SSI 2012 provides a big picture of each country. Furthermore, it can help to clarify which areas have challenges and should be considered more than others. It should be noted that renewable energy and organic farming indicators have very low points; however, it was found that most countries have low scores in both indicators. The consumption indicator in SSI has been calculated from ecological footprints minus carbon footprints and measures of emissions of greenhouse gas. For example, Thailand has eight SSI indictors, which have scores lower than 5 points as shown in Table 6.12. Therefore, clean air, income distribution, good governance, air pollution, consumption, renewable energy, organic farming, and GDP were selected to be priority indicators for Thailand.

Table 6.12: Topics of Thailand Data that Have Score Lower than 5 Points

Dimension	**Score**	**Category**	**Score**	**Indicators**	**Score < 5 points**	**SSI Average for all countries**
Human	6.8	Basic Need	9.18			
		Health	6.17	Clean air	4.03	6.74
		People & Development	5.54	Income Distribution	4.40	4.95
				Good governance	4.32	4.78
Environmental	5.22	Nature & Environment	6.10	Air pollution	4.29	4.32
		Natural Resource	6.55	Consumption	4.94	4.69
		Climate & Energy	3.55	Renewable energy	1.97	3.58
Economic	4.68	Transition	3.05	Organic Farming	1.00	2.51
		Economic	7.08	GDP	4.92	4.86

6.5.4 Discussion

Using the SSI scores method to assess sustainability in each country, researches could spend less time and effort on the literature review method. The SSI scores method has both strengths and weaknesses as follows:

Strengths

- This method at least limits subjectivity and can be reproduced and be used to compare other countries.
- It is fast and straightforward to understand a big picture of each country, and it would apply to the country's level. There is no need to review dozens of documents.
- Easily accesses the data source (public, one source)

Weakness

- It only works at the country level since SSI data are only at the country level.
- There is a limited ratio of SSI scores between three dimensions. It gives really high weighting if one dimension is rated at nearly 10.
- Some SSI indicators may not relate with transportation indicators such as organic farming, and genuine savings. For example, it should be a good idea if there were global transportation indicators, which can rank countries such as using estimated road traffic death rates (per 100,000 populations) (WHO, 2013).

There are differences in the weighting ratios of dimensions in each country. The initial effort to modify Greenroads for Thailand by adjusting point values of existing credits was conducted. It found that it is impossible to change the weighting ratios between dimensions because

Greenroads credits frequently address more than one dimension as an interrelationship with indicators (see Table 5.1). The reason why this effort does not work could be explained that (1) the way of the process is the interrelationship of human, economy, and natural environment, which is logical, or (2) the natural of sustainability is always more focused on the environment than human wellbeing and economy. Thus, the research conducted an alternate method by using SSI scores to identify areas of importance within a country, instead of modification of weighting ratios between dimensions (human, environmental, economy).

6.6 Comparison of Two Methods

The results from the literature review method have been used in this research. It was found that priority topics from the document and policy literature review method and the SSI scores method are similar as shown in Table 6.13, excepting safety and workforce safety because road user safety and workforce safety are not included in SSI indicators; however, the safety of road users and workers has become a top priority for Thailand's transportation department. They are significant issues in Thailand. Therefore, the priorities of Thailand from the literature review method have been used including clean air, accessibility, good governance, saving energy, greenhouse gas emissions, logistics, and safety.

Table 6.13: Comparision Results from Two Methods

Priorities from the Literature Review Method	**Priorities from Using SSI Scores Method**
Clean air	Clean air
All year-round accessibility, connectivity	Income Distribution (the level of equality of the distribution of income of the richest 10% to the poorest 10% of the people in a country.)
Good management, Anti- corruption, and public participation	Good governance

Priorities from the Literature Review Method	**Priorities from Using SSI Scores Method**
Clean air	Clean air
All year-round accessibility, connectivity	Income Distribution (the level of equality of the distribution of income of the richest 10% to the poorest 10% of the people in a country.)
Good management, Anti- corruption, and public participation	Good governance
Clean air	Air pollution
Save energy and fuel and Greenhouse Gas Emission	Consumption (Greenhouse Gas Emission)
Priorities from the Literature Review Method	Priorities from Using SSI Scores Method
Save energy and fuel	Renewable Energy
(None)	Organic Farming
Logistics, Fright Access	GDP
Worker safety, road user safety, flooding	

Qualitative Comparison: The literature review method gives a better understanding of a country but it is time-consuming and must be done by an expert. For example, the author really needs to speak/read the language (Thai, in this case). The literature review method requires a higher level of skill in researching and analyzing documentation to identify the national priorities than using the SSI scores method. The literature review method is more time- consuming than the other because the data has to be collected from several sources to fulfill the breadth of sustainability. Researchers may spend lots of time to search all documentation; in contrast, using the SSI scores method is less time consuming because the SSI scores are assembled in one source in electronic format. Using SSI scores could reduce subjective biases better than using the literature review. Both methods are cost effective because the data is already published and free. They do not waste money for travel expenses and hiring groups of experts.

6.7 Modifying Greenroads:

This section explains how to adapt Greenroads based on priority indictors for Thailand and the international framework.

Step 1: Identify regional priority credits of Greenroads in Thai context, based on the resulting Thai context, represented by key priority indicators found in the literature review method as shown in the first column in Table 6.10 in Section 6.6.1.

Step 2: Modify point values of regional priority Greenroads credits for Thailand (from step 1) and create custom credits in the rating system based on priority indictors for Thailand and the international framework.

- Modify point values and add more details in credits: changing point values of Project Requirements and regional priority credits of Thailand, and adding more details in a workforce safety credit in Section 6.6.2.1.
- Add new custom credits in the rating system and change all custom credits to main credits in Section 6.6.2.2. How to select custom credits is based on:
    - Custom credits address regional priority topics in Thailand and they are not addressed in Greenroads rating system:

      CC-10 Climate Change Adaption

      CC-11 Anti-corruption

      CC-13 Year-round Access

      CC-16 Dust Control on Construction Site
    - Custom credits address topics in the international framework which have not been addressed in Greenroads rating system:

      CC-12 Prevailing Wages

CC-14 Local Employment

CC-15 Job Training

CC-17 Environmental Justice Gender Diversity

6.7.1 Identify Regional Priority Credits of Greenroads for Thailand

In order to identify regional priority credits of Greenroads for Thailand, priority topics in Thai context (section 6.5) will be matched with Greenroads credits from Greenroads version 1.5 with errata.

Step 1: Determine the priority indicators in Thai context addressed by each Greenroads credit. This step considers only credits which address primary benefits indicators.

Step 2: Then, choose Greenroads credits, which are related with primary benefits of priority indictors.

For example, access and connection is one of the priority indictors in Thailand. It came out that AE-5 Pedestrian Access (disabilities and elderly people), AE-6 Bicycle Access, and AE-7 Transit & HOV Access were significant. The results are shown in Table 6.14.

Table 6.14: Regional Priority Credits of Thailand

Key Priority Indicators in Thai context	Regional Priority Greenroads Credits in Thai context
Access, connection	AE-5 Pedestrian Access (disabilities and elderly people)
	AE-6 Bicycle Access
	AE-7 Transit & HOV Access
	AE-8 Scenic Views
	CC-13 Year-round Access
Safety	AE-1 Safety Audit (including two wheels)
	CC-2 Workzone Safety
	CC-10 Climate Change Adaptation

Key Priority Indicators in Thai context	Regional Priority Greenroads Credits in Thai context
Clean Air	AE-4 Traffic Emissions Reduction
	CA-5 Equipment Emission Reduction
	CA-6 Paving Emissions Reduction
Energy Consumption	CA-4 Fossil Fuel Reduction
	CC-5 Alternative Energy
Good Governance	AE-3 Context Sensitive Solutions
	CC-11 Anti-corruption
Logistics	CC-7 Freight Access

6.7.2 Point Value Modifications

Greenroads will be modified in this step by modifying point values and credits, and adding new credits based on the key priority indicators and the international framework.

Step 1: Modify point values and add details in Greenroads credits

- Change Project Requirements to 5-point credits because it may be more flexible to implement in Thailand and flexible enough to meet individual unique requirements.
- Change point values of regional priority credits to 5 points, which are the maximum points in Greenroads, since the regional priority credits are very important and should be weighted heavily.
- Edit and add details in Greenroads credits, which are high level and not suited to apply in Thailand when comparing with the national standard.
    - Workforce safety: Standard OSHA Thailand or US OSHA would be required of all types of roadway projects in CC-2 Work Zone safety including safety training based on 29 CFR 1926 OSHA subpart B General Safety and Health Provisions.

Step 2: Add new custom credits in the rating systems and change all custom credits to main credits.

The new custom credits are chosen based on the priority indictors in the Thai context and the international framework.

- **CC-10 Climate Change Adaptation** adapted from SP-16 Infrastructure Resiliency from the INVEST rating system (FHWA, 2012) and ENV-5 Climate Resilience from the Toward a Sustainability Appraisal Framework (Véron-Okamoto & Sakamoto, 2014).

  Intent: To ensure the project is resilient regarding the current and future hazards including those associated with climate change (flooding, hurricanes, earthquakes etc.).

  1 Point. Hazard Identification

  2 Points. Vulnerability Assessment

  2Points. Risk Assessment

  4 Points. Development and Implementation Adaptation Strategies

- **CC-11 Anti-corruption:** To prevent and detect corruption on projects

  1 to 2 points.

  The project will be able to earn bonus points based on CPI 2014, a country or territory's score divided by 35 and then rounded up to the nearest whole number. Based on CPI 2014 scores, two-thirds of countries score below 50 and the global average 43.

Transparency International (TI) has developed the Corruption Perception Index (CPI) which ranks countries and territories in terms of the perceived levels of public sector corruption based on expert opinion including country experts, both residents and non-residents, and business leaders. The index is a “poll of polls” and calculated using data from 12 data sources as listed below by independent institutions. It scores in a range between 100 (very clean), and 0 (highly corrupt) (TI, 2014). However, these are measures of corruption perceptions and not actual levels of corruption.

OR

2 Points. PACS has been implemented in projects.

The Project Anti-Corruption System (PACS) have been developed by (Global Infrastructure Anti-Corruption Center (GIACC) and Transparency International (TI), (UK) in order to prevent corruption. It comprises two sections: the PACS standards and the PACS templates, which can be used to assist project participants in implementing anti-corruption measures on projects. It includes independent assessment, transparency, procurement, pre-contract disclosure, project anti-corruption commitments, funder anti-corruption commitments, government anti-corruption commitments, raising awareness, compliance, auditing, reporting, and enforcement (TI, 2013).

- **CC-1 2 Prevailing Wages:** According to Social Life Cycle Assessment (S-LCA), fair wage means “a wage fairly and reasonably commensurate with the value of a particular service or class of service rendered, and, in establishing a minimum fair wage for such service or class of service”. (UNEP, 2013)

1 point. Workers get a fair salary. Comparison between lowest paid workers and country minimum wage and interview with directors or human resources officer and workers. List of minimum wages by country (UNEP, 2013).

- **CC-13 Year-round Access** 2 points: Add more extra points if the project provides access and operates all year round or is within walking distance to bus stops or facilities (1/2-mile).
- **CC-14 Local Employment** 2 points: to hire employees who live close to the construction sites. It helps to address unemployment issues, boost local economy, and reduce the environmental impact. (More than 20% of project work hours by local residents).
- **CC-15 Job Training** 1 point: documentation of proposed education and training programs to be developed and implemented as (QL1.3 Develop Local Skills and Capabilities in Envision (Institute for Sustainable Infrastructure & Zofnas Program for Sustainable , 2012).
- **CC-16 Dust Control on Construction Sites** 2 points: conduct a dust control on the project roadway in accordance with the procedures in set rules and regulations to dust control from roads construction activities and trucks and transport material of Pollution Control Department (PCD, 2004)
- **CC-17 Environmental Justice/Gender Diversity** 2 points: the promotion of dignified access for all persons, in particular people with disabilities and the elderly, could be addressed in Thailand's Greenroads. The standard should follow the Americans with Disabilities Act (ADA). Moreover, low income and minority communities should be afforded access to basic needs (i.e. hospitals, schools,

jobs, social services, etc.). Moreover, the agency promotes programs or policies supporting minority populations and low-income populations.

6.7.3 Results

This section presents (1) the Thailand rating system based on the international framework and Thailand priorities as shown in Table 6.15. Credits were highlighted because they are different from Greenroads; (2) there are four levels of certification in Table 6.16. The percentage of total points a project earns determines the level of Greenroads Thailand certification that the project will receive; (3) Figure 6.4 shows sustainability breakdown by dimension and category levels for Greenroads and Greenroads Thai version; and (4) the influence of each international framework indicator for each rating system is shown in Table 6.17. “Influence” refers to the relative fraction of total points for a rating system assigned to a particular indicator.

Table 6.15: The Thailand Rating System (credits highlighted represented Thai version credits different from Greenroads credit.)

No.	Title	Greenroad's Maximum point values	Thai Version's Maximum point values
PR-1	**Environmental Review Process**	**Req**	**5**
PR-2	**Lifecycle Cost Analysis (LCCA)**	**Req**	**5**
PR-3	**Lifecycle Inventory (LCI)**	**Req**	**5**
PR-4	**Quality Control Plan**	**Req**	**5**
PR-5	**Noise Mitigation Plan**	**Req**	**5**
PR-6	**Waste Management Plan**	**Req**	**5**
PR-7	**Pollution Prevention Plan**	**Req**	**5**
PR-8	**Low Impact Development (LID)**	**Req**	**5**
PR-9	**Pavement Management System**	**Req**	**5**
PR-10	**Site Maintenance Plan**	**Req**	**5**
PR-11	**Education Outreach**	**Req**	**5**
EW-1	Environmental Management System	2	2
EW-2	Runoff Flow Control	1-3	1-3
EW-3	Runoff Quality	1-3	1-3
EW-4	Stormwater Cost Analysis	1	1
EW-5	Site Vegetation	1-3	1-3
EW-6	Habitat Restoration	3	3
EW-7	Ecological Connectivity	1-3	1-3
EW-8	Light Pollution	3	3
AE-1	**Safety Audit**	**1-2**	**1-5**
AE-2	Intelligent Transportation Systems (ITS)	2-5	2-5
AE-3	Context Sensitive Solutions	5	5
AE-4	Traffic Emissions Reduction	5	5

No.	Title	Greenroad's Maximum point values	Thai Version's Maximum point values
AE-5	**Pedestrian Access**	**1-2**	**1-5**
AE-6	**Bicycle Access**	**1-2**	**1-5**
AE-7	**Transit Access**	**1-5**	**1-5**
AE-8	Scenic Views	1-2	1-2
AE-9	Cultural Outreach	1-2	1-2
CA-1	Quality Management System	2	2
CA-2	Environmental Training	1	1
CA-3	Site Recycling Plan	1	1
CA-4	**Fossil Fuel Reduction**	**1-2**	**1-5**
CA-5	**Equipment Emissions Reduction**	**1-2**	**1-5**
CA-6	**Paving Emissions Reduction**	**1**	**5**
CA-7	Water Tracking	2	2
CA-8	Contractor Warranty	3	3
MR-1	Life Cycle Assessment (LCA)	2	2
MR-2	Pavement Reuse	1-5	1-5
MR-3	Earthwork Balance	1	1
MR-4	Recycled Materials	1-5	1-5
MR-5	Regional Materials	1-5	1-5
MR-6	Energy Efficiency	1-5	1-5
PT-1	Long-life Pavement	5	5
PT-2	Permeable Pavement	3	3
PT-3	Warm Mix Asphalt (WMA)	3	3
PT-4	Cool Pavement	5	5
PT-5	Quiet Pavement	2-3	2-3
PT-6	Pavement Performance Tracking	1	1
CC-1	Sustainable Transportation Professional	1-2	1-2

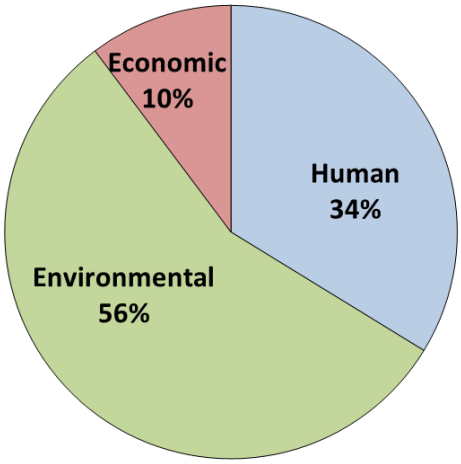
No.	Title	Greenroad's Maximum point values	Thai Version's Maximum point values
CC-2	**Work zone Safety**	**1-2**	**1-5**
CC-3	Pavement Smoothness	1-5	1-5
CC-4	Roadside Revegetation	1-3	1-3
CC-5	Electric Vehicle Infrastructure	1-5	1-5
CC-6	Alternative Energy	1-5	1-5
CC-7	Freight Access	1-5	1-5
CC-8	Design for Disassembly	1-5	1-5
CC-9	VOC Reduction	1-2	1-2
CC-10	**Climate change adoption (flooding)**	**0**	**5**
CC-11	**Anti-corruption**	**0**	**5**
CC-12	**Prevailing wages**	**0**	**1**
CC-13	**Year-round access**	**0**	**2**
CC-14	**Regional Employment**	**0**	**2**
CC-15	**Job training**	**0**	**1**
CC-16	**Dust Control**	**0**	**2**
CC-17	**Environmental Justice/gender diversity**	**0**	**2**

Table 6.16: Levels of Certification

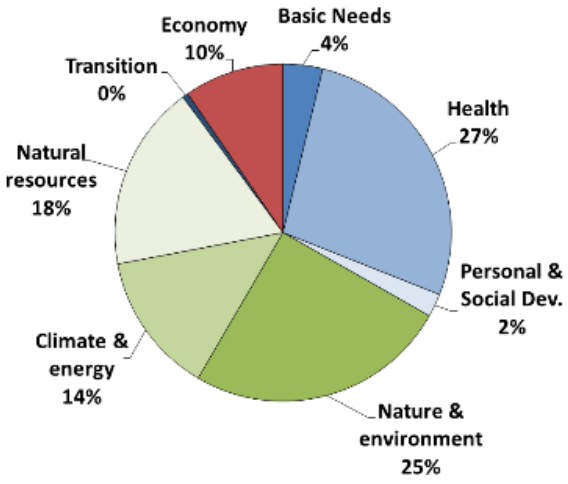
Levels of Certification	% Score
Certified	30-40% of total
Silver	40-50 % of total
Gold	50-60 % of total
Evergreen	> 60 % of total

Original Greenroads without Custom Credits

A Breakdown Greenroads Credits with SSI Dimensions

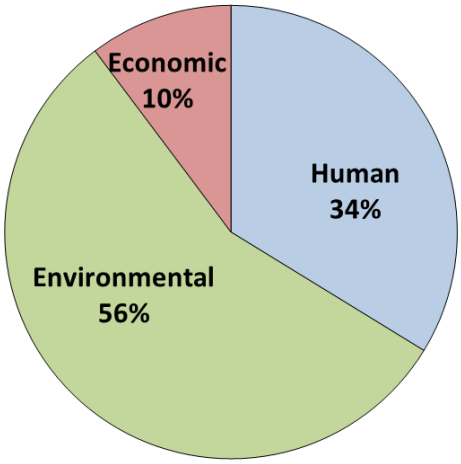


A Breakdown Greenroads Credits with SSI Categories



Greenroads Thai version with Custom Credits

A Breakdown Greenroads Thai Version Credits with SSI Dimensions



A Breakdown Greenroads Thai Version Credits with SSI Categories

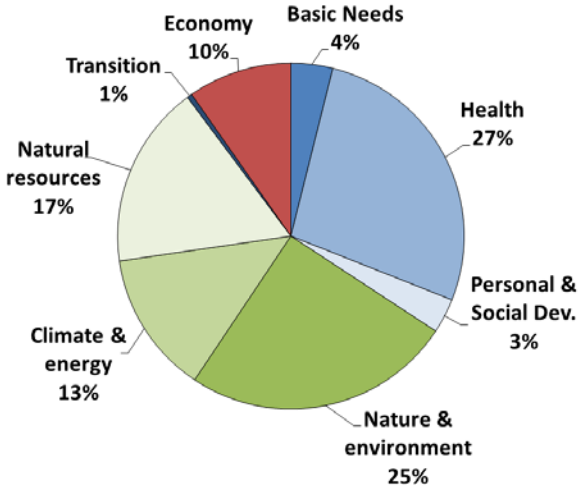


Figure 6.4: Sustainability Breakdown by Dimension and Category Levels for Greenroads and Greenroads Thai Version

Table 6.17: Most and Least Influential International Framework Indicators

	Greenroads		Greenroads Thailand Version
Healthy Life	15%	Healthy Life	15%
Consumption	12%	Consumption	13%
GHG Emissions	11%	GHG Emissions	12%
Clean Air	9%	Clean Air	9%
Cost-Benefit	9%	Cost-Benefit	9%
Clean Land	7%	Ecological Resources	6%
Ecological Resources	7%	Safety	6%
Safety	6%	Clean Land	6%
Aesthetics	6%	Aesthetics	5%
Clean Water	5%	Clean Water	5%
Water Resources	4%	Water Resources	4%
Access	2%	Access	3%
Culture and History	2%	Culture and History	1%
Good Governance	1%	Good Governance	1%
Education	< 1%	Education	< 1%
Financial Impact	< 1%	Financial Impact	< 1%
Equality	< 1%	Equality	< 1%
Income Distribution	0%	Income Distribution	< 1%
Renewable Energy	0%	Renewable Energy	< 1%
Transition	0%	Transition	< 1%
Employment	0%	Employment	< 1%
Mean	4.8%		4.8%
Median	4.0%		3.8%

Notes:
a. Color legend: Dark Green = ≥ 10%, light green = ≥ 5% and < 10%, light red = <1%, dark red = 0%
b. Bar legend: First dark bar = sum of indicators above line constitute > 50% of rating system, second dark line = indicators below make up <1% of rating system, third dark line = indicators below are not represented in rating system.

6.7.4 Discussion

- Thailand rating system has been designed based on regional priority credits of Greenroads for Thailand which provide access to basic needs services, protect clean air, reduce GHG emissions, and save energy. The result of Thailand rating system reflects the sustainability scopes in the following descending order: environmental wellbeing dimension, human wellbeing dimension, and economic wellbeing dimension as the same as Greenroads (U.S.). Because these regional priority credits are mainly addressed in secondary benefits of GHG emissions, clean air and consumption, which address in environmental wellbeing dimension.
- When comparing with the environmental wellbeing dimension, the human wellbeing and economic wellbeing dimension showed fewer direct Greenroads Thailand version credits. For example, direct credits for the human wellbeing and economy dimensions, such as Anti-corruption (CC-11), Prevailing wages (CC-12), Year-round access (CC-13), and Environmental justice/gender diversity (CC-17), result in the smaller percentage of the human and economy wellbeing dimension (Environmental (56%): human (34%): Economy (10%)).
- Greenroads (U.S.) designed by developed countries cannot serve the needs of developing countries. Therefore, four indicators, which did not meet the benefit criteria of Greenroads (U.S.) consisting of Income Distribution, Renewable Energy, Transition, and Employment indicators were fulfilled in Greenroads Thailand version, which are important.

6.8 Summary

The chapter modified Greenroads version 1.5 for Thailand is based on the Thai context. There are two methods of defining the Thai context: (1) an extended document and policy literature review method, and (2) a quick method based on SSI 2012 scores. The results of the first method were chosen to use in the research. Modified Greenroads Thai version shows:

- The priorities of Thailand are clean air, accessibility, and good governance, saving energy, greenhouse gas emission, logistics, and safety. Two different methods of identifying the Thailand context are discussed: (1) an extended document and policy literature review method, and (2) SSI 2012 scores method. Both methods arrive at a similar list of priorities. Using the SSI scores method is more convenient, more straightforward, and reduces subjective bias from developers. However, an extended document and policy literature review method needs more effort than using SSI scores in terms of skills for collecting and analyzing data, and understand local knowledge (language and background).
- Greenroads is modified in the following manner:
    1) Use Thailand priorities to identify regional priority credits
    2) Increase point values of regional priority credits
    3) Create custom credits and modify point values
- Thailand rating system has similar sustainability scopes as Greenroads by favoring the environmental dimension the most, followed by the human dimension and the economic dimension.
- Analysis of the international framework indicators against Greenroads shows that both have a similar sustainability scope at the dimension and category level, due to the fact

that human health and greenhouse gas emission are seen as major priorities for Thailand as in Greenroads.

- The weighting ratios of points devoted to change each dimension and category of the framework made it nearly impossible to change these fractions by adjusting point values or adding new credits due to the interrelated nature of credits. One credit usually contributes to more than one SSI indictor.

Chapter 7 Conclusion

Over the last decade there has been a proliferation of infrastructure sustainability rating systems. These systems are essentially performance metrics in that they measure infrastructure project features and actions against a sustainability standard and could, presumably, be used to measure progress against that standard. However, the sustainability standard is rather difficult to identify within most sustainability rating systems because there is no consistent, identifiable framework for addressing the breadth of sustainability to be considered and the prioritization of specifics in within a rating system.

Because the global future of roadway rating systems (and other infrastructure rating systems) appears to favor the continued development of more customized individual systems (e.g., for a region or country or industry) rather than universally applicable systems, one rating system is not appropriate to apply everywhere. The dissertation began with the research question:
"How do you make a rating system that addresses the breadth and the context of sustainability?"

To fulfill the research question, this dissertation developed an international framework for the creation, modification, and analysis of sustainability rating systems for roadways. The framework addresses two problems: 1) sustainability definitions are context sensitive, which can influence priority issues on sustainability solutions; and 2) there is no documented framework that developers can follow to develop a rating system in a new context. Such a framework can be useful to develop individual rating systems instead of developing universal rating systems.
The development of the international framework started using the 2012 Sustainable Society Index (SSI-2012) as a starting point. The framework identifies specific roadway-related

categories based on a review of eleven existing roadway-related rating systems, and draws conclusions about the collective sustainability scope of these rating systems and the implications of that scope. This dissertation then applies this framework in two case studies:

- Evaluate an existing roadway sustainability rating system. Greenroads is evaluated and the framework is used to identify Greenroads' implicit sustainability scope and, thus, the behavior modification it seeks.
- Adapt an existing rating system for use in another country. Greenroads is adapted for use in Thailand. The framework is used to identify recommended modifications to Greenroads based on an identified Thailand context.

The following sections summarize this dissertation, make explicit its contributions to domain knowledge, and make recommendations for future research.

7.1 Summary

Chapter 2 defined sustainability as the holistic consideration of economic, social, and environmental issues. These represent separate (see the specific priorities for an examination of their correlation) and often competing concerns. Most alarming is that environment and social (human) concerns are negatively correlated implying that human and environmental wellbeing may be mutually exclusive (Kaivo-oja, 2013).

Prioritization of these dimensions and their particulars is often necessary. Many definitions call for "balance" amongst the three sustainability dimensions, but none attempt to precisely define "balance." Muench et al. (2012) argue that the application of sustainability actually requires prioritization of dimensions and categories within sustainability; ideally based on project or organizational goals. The dimensions and categories a rating system addresses, and in what

priority (typically done with a weighting scheme), implicitly define what we term a "sustainability scope," (the breadth of sustainability addressed and prioritization within) of what will likely drive behavior when using that system (e.g., if there are more credits and points for environmental wellbeing activities/features, then these areas may be preferentially pursued).

Context sensitivity. The specific priorities or actions associated with sustainable solutions depend on space and time boundary conditions (Brown et al. (1987); Todd and Geissler, (1999); Kohler (1999), and Anderson (2008). Thus, sustainable solutions within one context may differ greatly from those in another. This idea is often used as the justification for new rating system development.

Chapter 3 reviewed the state-of-the practice for sustainable roadway rating systems and concluded as shown in Table 7.1:

- All rating systems define sustainability in some way.
- The project scope (aspects of a typical project after (Zietsman et al., 2011) is not often overtly stated.
- No rating system states its sustainability scope.
- Sustainability is context sensitive based on different priorities and national conditions and in relation to location and with time scales.
- Universal rating systems are not appropriate because they do not address issues in developing countries such as accessing to basic need services, poverty alleviation, and local resources.

Table 7.1: The State-of-the Practice for Sustainable Roadway Rating Systems

Rating system	Version Reviewed[a]	Sustainability Definition[b]	Project Scope[c]	Sustainability Scope[d]	Validation Envidence[e]	Weighting Transparency[f]	3rd Party Review[g]
Road Rating Systems: those specifically intended to rate road projects only							
Greenroads	1.5	Yes	DC	No	Yes	Yes	Yes
GreenLITES	2.1.0	Yes	PDOM	No	Yes	No	No
INVEST (FHWA)	1.0	Yes	PDCOM	No	Yes	No	No
INVEST (VicRoads)	1.0	Yes	DC	No	Yes	No	Yes
I-LAST	1.0.1	Yes	PDCO	No	Yes	No	No
STARTS	1.0	Yes	P	No	Yes	No	Yes
STEED	2008	Yes	PDC	No	Yes	No	No
Infrastructure Rating Systems: those intended to rate multiple types of infrastructure							
CEEQUAL	4.1	Yes	PDC	NO	Yes	No	Yes
Envision	2.0	Yes	PD	NO	Yes	No	Yes
IS	1.0	Yes	DCO	NO	Yes	No	Yes
LEED-ND	2009	Yes	PDC	NO	Yes	No	Yes

Notes:
a. Version of the manual reviewed for this table.
b. Yes/No. Yes given if the system manual, website, or refereed journal article states a sustainability definition.
c. P = planning, D = design, C = construction, O = operations, M = maintenance. Most systems do not overtly state which project elements they address. This column was constructed based on our interpretation of credits. For future work, a framework similar to (Veeravigrom et al., 2015) could be developed for project scope.
d. Yes/No. Yes given if system overtly states sustainability scope in terms of (1) which dimensions are addressed, and (2) priority of dimensions.
e. Yes/No. Yes given if system manual, website, or refereed journal article cites evidence that the system was tested on at least one actual project.
f. Yes/No. Yes given if the system manual, website, or refereed journal article explains the logic behind system weighting.
g. Yes/No. Yes given if the system advertises its use as a 3rd party review tool. No determination is made as to whether it actually has been used as such.

Chapter 4 proposed the international framework based on eleven existing roadway rating systems (Table 7.2).

Table 7.2: The International Framework for Creating Sustainability Rating Systems

Dimension	Category	Indicator	Topic[b]
Human	Basic Needs	*Access*	Modal access (ped, bike, bus, HOV)
	Health	Healthy Life	Livability Noise reduction
		Safety	Worker/jobsite safety Traffic/road user safety Infrastructure resiliency
		Culture and History	Cultural preservation and outreach Historical preservation
		Aesthetics	Scenic views Aesthetics of earthwork and structures
	Personal & Social Development	Education	Job training
		Equality	Environmental justice/ gender diversity
		Income Distribution	*Prevailing wages*
		Good Governance	Context Sensitive Solutions (CSS) *Anti-corruption/collusion*
Environment	Nature & Environment	*Clean Air*	Construction Equipment Emissions Materials Transport Emissions Materials Production Emissions Traffic Emissions
		Clean Water	Clean water Stormwater runoff quality Groundwater quality
		Clean Land	Contaminated soil - brownfield Waste Management/minimization
		Ecological Resources	Habitat creation Habitat preservation/conservation Wildlife conservation Stormwater runoff volume/flow Ecological connectivity Light pollution/reduction and glare Non-hazardous materials
	Natural Resources	*Water Resources*	Water use Renewable water resources (potable water conservation)
		Consumption	Material reuse Material recycling Minimize materials Local materials Durable structures Quality control Reduce non-renewable energy use Fuel use
	Climate & Energy	Renewable Energy	Encourage renewable energy use
		GHG Emissions	Lifecycle assessment (LCA) Greenhouse gas emissions

Dimension	Category	Indicator	Topic[b]
Economy	Transition	*Transition*	*Climate change adaptation* *Electric vehicles infrastructure*
	Economy	*Financial Impact*	Local economy
		Employment	Local employment
		Cost-Benefit	Cost-benefit

a. Titles in italics indicate a change from the wording of the SSI-2012.
b. The roadway topics associated with the indicator as identified in the analysis of the eleven roadway rating systems.

Chapter 5 analyzed Greenroads using the international framework and found:

- The sustainability scope of Greenroads favors the Environmental dimension significantly over the Human and Economic dimensions of sustainability.
- Greenroads may be appropriate for high-income countries but it may not be appropriate for non-high-income countries without modification.
- The road project appears to operationalize sustainability in a rather simplistic fashion. It means contribute to human health and happiness while consuming less.
- The top three indicators of Greenroads system are: healthy life, consumption, and GHG emissions. Healthy life and GHG emissions are often secondary indicators with GHG emissions almost always linked to consumption.
- Greenroads usually only gives points for actions that are beyond regulatory requirements or common practice.

Chapter 6 describes the methods proposed to modify Greenroads for use in Thailand.

- Two different methods of identifying the Thailand context are discussed: document review, and SSI 2012 scores. Both methods arrive at a similar list of priorities.
- Greenroads is modified in the following manner:
    - Create custom credits
    - Use Thailand priorities to identify regional priority credits
    - Increase point values of regional priority credits

- It was found that it was difficult to change the dimensional weights by changing point values and adding credits due to the interrelated nature of credits.
- The priorities of Thailand are accessibility, safety, good governance, greenhouse gas emission, saving energy, logistics, and environment impacts.

7.2 Contributions to Knowledge

The dissertation contributes to knowledge in four ways:

1. Developed an international framework for analyzing and developing sustainability rating systems for roadway projects because there is no documented framework for addressing sustainability scope in a rating system. A defined framework for the development and analysis of roadway rating systems makes a contribution to the state of the practice of rating systems because it allows researchers and practitioners to better understand the scope of sustainability addressed by a rating system, and thus the behavior modification sought by a rating system. Given this, this international framework can assist organizations in developing new rating systems or adapting existing ones so that they conform to their stated sustainability goals.

2. Developed and tested a process used to evaluate existing roadway (and other) rating systems. The process used to evaluate Greenroads can also be used to evaluate other roadway rating systems or infrastructure rating systems. The identified sustainability scope can then be used to determine how well a rating system may suit an organization's sustainability goals. The evaluation process also leads to unique insight into the nature of roadway rating systems in general.

3. Developed and tested a process for modifying an existing rating system for a new context. The process for modifying Greenroads for use in Thailand can be replicated for any other country and likely for any other locality (e.g., a U.S. State, a world climate region, etc.). This would also ensure modifications were made in a reproducible and transparent manner, and that such modifications could be tracked to identify contextual sustainability priorities.
4. Used the framework can contribute to an understanding of trade-offs between elements in the framework. It helps agencies better understand and articulate the trade-offs in planning and policy. The framework also has the potential to show the regional issues that they may need to consider in developing countries.

7.3 Recommendations for Future Work

Recommendations are addressed from two perspectives: expansion of the framework scope, and expansion of the implementation framework.

- The research was limited in scope to the design and construction phase. It is recommended that future research investigate the implications of using this framework during the planning and maintenance phases as described in FHWA's INVEST rating system.

- Investigate the relationship between dimensions (human, environment, economic) since it is impossible to change weighting ratios between dimensions due to the interrelated nature of credits. Greenroads credits address multiple dimensions.

- Evaluate a whole range of other rating systems
    - Road-specific systems

        - GreenLITES: U.S., 2008
        - INVEST (FHWA): U.S., 2010
        - INVEST (VicRoads): Australia, 2011
        - I-LAST: U.S., 2009
        - STARS: U.S., 2008
        - STEED: U.S., 2008
    - Civil infrastructure systems (these include but are not limited to roads)
        - CEEQUAL, U.K., 2003
        - Envision: U.S., 2010
        - Infrastructure Sustainability: Australia, 2008
        - LEED-ND: U.S., 2007

- Evaluate building rating systems with the existing framework or create a framework for building in the same manner.
- Replicate the modification of an existing rating system using different countries and rating systems to test the robustness of the process.
- Modify the SSI method of determining priorities because there were a few issues (e.g., countries scoring nearly 10 on some areas).
- Write the details of the Thailand rating system.

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Appendix A: Evaluation of Existing Rating Systems

These tables take the definition of sustainability according to the Sustainable Society Index (SSI) (Saisana and Philipas, 2012) and uses the SSI categories to subdivide "sustainability" into major topics. It then translates each of these major topics into a roadway topic. This roadway topic is meant to describe how a road project can address the sustainability topics to the left. For instance, clean water is largely addressed by considering the water quality and pollution loading of stormwater runoff. The right lists which rating system credits are applicable to each sustainability topic. (SSI Framework: http://www.ssfindex.com/ssi/framework).

Eleven rating systems are:

- Road-specific systems
  - GreenLITES: U.S., 2008
  - INVEST (FHWA): U.S., 2010
  - INVEST (VicRoads): Australia, 2011
  - I-LAST: U.S., 2009
  - STARS: U.S., 2008
  - STEED: U.S., 2008
- Civil infrastructure systems (these include but not limited to roads)
  - CEEQUAL, U.K., 2003
  - Envision: U.S., 2010
  - Infrastructure Sustainability: Australia, 2008
  - LEED-ND: U.S., 2007

Greenroads

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Greenroads V1.5	Credit
Equity (Human Wellbeing)	**Basic Needs**	**Sufficient food**	Access to food	Intelligent Transportation Systems	AE-2
				Pedestrian Access	AE-5
				Bicycle Access	AE-6
				Transit & HOV Access	AE-7
				Rural Access Index (the number of rural people who live within two kilometers of all-season road as a proportion of the total rural population)	
		Sufficient to drink	Access to drinking water Utilities include water Access to clean energy (table1)		
		Safe Sanitation	Utilities include sanitation		
	Personal Development	**Healthy life**	Access and mobility to hospitals and health places	same as access to food	
			Clean air (human)	Environmental Review Process	
				Lifecycle Inventory (LCI)	
				Quality Management System	PR-1
				Site Maintenance Plan	PR-10
				Environmental Management System	EW-1
				Light Pollution	EW-8
				Intelligent Transportation Systems	AE-2
				Traffic Emissions Reduction	AE-4

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Greenroads V1.5	Credit
				Pedestrian Access	AE-5
				Bicycle Access	AE-6
				Transit & HOV Access	AE-7
				Environmental Training	CA-2
				Site Recycling Plan	CA-3
				Fossil Fuel Reduction	CA-4
				Quality Management System	CA-1
				Equipment Emission Reduction	CA-5
				Context Sensitive Solutions	AE-3
				Paving Emission Reduction	CA-6
				Pavement Reuse	MR-2
				Earthwork Balance	MR-3
				Recycled Materials	MR-4
				Regional Materials	MR-5
				Energy Efficiency	MR-6
				Long-life pavement	PT-1
				Permeable Pavement	PT-2
				Warm Mix Asphalt	PT-2
			Livability (location and quality of Transportation facilities, TIS, quite pavement, travel demand management)	Livability (location and quality of transportation facilities, TIS, quite pavement, travel demand management)	
			Noise reduction	Noise Mitigation Plan	PR-5
				Quiet Pavement	PT-5
		Safety	Safety - worker/ jobsite safety		
			- traffic/road user safety	Site Maintenance Plan	PR-10

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Greenroads V1.5	Credit
			(clean roadside hazards, Horizontal realignment of dangerous curves, Improved realignment)	Safety Audit Ecological	AE-1
				Connectivity	EW-7
				Intelligent Transportation Systems	AE-2
			Roundabout		
		Education Opportunities	Access to school	Same as access to	
			Training	food Educational	PR-11
			Mobility (More mode choice, public transportation access, bicycle)	Outreach	
				Context Sensitive Solutions: multimodal Access	AE-3
			Access to workplaces	Same as access to food	
			Local jobs		
		Cultural and historic	Cultural and Cultural heritage preservation	Cultural Outreach	AE-9
		Aesthetics	Aesthetics	Pavement Management System	PR-9
				Site Vegetation	EW-5
				Habitat Restoration	EW-6
				Light Pollution	EW-8
			Access to view scenery	Scenic Views	AE-8
				Context Sensitive Solutions	AE-3
				Permeable Pavement	PT-2
				Cool Pavement	PT-4
		Public Participation	Public Participation	Context Sensitive Solutions	AE-3

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Greenroads V1.5	Credit
				Educational outreach	PR-11
		Equality	Environmental justice/gender diversity All people including women, the poor, the rural, and the disabled (well measured)		
		Social Impact			
	Well-balanced Society	**Good Governance** **Income Distribution** **Population Growth** Security in the community Decent work	Anti-corruption/collusion	Context Sensitive Solutions	AE-3
Ecology (Environmental Wellbeing)	**Healthy Environment**			Environmental Review Process	PR-1
				Environmental Management System	EW-1
				Environmental Training	CA-2

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Greenroads V1.5	Credit
		Clean Air	Construction equipment emissions and construction activity emissions	Fossil Fuel Reduction	CA-4
				Equipment Emission Reduction	CA-5
				Paving Emissions Reduction	CA-6
			Material Transport Emissions	Earthwork Balance	MR-3
				Regional Materials	MR-5
				Lifecycle Inventory (LCI)	PR-3
			Material Production Emissions		
				Warm Mix Asphalt	PT-3
				Long-life pavement	PT-1
				Recycled Materials	MR-4
				Pavement Reuse	MR-2
				Lifecycle Inventory (LCI)	PR-3
			Traffic Emissions	Traffic Emissions Reduction	AE-4
		Clean water	Clean water	Pollution Prevention	PR-7
				Low Impact Development (BMPs)	PR-8
				Site Maintenance Plan	PR-10
			Stormwater runoff quality	Environmental Management System	EW-1
				Low Impact Development (BMPs)	PR-8
				Site Maintenance Plan	PR-10
				Environmental Management System	EW-1
			Volume	Runoff Flow Control	EW-2
			Quality	Runoff Quality	EW-3

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Greenroads V1.5	Credit
				Site Vegetation	EW-5
				Permeable Pavement	PT-2
			Groundwater quality		
			Drinking water		
		Clean Land			
			Contaminated soil-brownfield development	Environmental Review Process	PR-1
			Land use (don't take land more than use)	Pollution Prevention	PR-7
				Environmental Management System	EW-1
				Environmental Training	CA-2
				Earthwork Balance	MR-3
			Steep Slopes		
			Floodplain		
			Waste Management/Minimization	Environmental Review Process	PR-1
				Environmental Management System	EW-1
				Waste management plan	PR-6
				Solid waste management	
				Site Maintenance Plan	PR-10
				Environmental Training	CA-2
				Site Recycling Plan	CA-3
				Earthwork Balance	MR-3
				Recycled Materials	MR-4
				Long-life pavement	PT-1
			Site selection	*Wetland and water body conservation*	

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Greenroads V1.5	Credit
				Agricultural Land conservation *Floodplain avoidance Cultural* *heritage preservation*	
		Ecosystem Preservation - wetland -forest -coastal zone, Marine environment -Biodiversity Forest area (Biodiversity)	Ecological connectivity (Avoid/Minimize/Mitigate) - Deforestation - Wildlife Population Habitat creation Habitat preservation/conservation Minimize footprints noise pollution/reduction Light pollution/reduction Vibration	Low Impact Development Environmental Management System Site Vegetation Ecological Connectivity Environmental Training Permeable Pavement Habitat Restoration Noise mitigation plan Quiet Pavement Light Pollution	PR-8 EW-1 EW-5 EW-7 CA-2 PT-2 EW-6 PR-5 PT-5 EW-8

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Greenroads V1.5	Credit
	Natural Resources	Material (recycle/reuse/local) - pavement, wood, metals, minerals	Material reuse	Lifecycle Inventory (LCI)	PR-3
			Minimize materials (reduce)	Traffic Emissions Reduction	AE-4
				Site Recycling Plan	CA-3
				Pavement Reuse	MR-2
				Long-life pavement	PT-1
			Material recycling	Recycled Materials	MR-4
			Fuel use	Fossil Fuel Reduction	CA-4
		Water availability	Water use	Water Use Tracking	CA-7
			Minimum water use		
			Renewable water resources (potable water conservation)		
	Climate &Energy	**Greenhouse gas emission**	Greenhouse gas emission	Lifecycle Inventory (LCI)	PR-3
			LCA	Environmental Management System	EW-1
				Site Vegetation	EW-5
				Light Pollution	EW-8
				Intelligent Transportation Systems	AE-2
				Traffic Emissions Reduction	AE-4
				Fossil Fuel Reduction	CA-4
				Equipment Emission Reduction	CA-5
				Intelligent Transportation Systems	AE-2
				Paving Emissions Reduction	CA-6

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Greenroads V1.5	Credit
				Pavement Reuse	MR-2
				Recycled Materials	MR-4
				Regional Materials	MR-5
				Energy Efficiency	MR-6
				Long-life Pavement	PT-1
				Warm Mix Asphalt	PT-3
				Cool Pavement	PT-4
		Renewable energy	Renewable energy use (encourage)	Lifecycle Inventory (LCI) *Renewable energy*	PR-3
		Energy consumption	Non-renewable energy use (discourage) LCA	Lifecycle Inventory (LCI) Light Pollution Energy Efficiency Cool Pavement	PR-3 EW-8 MR-6 PT-3 PT-4
Economy **(Economic Wellbeing)**	**Prepare for the future**	**Material Consumption (reuse/recycling/local)**	Materials reuse Material recycling Minimize materials Local Materials	Pavement Reuse Recycled Materials Regional Materials	MR-2 MR-4 MR-5
		Organic Farming **Genuine Saving**			

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Greenroads V1.5	Credit
	Economy	**Public debt** (Economic Vitality GDP)	LCCA and or cost-benefit	Lifecycle cost analysis	PR-2 LCCA
				Quality Control Plan	PR-4
				Waste Management	PR-6
				Pavement Management System	PR-9
				Site Maintenance Plan	PR-10
				Stormwater Cost Analysis	EW-4
				Traffic Emissions Reduction	AE-4
				Site Recycling Plan	CA-3
				Contractor Warranty	CA-8
				Lifecycle Assessment	MR-1
				Pavement Reuse	MR-2
				Earthwork Balance	MR-3
				Regional Materials	MR-5
				Energy Efficiency	MR-6
				Long-life pavement	PT-1
				Warm Mix Asphalt	PT-2
				Pavement Performance Tracking	PT-6
			Durable structures	Long--life pavement	PT-1
			Quality construction control	Quality control plan (QCP)	PR-4, CA-1, CA-8, PT-6, PT-1
				Pavement Management System	PR-9
				Site Maintenance Plan	PR-10
				Environmental Management System	EW-1
				Quality Management System	CA-1
				Contractor Warranty	CA-8
				Pavement Performance Tracking	PT-6

SSI Dimension	SSI Category	SSI Indicator	Transportation-focused topics	Greenroads V1.5	Credit
		Employment Economic Vitality (Gross Domestic Product (GDP))	Local employment ***Regional workers*** Local economy **Improved economy** Access to view scenery (same as above) **Freight Mobility**	Regional Materials	MR-5

GreenLITES

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	GreenLITES	Credit
Equity (Human Wellbeing)	**Basic Needs**	**Sufficient food**	Access to food	Improve Bicycle and Pedestrian Facilities	E-4
		Sufficient to drink	Access to drinking water Utilities include water Access to clean energy (table1)		
		Safe Sanitation	Utilities include sanitation		
	Personal Development	**Healthy life**	Access and mobility to hospitals and health places Livability (location and quality of transportation facilities, TIS, quite pavement, travel demand management) Noise reduction		
		Safety	Safety - worker/ jobsite safety - traffic/road user safety		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	GreenLITES	Credit
			(clean roadside hazards, Horizontal realignment of danagerous curves, Improved realignment) Roundabout		
		Education Opportunities	Access to school Training Mobility (More mode choice, public transportation access, bicycle) Access to workplaces Local jobs		
		Cultural and historic	Cultural and Cultural heritage preservation		
		Aesthetics	Aesthetics Access to view scenery		
		Public Participation	Public Participation	Context Sensitive Solutions	S-2
		Equality	Environmental justice/gender diversity		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	GreenLITES	Credit
			All people including women, the poor, the rural, and the disabled (well measured)		
		Social Impact			
	Well-balanced Society	**Good Governance** **Income Distribution** **Population Growth** Security in the community Decent work	Anti-corruption/collusion		
Ecology **(Environmental Wellbeing)**	**Healthy Environment**	Clean Air	Construction equipment emissions and construction activity emissions		
			Material Transport Emissions	Locally provided Material	M-3
			Material Production Emissions	Recycled Content	M-2
				Reuse of Materials	M-1
			Traffic Emissions	Improve Air Quality by Improving Traffic Flow	E-1

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	GreenLITES	Credit
		Clean water	Clean water		
			Stormwater runoff quaility	Best Management Practices (BMPs)	
			Volume	Stormwater Management (Volume and Quality)	W-1
			Quality	Stormwater Management (Volume and Quality)	W-1
			Groundwater quality		
			Drinking water		
		Clean Land	Contaminated soil-brownfield development		
			Land use (don't take land more than use)	Land Use/ Community Planning	S-3
				Bioengineering Techniques	M-4
			Steep Slopes		
			Floodplain		
			Waste Management/Minimization	Recycled Content	M-2

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	GreenLITES	Credit
			Site selection		
		Ecosystem Preservation - wetland - forest - costal zone, Marine environment -Biodiversity	Ecological connectivity (Avoid/Minimize/Mitigate)	Protect, Plant or Mitigate for Removal of Trees and Plant Communities	S-5
		Forest area (Biodiverity)	- Deforestation - Wildlife Population		
			Habitat creation	Protect, Enhance or Restore Wildlife Habitat	S-4
			Habitat preservation/conservation	Protect, Enhance or Restore Wildlife Habitat	S-4
			Minimize footprints		
			Noise pollution/reduction	Noise Abatement	E-5
			Light pollution/reduction	Stray Light Reduction	E-6

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	GreenLITES	Credit
			Vibration		
	Natural resources	non- renewable material (recycle/reuse/local) - pavement, wood, metals, minerals	Material reuse		
			Minimize materials (reduce)		
				Reuse of Materials	M-1
			Material recycling	Recycled Content	M-2
			Fuel use		
		Water availability	Water use ***Minimum water use*** Renewable water resources (potable water conservation)		
	Climate &Energy	**Greenhouse gas emission**	Greenhouse gas emission	Recycled Content Reuse of Materials	M-2 M-1
				Locally provided Material	M-3
				Reduce Electrical Consumption	E-2
				Stray Light Reduction	E-6
			LCA		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	GreenLITES	Credit
		Renewable energy	Renewable energy use (encourage)		
		Energy consumption	Non-renewable energy use (discourage)	Reduce Electrical Consumption	E-2
				Reduce Petroleum Consumption	E-3
			LCA		
Economy (Economic Wellbeing)	**Prepare for the future**	**Material Consumption (reuse/recycling/local)**	Materials reuse	Reuse of Materials	M-1
			Material recycing	Recycled Content	M-2
			Minimize materials	Locally provided Material	M-3
			Local Materials		
		Organic Farming			
		Genuine Saving			
	Economy	**Public debt** (Eoonomic Vitality GDP)	LCCA and or cost-benefit		
			Durable structures		
			Quality construction control		
		Employment	Local employment ***Regional workers***		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	GreenLITES	Credit
		Economic Vitality (Gross Domestic Product (GDP))	Local economy **Improved economy** Access to view scenery (same as above) **Freight Mobility**		

INVEST

SSI Dimension	SSI Category	SSI Indicator	Transportation-focused topics	INVEST V.1 (not include O&M)	Credit
Equity (Human Wellbeing)	**Basic Needs**	**Sufficient food**	Access to food	Integrated Planning: Social	SP-03
				ITS for System Operations	PD-14
				Pedestrian Access	PD-10
				Bicycle Access	PD-11
				Access and Affordability (Rural Access)	SP-05
		Sufficient to drink	Access to drinking water Utilities include water Access to cleanenergy (table1)		
		Safe Sanitation	Utilities include sanitation		
	Personal Development	**Healthy life**	Access and mobility to hospitals and health places	Multimodal Transportation and Public Health	SP-07
			Clean air (human)	ITS for system Operations	PD-14
				Travel Demand Management	SP-09
				Transportation System Management and Operations	SP-14
				Pedestrian Access	PD-10
				Bicycle Access	PD-11
				Transit & HOV Access	PD-12
				Construction Environmental Training	PD-25
				Construction Equipment Emission Reduction	PD-26
				Context Sensitive Project Development	PD-03
				Reduce and Reuse Materials	PD-19
				Earthwork Balance	PD-21
				Recycle Materials	PD-20

SSI Dimension	SSI Category	SSI Indicator	Transportation-focused topics	INVEST V.1 (not include O&M)	Credit
				Energy Efficiency	PD-17
				Long-life Pavement Design	PD-22
				Reduced Energy and Emissions in Pavement Materials	PD-23
			Livability (location and quality of transportation facilities, TIS, quite pavement, travel demand management)	Multimodal Transportation and Public Health	SP-07
				Travel Demand Management	SP-09
			Noise reduction	Construction Noise Mitigation	PD-27
		Safety	safety - worker/ jobsite safety	Workzone Traffic Control	OM-14
			- traffic/road user safety (clean roadside hazards, Horizontal realignment of dangerous curves, Improved realignment)	Safety Planning	SP-06
				Highway and Traffic Safety	PD-4
				Safety Management	OM-05
				ITS of System Operations	PD-14
			Roundabout		
		Education Opportunities	Access to school Training Mobility (More mode choice, public transportation access, bicycle)	Educational Outreach	

SSI Dimension	SSI Category	SSI Indicator	Transportation-focused topics	INVEST V.1 (not include O&M)	Credit
			Access to workplaces Local jobs		
		Cultural and historic	Cultural and Cultural heritage preservation	Historical, Archaeological, and Cultural Preservation	PD-15
		Aesthetics	Aesthetics	Site Vegetation Habitat Restoration	PD-18 PD-07
			Access to view scenery	Scenic, Natural, or Recreational Qualities Context Sensitive Project Development	PD-16 PD-03
		Public Participation	Public Participation	Context Sensitive Project Development Education Outreach	PD-03 PD-05
		Equality	Environmental justice/gender diversity all people including women, the poor, the rural, and the disabled (well measured)	Access and Affordability	SP-05
		Social Impact			
	Well-balanced Society	**Good Governance** **Income Distribution** **Population Growth**	Anti-corruption/collusion		

SSI Dimension	SSI Category	SSI Indicator	Transportation-focused topics	INVEST V.1 (not include O&M)	Credit
		Security in the community Decent work		Context Sensitive Project Development	PD-03
Ecology (Environmental Wellbeing)	**Healthy Environment**			Tracking Environmental Commitments Intergrated Planning: Natual Environment Linking Planning and NEPA Construction Environmental Training	PD-06 SP-02 SP-17 PD-25
		Clean Air	Construction equipment emissions and construction activity emissions Material Transport Emissions Material Production Emissions	Air Quality Construction Equipment Emission Reduction Reduced Energy and Emissions in Pavement Materials Earthwork Balance Reduced Energy and Emissions in Pavement Materials Long-Life pavement Design Recycle Materials	SP-10 PD-26 PD-23 PD-21 PD-23 PD-22 PD-20

SSI Dimension	SSI Category	SSI Indicator	Transportation-focused topics	INVEST V.1 (not include O&M)	Credit
			Traffic Emissions	Reduce and Reuse Materials	PD-19
		Clean water	Clean water		
			Stormwater runoff quality		
			Volume	Stromwater	PD-08
			Quality	Stromwater	PD-08
				Site vegetation	PD-18
			Groundwater quality		
			Drinking water		
		Clean Land			
			Contaminated soil-brownfield development		
			Land use (don't take land more than use)		
				Construction Environmental Training	PD-25
				Earthwork Balance	PD-22
			Steep Slopes		
				Integrated Planning: Economic	
			Floodplain	Development and Land Use	SP-01
			Waste Management/Minimization		
				Construction Waste Management	PD-29
				Construction Equipment Training	PD-25
				Earthwork Balance	PD-21
			Site selection		

SSI Dimension	SSI Category	SSI Indicator	Transportation-focused topics	INVEST V.1 (not include O&M)	Credit
		Ecosystem Preservation - wetland - forest - coastal zone, Marine environment -Biodiversity	Ecological connectivity (Avoid/Minimize/Mitigate)	Ecological Connectivity Site Vegetation Ecological Connectivity Construction Environmental Training	PD-09 PD-18 PD-09 PD-25
		Forest area (Biodiversity)	- Deforestation - Wildlife Population Habitat creation		
			Habitat preservation/conservation Minimize footprints	Habitat restoration Ecological connectivity	PD-7 PD-9
			noise pollution/reduction Light pollution/reduction Vibration	Construction Noise Mitigation Construction Environmental Training	PD-27 PD-25
	Natural resources	Material (recycle/reuse/local)	Material reuse	Integrated Planning: natural Environment	SP-02

SSI Dimension	SSI Category	SSI Indicator	Transportation-focused topics	INVEST V.1 (not include O&M)	Credit
		- pavement, wood, metals, minerals	Minimize materials (reduce)		
				Reduce and Reuse Materials	PD-19
			Material recycling Fuel use	Energy and Fuels	SP-11
		Water availability	Water use ***Minimum water use*** Renewable water resources (potable water conservation)		
	Climate &Energy	**Greenhouse gas emission**	Greenhouse gas emission LCA		
				Site Vegetation	PD-18
				ITS for system Operations	PD-14
				Construction Equipment Emission Reduction	PD-26
				ITS for System Operations	PD-14
				Reduce and Reuse Materials	PD-19
				Energy Efficiency	PD-17
				Long-life Pavement Design	PD-22
				Reduced Energy and Emissions in Pavement Materials	PD-23

SSI Dimension	SSI Category	SSI Indicator	Transportation-focused topics	INVEST V.1 (not include O&M)	Credit
Economy (Economic Wellbeing)		Renewable energy	Renewable energy use (encourage)		
		Energy consumption	Non-renewable energy use (discourage)	Energy and Fuels	SP-11
			LCA		
				Energy Efficiency	PD-17
				Reduced Energy and Emissions in Pavement Materials	PD-23
	Prepare for the future	**Material Consumption (reuse/recycling/ local)**	Materials reuse	Reduce and Reuse Materials	PD-19
			Material recycling	Recycle Materials	PD-20
			Minimize materials	Reduce and Reuse Materials	PD-19
			Local Materials		
		Organic Farming			
		Genuine Saving			
	Economy	**Public debt** (Economic Vitality GD	LCCA and or cost-benefit	Integrated Planning: Economic Development and Land use	SP-01
				Lifecycle Cost Analyses	PD-02
				Construction Quality Control Plan	PD-28
				Construction Waste Management	PD-29
				Linking Asset Management and Planning	SP-15
				Economic Analyses	PD-1
				Contractor Warranty	PD-24
				Reduce and Reuse Materials	PD-19
				Earthwork Balance	PD-21

SSI Dimension	SSI Category	SSI Indicator	Transportation-focused topics	INVEST V.1 (not include O&M)	Credit
				Energy Efficiency	PD-17
				Reduced Energy and Emissions in Pavement Materials	PD-23
				Economic Analyses (Benefit-cost Analysis (BCA) or economic impact analysis (EIA))	PD-01
			Durable structures	Long-Life Pavement Design	PD-22
			Quality construction control	Construction Quality control plan	PD-28
				Contractor Warranty	PD-24
		Employment Economic Vitality (Gross Domestic Product (GDP))	Local employment ***Regional workers*** local economy **Improved economy** Access to view scenery (same as above) **Freight Mobility**	Financial Sustainability **Freight Mobility** Freight and Goods Movement	SP-12 **PD-13** SP-08

INVEST (VicRoads)

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	INVEST_VicRoads	Credit
Equity (Human Wellbeing)	**Basic Needs**	**Sufficient food**	Access to food	Inclusion of Multimodal Transport options	10a
		Sufficient to drink	Access to drinking water Utilities include water Access to clean energy		
		Safe Sanitation	Utilities include sanitation		
	Personal Development	**Healthy life**	Access and mobility to hospitals and health places		
			clean air (human)	Dust monitoring	1a
				Dust Mitigation	1b
				Reuse waste material from local sources	7b
				Reuse contaminated fill material (including biosolids)	7c
				Use of existing infrastructure	8e
				Balancing of earthworks	8d
				Use of products and materials with greater environmental benefits	7a
			livability (location and quality of transportation facilities, TIS, quite pavement, travel demand management)	Inclusion of Multimodal Transport options	10a

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	INVEST_VicRoads	Credit
			Noise reduction	Construction of new noise barrier to achieve 2 db below compliance project noise targets	6a
				Construction of Sound Absorbent Noise Walls	6b
				Temporary noise attenuation measures during construction	6e
		Safety	Safety - worker/ jobsite safety - traffic/road user safety (clean roadside hazards, Horizontal realignment of dangerous curves, Improved realignment) roundabout		
		Education Opportunities	Access to school Training	Environmental Awareness	2a
			Mobility (More mode choice, public transportation access, bicycle)		
			Access to workplaces		
			Local jobs	Creation of employment opportunities for local indigenous communities	4g

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	INVEST_VicRoads	Credit
		Cultural and historic	Cultural and Cultural heritage preservation	Avoidance of Cultural Heritage sites within project area	4a
				Relocation of impacted heritage	4b
				Creation of interpretive displays	4c
				Development and implementation of naming proposal	4d
				Development and installation of "Welcome to Country signage"	4e
				Implementation of heritage-based education initiatives	4f
		Aesthetics	Aesthetics	Noise walls that provide multiple community functions	6c
				Noise protection provided for public open space	6d
				Provision of aesthetic views and community infrastructure	10b
			Access to view scenery		
		Public Participation	Public Participation	Coordination of construction works with other public infrastructure works	8a

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	INVEST_VicRoads	Credit
				Implementation of a stakeholder engagement plan Managing stakeholder complaints Reservation of land for public value purposes	9a 9b 9c
		Equality	Environmental justice/gender diversity all people including women, the poor, the rural, and the disabled (well measured)		
		Social Impact			
	Well-balanced Society	**Good Governance** **Income Distribution** **Population Growth** Security in the community Decent work	Anti-corruption/collusion		
Ecology (Environmental Wellbeing)	**Healthy Environment**			Permit and Planning Approval Requirements Compliance with Vicroads Environmental Policies Compliance with legislative requirements Environmental Reporting	

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	INVEST_VicRoads	Credit
				Environmental Awareness	2a
		Clean Air	Construction equipment emissions and construction activity emissions	Dust monitoring	1a
				Dust Mitigation	1b
			Material Transport Emissions	Balancing of earthworks	8d
			Material Production Emissions		
			Traffic Emissions	Design for traffic movement	8f
		Clean water	Clean water		
			Stormwater runoff quality	Incorporate Water Sensitive Road Design (WSRD)	11d
			Volume		
			Quality		
			Groundwater quality		
			Drinking water	Use of non-potable water	11a
		Clean Land	Contaminated soil-brownfield development		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	INVEST_VicRoads	Credit
			Land use (don't take land more than use)		
				Balancing of earthworks	8d
			Steep Slopes		
			Floodplain		
			Waste Management/Minimization		
				Introduce Office Sustainability initiatives	2b
			site selection		
			Ecological connectivity (Avoid/Minimize/Mitigate)	Reduce the impact of habitat fragmentation by linking vegetation corridors and ecological communities	3d
		Ecosystem Preservation - wetland - forest - coastal zone, Marine environment -Biodiversity		Provision of net gain offsets	3c
		Forest area (Biodiversity)	- Deforestation - Wildlife Population		
			Habitat creation	Creation of additional habitat through the reuse of natural material removed during construction	3a

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	INVEST_VicRoads	Credit
			Habitat preservation/conservation	Creation of additional habitat through revegetation Wildlife crossing	3b
			Minimize footprints		
			noise pollution/reduction	Construction of new noise barrier to achieve 2db below compliance project noise targets Construction of Sound Absorbent Noise Walls	6a 6b
			Light pollution/reduction		
			Vibration		
	Natural resources	Non- renewable material (recycle/reuse/local) - pavement, wood, metals, minerals	Material reuse		
			Minimize materials (reduce)	Use of existing infrastructure	8e
				Coordination of off-site recycling/ reuse of excess material	7d
				Reuse waste material from local sources	7b
				Reuse contaminated fill material (including biosolids)	7c
			Material recycing Fuel use	Use of products and materials with greater environmental benefits	7a

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	INVEST_VicRoads	Credit
		Water availability	Water use	Use of non-potable water	11a
			Minimum water use	Design and use of permanent water infrastructure	
			Renewable water resources (potable water conservation)		
				Undertaking rehabilitation works of local waterways	11c
	Climate &Energy	**Greenhouse gas emission**	Greenhouse gas emission	Purchase of carbon offsets (GHG)	5d
				Reuse waste material from local sources	7b
				Reuse contaminated fill material (including biosolids)	7c
				Use of existing infrastructure	8e
				Use of products and materials with greater environmental benefits	7a
				Reduction in electrical energy consumption	5a
			LCA		
		Renewable energy	Renewable energy use (encourage)		
				Substitution of electrical energy sources	5b
				Purchase green power for non-office use	5c
				Installation of Road Energy Systems	5e
		Energy consumption	Non-renewable energy use (discourage)	Reduction in electrical energy consumption	5a
			LCA		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	INVEST_VicRoads	Credit
Economy (Economic Wellbeing)	**Prepare for the future**	**Material Consumption (reuse/recycling/local)** **Organic Farming** **Genuine Saving**	Materials reuse Material recycling Minimize materials Local Materials	Reuse waste material from local sources Reuse contaminated fill material (including biosolids) Use of existing infrastructure	7b 7c 8e
	Economy	**Public debt** (Eoonomic Vitality GDP)	LCCA and or cost-benefit	Reuse waste material from local sources Reuse contaminated fill material (including biosolids) Use of existing infrastructure Balancing of earthworks Use of products and materials with greater environmental benefits	7b 7c 8e 8d 7a

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	INVEST_VicRoads	Credit
			Durable structures		
			Quality construction control	Considering constructability and construction planning to avoid re-work, wastage and delays	8b
		Employment	Local employment ***Regional workers***	Creation of employment opportunities for local indigenous communities	4g
		Economic Vitality (Gross Domestic Product (GDP))	Local economy **Improved economy**		
			Access to view scenery (same as above) **Freight Mobility**		4e

I-LAST

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	I-LAST	Credits
Equity (Human Wellbeing)	**Basic Needs**	**Sufficient food**	Access to food	Provide new multi-modal connections	T-2e
				Improve Bicycle and Pedestrian Facilities	T-3
				Improve Bicycle and Pedestrian Facilities	T-3
				Traffic Operations: High Occupancy Vehicle	T-1
				Transit	T-2
				Land Use/Community Planning	P-2
		Sufficient to drink	Access to drinking water Utilities include water		
			Access to Clean energy (table1)		
		Safe Sanitation	Utilities include sanitation		
	Personal Development	**Healthy life**	Access and mobility to hospitals and health places		
			Clean air (human)	Allow the use of locally produced by-products to be reused	M-1f
				Reuse of spoils within project corridor to minimize material in and out of site	M-1c

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	I-LAST	Credits
				Reuse of top soil	M-1a
				Allow the use of recycled asphalt pavement (RAP)	M-1g
				Soil stabilization with cementitious and recycled materials	M-1k
				Consider locally available materials in developing specifications for the project	M-1I
				Incorporate locally produced or native materials	D-2b
				Reduced Electrical Consumption	L-1
			Livability (location and quality of transportation facilities, TIS, quite pavement, travel demand management)	Transit	T-2
				Provide new multi-modal connections	T-2e
			Noise reduction		
		Safety	Safety - worker/ jobsite safety		
			- traffic/road user safety	Items fit context of surrounding (safety or comfort for non-motorized users)	D-2d

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	I-LAST	Credits
			(clean roadside hazards, Horizontal realignment of dangerous curves, Improved realignment) Roundabout		
		Education Opportunities	Access to school Training Mobility (More mode choice, public transportation access, bicycle) Access to workplaces Local jobs		
		Cultural and historic	Cultural and Cultural heritage preservation		
		Aesthetics	Aesthetics Access to view scenery	Bridge Aesthetics Context Sensitive Design: Visual enhancements	D-2e D-2C
		Public Participation	Public Participation	Identify Stakeholders and develop Stakeholders Involvement Plan	P-1a

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	I-LAST	Credits
				Engage Stakeholders to conduct Context Audit and develop project purpose Involve Stakeholders to develop and evaluate alternatives Employ Stakeholder involvement techniques to achieve consensus for Preferred Project Alternative	P-1b P-1c P-1d
		Equality	Environmental justice/gender diversity All people including women, the poor, the rural, and the disabled (well measured)		
		Social Impact			
	Well-balanced Society	**Good Governance** **Income Distribution** **Population Growth** Security in the community Decent work	Anti-corruption/collusion		
Ecology **(Environmental Wellbeing)**	**Healthy Environment**	Clean Air	Construction equipment emissions and construction activity emissions		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	I-LAST	Credits
			Material Transport Emissions	Incorporate locally produced or native materials	D-2b
			Material Production Emissions		
			Traffic Emissions		
		Clean water	Clean water		
				Construction Practices to Protect Water Quality	W-3
				Reduce Impervious Area	W-1
			Stormwater runoff quality	Use of ditches	W-1a
				Replacement of paved median	W-1b
				Reduction of paved shoulder areas	W-1c
				Shoulders constructed of permeable pavement	W-1d
				Replacement of paved bike paths with permeable pavement or permeable material	W-1e
			Volume		
			Quality	Stormwater Treatment	W-2
				Use of bioretention cells	W-2a
				Use of constructed wetlands	W-2b
				Use of bioswales	W-2c
				Use of mechanical stormwater treatment systems	W-2d
				Use of catch basins	W-2e
				Use of infiltration trenches	W-2f
				Use of rain gardens	W-2g
				Use of sand filters	W-2h

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	I-LAST	Credits
			Groundwater quality	Use of ditch checks	W-2i
				Use of sediment traps and forebays	W-2j
			Drinking water		
		Clean Land			
			Contaminated soil-brownfield development	Utilize brownfield Locations	D-1g
			Land use (don't take land more than use)	Land Use/Community Planning	P-2
				Balance cuts and fills	M-1b
			Steep Slopes		
			Floodplain		
			Waste Management/Minimization		
			site selection		
		Ecosystem Preservation -wetland -forest	Ecological connectivity (Avoid/Minimize/Mitigate)	Wetland restoration/mitigation	E-1d

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	I-LAST	Credits
		- coastal zone, Marine environment -Biodiversity		Reduce urban "heat island" effect Provide wildlife crossings Provide fish passage Provide mussel relocation prior to construction	D-2f E-1f E-1g E-1h
		Forest area (Biodiversity)	- Deforestation - Wildlife Population	Provide right-of-way wildlife barriers Provide mowing markers Schedule construction to avoid wildlife disruption Avoidance/protection of individual and contiguous stands of specimen trees and localized areas of established, desirable vegetation (Preservation and Designs which demonstrate an anticipated ultimate net increase in tree species Re-establish/expand native vegetation in reclaimed work areas or abandoned old alignments Use of plant material in lieu of or to enhance structural features, such as living snow fences, sight screens (viburnum, dogwood,etc.) Use of native species of plugs, seed mixes, perennial and other plantings Planting trees, shrubs and/or native plant material in highway right-of-way	E-1i E-1j E-1k E-2a E-2b E-2c E-2d E-2e E-2f

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	I-LAST	Credits
				Tree replacement ratios equal to or greater than 1:1	E-2g
				Minimize potential salt splash impacts through use of berms or vegetative screening	E-2h
				Removal of undesirable plant species, removal of invasive species	E-2i
				Topsoil Preservation	E-2j
			Habitat creation	Provide nesting locations	E-1e
			Habitat preservation/conservation	Avoid habitat fragmentation	E-1a
				Minimize habitat fragmentation	E-1b
			Minimize footprints	Mitigate habitat fragmentation	E-1c
			Noise pollution/reduction	Construction of noise barriers	E-3a
				Incorporate traffic system management techniques to reduce existing noise levels	E-3b
				Provide a buffer zone for adjacent receptors	E-3c
				Provide sound insulation to public or non-profit institutional structures	E-3d
				Tinning of pavement to reduce noise levels	E-3e
				Provide plantings or sight screen to separate receptors from roadway	E-3f
			Light pollution/reduction		
			Vibration		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	I-LAST	Credits
	Natural resources	Material (recycle/reuse/local)	Material reuse	Allow the use of locally produced by-products to be reused	M-1f
		- pavement, wood, metals, minerals	Minimize materials (reduce)	Reuse of spoils within project corridor to minimize material in and out of site	M-1c
				Reuse of top soil	M-1a
				Allow the use of recycled asphalt pavement (RAP)	M-1g
			Material recycling	Soil stabilization with cementitious and recycled materials	M-1k
				Consider locally available materials in developing specifications for the project	M-1I
		Water availability	Fuel use Water use ***Minimum water use*** Renewable water resources (potable water conservation)		
	Climate &Energy	**Greenhouse gas emission**	Greenhouse gas emission LCA	Reduce urban "heat island" effect	D-2f

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	I-LAST	Credits
				Allow the use of locally produced by-products to be reused	M-1f
				Reuse of spoils within project corridor to minimize material in and out of site	M-1c
				Reuse of top soil	M-1a
				Allow the use of recycled asphalt pavement (RAP)	M-1g
				Soil stabilization with cementitious and recycled materials	M-1k
				Consider locally available materials in developing specifications for the project	M-1I
				Incorporate locally produced or native materials	D-2b
				Reduced Electrical Consumption	L-1
				Stray Light Reduction	L-2
		Renewable energy	Renewable energy use (encourage)		
		Energy consumption	Non-renewable energy use (discourage)	Reduced Electrical Consumption	L-1
				Stray Light Reduction	L-2
			LCA		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	I-LAST	Credits
				Reduced Electrical Consumption	L-1
Economy **(Economic Wellbeing)**	**Prepare for the future**	**Material Consumption (reuse/recycling/local)** **Organic Farming** **Genuine Saving**	Materials reuse Material recycling Minimize materials Local Materials	Allow the use of locally produced by-products to be reused Reuse of spoils within project corridor to minimize material in and out of site Reuse of top soil Consider locally available materials in developing specifications for the project Soil stabilization with cementitious and recycled materials Consider locally available materials in developing specifications for the project Incorporate locally produced or native materials	M-1f M-1c M-1a M-1I M-1k M-1I D-2b
	Economy	**Public debt** (Economic Vitality GDP)	LCCA and or cost-benefit	Allow the use of locally produced by-products to be reused Reuse of spoils within project corridor to minimize material in and out of site Reuse of top soil	M-1f M-1c M-1a

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	I-LAST	Credits
				Allow the use of recycled asphalt pavement (RAP)	M-1g
				Soil stabilization with cementitious and recycled materials	M-1k
				Consider locally available materials in developing specifications for the project	M-1l
				Incorporate locally produced or native materials	D-2b
			Durable structures		
			Quality construction control		
		Employment	Local employment ***Regional workers***		
		Economic Vitality (Gross Domestic Product (GDP))	local economy **Improved economy**		
				Incorporate locally produced or native materials	D-2b
			Access to view scenery (same as above)		
			Freight Mobility		

STARS

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STARS	Credit
Equity (Human Wellbeing)	**Basic Needs**	**Sufficient food**	Access to food	Establish Access Goals and Objectives Evaluate Expanded Transportation Demand Management Strategies Evaluate Expanded Transportation System Management Strategies Evaluate Expanded Transportation Supply and Service	A1 A2 A3 A5
		Sufficient to drink	Access to drinking water Utilities include water Access to clean energy		
		Safe Sanitation	Utilities include sanitation		
	Personal Development	**Healthy life**	Access and mobility to hospitals and health places Clean air (human) livability (location and quality of transportation facilities, TIS, quite pavement, travel demand management) Noise reduction	Evaluate Expanded Transportation Demand Management Strategies Evaluate Expanded Transportation System Management Strategies Evaluate Expanded Transportation Supply and Service	A2 A3 A5

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STARS	Credit
		Safety	Safety - Worker/ jobsite safety - Traffic/road user safety (Clean roadside hazards, Horizontal realignment of dangerous curves, Improved realignment) Roundabout		
		Education Opportunities	Access to school Training Mobility (More mode choice, public transportation access, bicycle) Access to workplaces Local jobs		
		Cultural and historic	Cultural and Cultural heritage preservation		
		Aesthetics	Aesthetics Access to view scenery		
		Public Participation	Public Participation	Establish Project Framework and Goals	IP1

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STARS	Credit
				Multi-Discipline Project Team Public Stakeholder Engagement	IP2 IP3
		Equality	Environmental justice/gender diversity All people including women, the poor, the rural, and the disabled (well measured)		
		Social Impact			
	Well-balanced Society	**Good Governance** **Income Distribution** **Population Growth** Security in the community Decent work	Anti-corruption/collusion		
Ecology (Environmental Wellbeing)	**Healthy Environment**	Clean Air	Construction equipment emissions and construction activity emissions Material Transport Emissions	Evaluate Construction Materials and Methods: locally or Transport Sustainably	CE4

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STARS	Credit
			Material Production Emissions Traffic Emissions	Evaluate Construction Materials and Methods: Source Sustainably Produced Construction Materials	CE4
		Clean water	Clean water Stormwater runoff quaility Volume Quality ***Groundwater quality*** ***Drinking water***	Stormwater Quantity and Quality Management Stormwater Quantity and Quality Management	EF3 EF3
		Clean Land	Contaminated soil-brownfield development Land use (don't take land more than use) ***Steep Slopes*** ***Floodplain*** Waste Management/Minimization ***Site selection***	Evaluate Expanded Land Use Strategies	A4

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STARS	Credit
		Ecosystem Preservation - wetland - forest - coastal zone, Marine environment -Biodiversity	Ecological connectivity (Avoid/Minimize/Mitigate)		
		Forest area (Biodiverity)	- Deforestation - Wildlife Population Habitat creation Habitat preservation/conservation Minimize footprints noise pollution/reduction Light pollution/reduction Vibration		
	Natural resources	Non- renewable material (recycle/reuse/local) - pavement, wood, metals, minerals	Material reuse Minimize materials (reduce)	Evaluate Construction Materials and Methods: Reuse	CE4

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STARS	Credit
			Material recycling	Evaluate Construction Materials and Methods: Recycling	CE4
				Evaluate Construction Materials and Methods: locally or Transport Sustainably	CE4
			Fuel use		
		Water availability	Water use		
			Minimum water use		
			Renewable water resources (potable water conservation)		
	Climate &Energy	**Greenhouse gas emission**	Greenhouse gas emission	Establish Climate and Energy Goals and Objectives	CE1
			LCA	Evaluate Vehicle Mile Reduction Strategies	CE2
				Evaluate Improving Vehicle Flow	CE3
				Evaluate Construction Materials and Methods	CE4
		Renewable energy	Renewable energy use (encourage)	Evaluate Renewable Energy and Energy Efficiency	CE5
		Energy consumption	Non-renewable energy use (discourage)		
			LCA		
Economy (Economic Wellbeing)	**Prepare for the future**	**Material Consumption (reuse/recycling/local)**	Materials reuse		
			Material recycling		
			Minimize materials		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STARS	Credit
			Local Materials	Evaluate Construction Materials and Methods: locally or Transport Sustainably	CE4
		Organic Farming **Genuine Saving**			
	Economy	**Public debt** (Economic Vitality GDP)	LCCA and or cost-benefit	Cost Estimation and Cost-Effective Calculations Selecting Cost-Effective Projects and Programs	CEA1 CEA2
			Durable structures Quality construction control		
		Employment Economic Vitality (Gross Domestic Product (GDP))	Local employment ***Regional workers*** Local economy **Improved economy** Access to view scenery (same as above) **Freight Mobility**		

STEED

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STEED	Point
				Equity: minority and low-income populations	6
Equity (Human Wellbeing)	**Basic Needs**	**Sufficient food**	Access to food	Multiple Modes & Modal Connectivity	6
		Sufficient to drink	Access to drinking water Utilities include water Access to clean energy		
		Safe Sanitation	Utilities include sanitation		
	Personal Development	**Healthy life**	Access and mobility to hospitals and health places	Multiple Modes & Modal Connectivity	6
			Clean air (human)		
				Material Sources & Reuse	10
				Material Sources & Reuse	10
				Material Sources & Reuse	10
			Livability (location and quality of transportation facilities, TIS, quite pavement, travel demand management)	Aesthetics & Livability	10
			Noise reduction	Light & noise	11
				Light & noise	11
		Safety	Safety - worker/ jobsite safety - traffic/road user safety	Safety & Security	7

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STEED	Point
			(clean roadside hazards, Horizontal realignment of dangerous curves, Improved realignment) Roundabout		
		Education Opportunities	Access to school Training Mobility (More mode choice, public transportation access, bicycle) Access to workplaces Local jobs	Life-Cycle Considerations: local contractors	5
		Cultural and historic	Cultural and Cultural heritage preservation	Cultural & Historic Preservation	
		Aesthetics	Aesthetics Access to view scenery	Aesthetics & Livability Art in the design of walls, bridge rails	10
		Public Participation	Public Participation	Public Involvement	6
		Equality	Environmental justice/gender diversity	Equity	6

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STEED	Point
			all people including women, the poor, the rural, and the disabled (well measured)		
		Social Impact			
	Well-balanced Society	**Good Governance** **Income Distribution** **Population Growth** Security in the community Decent work	Anti-corruption/collusion	 Aesthetics & Livability	10 10
Ecology (Environmental Wellbeing)	**Healthy Environment**	Clean Air	 Construction equipment emissions and construction activity emissions Material Transport Emissions Material Production Emissions Traffic Emissions	Air quality	8
		Clean water	Clean water Stormwater runoff quality Volume	 Water resources: Stormwater runoff quality and quantity	

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STEED	Point
			Quality	Water resources: Stormwater runoff quality and quantity	
				Water resources	
			Groundwater quality	Water resources: ground water recharge	
			Drinking water		
		Clean Land			
			Contaminated soil-brownfield development	Environmental Cleanup (contaminated soil and groundwater)	8
			Land use (don't take land more than use)	Land & Geology (minimize the project footprint, amount of land area disturbed)	1
				Land & Geology slopes(minimize the probability of rock, snow, or mud slides)	**6**
			Steep Slopes		
			Floodplain	Flood impact (reduces upstream food impacts and downstream flood impacts)	
				Land Use/Transportation Integration	5
			Waste Management/Minimization	Material Sources & Reuse	10
			Site selection		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STEED	Point
		Ecosystem Preservation - Wetland - Forest - Coastal zone, Marine environment -Biodiversity	Ecological connectivity (Avoid/Minimize/Mitigate)	Biodiversity	8
		Forest area (Biodiversity)	- Deforestation - Wildlife Population		
			Habitat creation		
			Habitat preservation/conservation	Wildlife Refuges/Biodiversity	
			Minimize footprints		
			Noise	Light & Noise	
			pollution/reduction Light	Light & Noise	
			pollution/reduction		
	Natural resources	Non-renewable material (recycle/reuse/local) - Pavement, wood, metals, minerals	Material reuse	Material Sources & Reuse	10
			Minimize materials (reduce)		
			Material recycling		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STEED	Point
		Water availability	Fuel use Water use ***Minimum water use*** Renewable water resources (potable water conservation)	Energy Water resources	
	Climate &Energy	**Greenhouse gas emission** Renewable energy Energy consumption	Greenhouse gas emission LCA Renewable energy use (encourage) Non-renewable energy use (discourage) LCA	Energy Life Cycle Considerations Energy: Renewable Life Cycle Considerations	8 5 5
Economy (Economic Wellbeing)	**Prepare for the Future**	**Material Consumption (reuse/recycling/local)** **Organic Farming** **Genuine Saving**	Materials reuse Material recycling Minimize materials Local Materials	Material Sources & Reuse Material Sources & Reuse Material Sources & Reuse	10 10 10
	Economy	**Public debt** (Economic Vitality GDP)	LCCA and or cost-benefit Durable structures	Life Cycle Considerations Material Sources & Reuse	5 10

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	STEED	Point
			Quality construction control	**Construction Duration** **minimize construction duration**	**7**
		Employment	Local employment ***Regional workers***	Life-Cycle Considerations: local contractors	5
		Economic Vitality (Gross Domestic Product (GDP))	Local economy **Improved economy**	Material Sources & Reuse	10
			Access to view scenery (same as above)		
			Freight Mobility	**Freight Mobility**	8

CEEQUAL V4.1

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
Equity (Human Wellbeing)	**Basic Needs**	**Sufficient food**	Access to food	Transportation	10.1.1
			Utilities include water Access to clean energy (table1)		
		Safe Sanitation	Utilities include sanitation		
	Personal Development	**Healthy life**	Access and mobility to hospitals and health places		
			Clean air (human)	Air pollution, including dust and odors	11.4.1(a,b,c), 11.4.2,11.4.3
			Livability (location and quality of transportation facilities, TIS, quite pavement, travel demand management)		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
			Noise reduction	Noise	11.3.1 (a,b), 11.3.2((a,b), 11.3.3
		Safety	Safety - Worker/ jobsite safety - Traffic/road user safety (Clean roadside hazards, Horizontal realignment of dangerous curves, Improved realignment) Roundabout		
		Education Opportunities	Access to school Training Mobility (More mode choice, public transportation access, bicycle) Access to workplaces Local jobs		
		Cultural and historic	Cultural and Cultural heritage preservation	The Historic Environment The Historic Environment Legal requirements Conservation and enhancement	5.1.1 -2 5.2.1 - 2 5.3.1 -10

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
				The Historic Environment Information and Public Access	5.4.1 -2
		Aesthetics	Aesthetics Access to view scenery	Considered potential impacts of the project on the health and welfare of any occupants, users, neighbors and/or any operational staff High quality of design 'user enjoyment	12.4.2 12.4.4 12.4.5
		Public Participation	Public Participation	Relations with the local community and other stakeholders Engagement with relevant local interest groups Effectiveness of the community relations programme	12.1.1 -2 12.2.1-3 12.3.1-12.3.3
		Equality	Environmental justice/gender diversity All people including women, the poor, the rural, and the disabled (well measured)	Considered the needs of all different user groups	12.4.5

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
		Social Impact		Effects on Neighbors Consideration wider social impacts of the project during construction	11.1.1-3 and 11.2.1 (a)(b),11.2.2 12.4.1
	Well-balanced Society	**Good Governance** **Income Distribution** **Population Growth** Security in the community Decent work	Anti-corruption/collusion		
Ecology (Environmental Wellbeing)	**Healthy Environment**			Basic Principles and EMS Environmental Management Contractual and procurement processes Delivering performance on environmental and social aspects Construction Issues	1.1.1 -1.1.3 1.2.1- 1.2.6 1.3.1-1.3.3 1.4.1, 1.4.3, 1.4.4, 1.4.5 1.5.1, 1.5.2
		Clean Air	Construction equipment emissions and construction activity emissions	Air pollution, including dust and odors Considered the energy Consumption and carbon emissions	11.4.1(a,b,c), 7.3.1-6

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
				Construction plant and ancillary equipment maintained to maximize fuel efficiency and minimize carbon emissions	7.3.7
			Material Transport Emissions	Reducing the energy consumption and carbon emissions of the project	7.2.1-4
				Considered the energy consumption and carbon emissions	7.3.1-3
			Material Production Emissions	Considered the energy consumption and carbon emissions	7.3.1-6
			Traffic Emissions	Reducing the energy consumption and carbon emissions of the	7.2.1-4
				Minimize traffic impacts of the completed project on the local community	10.1.4

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
				Construction transport, including nuisance and disruption	10.2.1-7
		Clean water	Clean water	Has a plan to control the impacts of the water environment	6.1.1 a) b)
				The water environment Legal requirements	6.2.1 -2
				Enhancement of the water environment	6.5.1 -2
			Stormwater runoff quality		
			Volume Quality	Protection of the water environment (ground and surface water), incorporation of Sustainable Drainage Systems	6.4.1 - 4, 6.4.5 (a)(b),6.4.6-7
				Protection of the water environment (ground and surface water), incorporation of Sustainable Drainage Systems	6.4.1 - 4, 6.4.5 (a)(b),6.4.6-7
			Groundwater quality ***Drinking water***	Desk study assessing risk associated with the land including issues related to soil , groundwater	2.2.1 (a), 2.2.1(b),2.2.2

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
		Clean Land			
				Desk study assessing risk associated with the land including issues related to soil , groundwater contamination was present on site (CLR11), management ground-generated gases, remedial solution, prevent any future contamination	2.2.1 (a), 2.2.1(b),2.2.2 2.2.3-8
			Contaminated soil-brownfield development	Has the site been previously used?	2.1.4
			Land use (don't take land more than use)	Land use efficiency of the final design?	2.1.3
				minimized the long-term adverse impacts of temporary greenfield land	2.1.5
				Improved the capability or productivity of the land resource	2.1.6
				the conservation of topsoil, subsoil, on-site mineral resources	2.1.7
				cut and fill to reduce the quantity of excavated material to be taken off site	8.2.3
			Steep Slopes		
			Floodplain		
			Waste Management/Minimization	cut and fill to reduce the quantity of excavated material to be taken off site	8.2.3

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
				A plan for material use to minimize environmental impact (reduce, re-use, recycle)	8.1.1-2
				prefabricated units	8.2.1-2
				excavated material for use has been beneficially re-used on-site	8.2.4
				subsoil and topsoil for re-use after construction	8.2.5
				topsoil on the site or on a site within a reasonable distance	8.2.6
				materials have been stored appropriately so as to avoid wastage	8.2.7
				Waste Management, and Legal and other requirements	9.1.1 -2, 9.2.1-7
				Waste from Site preparation	9.3.1-5
				On-site waste management	9.4.1-6
			Site selection	Has a desk study been undertaken that assists to choose site	2.1.2
		Ecosystem Preservation	Ecological connectivity (Avoid/Minimize/Mitigate)	Ecology and Biodiversity	4.1.1 - 3
		- wetland		Ecology and Biodiversity_Lagal requirements protected species	4.2.1 -3

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
		- forest - coastal zone, Marine environment -Biodiversity		Maintain and monitoring any habitat creation or species conservation	4.5.1 - 2
		Forest area (Biodiversity)	- Deforestation	Considered retention of trees and other vegetation as part of design part of design and protected and effects mitigated during construction	3.2.3 -3.2.4
			- Wildlife Population	Trees protected be a tree preservation	3.2.5
			Habitat creation	Habitat creation measures	4.4.1 - 4
			Habitat preservation/conservation	Conservation and Enhancement of Biodiversity (conserving existing ecological features)	4.3.1 a, b, c
			Minimize footprints	monitored throughout the course of the contract, Does monitoring data show has been successful	4.3.2- 3
			noise pollution/reduction	noise	11.3.1 (a,b), 11.3.2((a,b), 11.3.3

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
			Light pollution/reduction	Light pollution	11.5.1(a,b), 11.5.2
			Vibration	vibration	11.3.4(a,b), 11.3.5(a,b), 11.3.6-7
	Natural resources	non- renewable material (recycle/reuse/local) - pavement, wood, metals, minerals	Material reuse	environmental impact (reduce, re- use, recycle)	8.1.1-2
			Minimize materials (reduce)	prefabricated units	8.2.1-2
				excavated material for use has been beneficially re-used on-site	8.2.4
				subsoil and topsoil for re-use after construction	8.2.5
				topsoil on the site or on a site within a reasonable distance	8.2.6
			Material recycling	responsible sourcing of materials	8.3.1-2
				highest possible proportion of timber and timber products used on permanent works (legal and sustainably managed sources with recognized timber labelling or from re-use	8.4.1

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
				highest possible proportion of timber and timber products used in temporary works has been from re-use or certified sources	8.4.2
				existing structures have been retained and used within the project/ recycled material, sub-base material from previously used material	8.5.1-3
				What percentage of unused materials have been beneficially re-used (or stored for re-use)?	9.4.6
			Fuel use	Does the waste minimization plan set targets to reduce, re-use and/or recycle waste	9.4.3(b)
		Water availability	Water use	Minimizing water usage (greywater and rainwater)	6.3.1 -2
				the amount of water used been measured and monitored, for example, by metering the input to the site	6.3.1-3
			Minimum water use Renewable water resources (potable water conservation)		
				predicted climate change scenarios	1.4.2
	Climate &Energy	**Greenhouse gas emission**	Greenhouse gas emission LCA		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
		Renewable energy	Renewable energy use (encourage)	incorporation of energy from renewable and/or low-or zero-carbon sources	7.2.3-4
				Have energy from renewable and/or low-or zero-carbon resources been used during construction	7.3.6
		Energy consumption	Non-renewable energy use (discourage)	percentage of the energy consumption reduction in the life-cycle assessment	7.1.2
				percentage of the carbon emission reduction in the life-cycle assessment	7.1.4
				reducing the energy consumption and carbon emissions of the project	7.2.1-2
				considered the energy consumption and carbon emissions	7.3.1-3
				monitor and controlled on site as and where possible	7.3.8
			LCA	life-cycle energy assessment	7.1.1
				life-cycle carbon assessment	7.1.3
Economy (Economic Wellbeing)	**Prepare for the future**	**Material Consumption (reuse/recycling/local)**	Materials reuse		
			Material recycling		
			Minimize materials		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	CEEQUAL V 4.1, August 2010	Credit
			Local Materials		
		Organic Farming **Genuine Saving**			
	Economy	**Public debt** (Economic Vitality GDP)	LCCA and or cost-benefit		
			Durable structures	Durability and maintenance	8.7.1-2
			Quality construction control		
		Employment	Local employment	Minimizing workforce travel	10.3.1-3
				client and principle contractor has taken steps to actively encourage	
			Regional workers	local firms to compete for work	12.4.3
		Economic Vitality (Gross Domestic Product (GDP))	Local economy **Improved economy**	locally available material sources including recycled materials	8.3.3
			Access to view scenery (same as above)		
			Freight Mobility		

Envision

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Envision V2.0	Credit
Equity (Human Wellbeing)	**Basic Needs**	**Sufficient food**	Access to food	Improve Community Mobility and Access	QL2.4
				Improve Community Mobility and Access	QL2.4
		Sufficient to drink	Access to drinking water Utilities include water Access to clean energy		
		Safe Sanitation	Utilities include sanitation		
	Personal Development	**Healthy life**	Access and mobility to hospitals and health places	Improve Community Mobility and Access	QL2.4
			Clean air (human)	Use Recycled Materials	RA 1.3
			livability (location and quality of transportation facilities, TIS, quite pavement, travel demand management)	Improve Community Quality of Life	QL1.1

SI Dimension	SSI Category	SSI Indicator	Roadway Topic	Envision V2.0	Credit
			Noise reduction	Minimize noise and vibration	QL2.2
		Safety	Safety - worker/ jobsite safety		
			- traffic/road user safety	Improve Accessibility, Safety and Wayfinding	QL 2.6
			(clean roadside hazards, Horizontal realignment of dangerous curves, Improved realignment)		
			Roundabout		
		Education Opportunities	Access to school	Improve Community Mobility and Access	QL2.4
			Training	Develop Local Skills and Capabilities: im**S**prove local worker skills	QL1.3
			Mobility (More mode choice, public transportation access, bicycle)	Improve Community Mobility and Access	QL2.4
				Encourage Alternative Modes of Transportation	QL2.5
			Access to workplaces		
			Local jobs	Develop Local Skills and Capabilities	QL1.3
				Stimulate Sustainable Growth and Development	QL1.2

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Envision V2.0	Credit
		Cultural and historic	Cultural and Cultural heritage preservation	Preserve Historic and Cultural Resources	QL3.1
		Aesthetics	Aesthetics	Minimize Light Pollution	QL 2.3
			Access to view scenery	Preserve Views and Local Character	QL3.2
		Public Participation	Public Participation	Provide for Stakeholder Involvement	LD 1.4
		Equality	Environmental justice/gender diversity all people including women, the poor, the rural, and the disabled (well measured)		
		Social Impact			
	Well-balanced Society	**Good Governance** **Income Distribution** **Population Growth**	Anti-corruption/collusion		
		Security in the community Decent work			
Ecology	**Healthy Environment**	Clean Air		Reduce Air Pollutant Emissions	CR 1.2

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Envision V2.0	Credit
(Environmental Wellbeing)			Construction equipment emissions and construction activity emissions		
			Material Transport Emissions		
			Material Production Emissions		
			Traffic Emissions	Reduce Air Pollutant Emissions	CR 1.2
		Clean water	Clean water	Protect Wetlands and Surface Water	NW 1.2
				Protect Fresh Water Availability	RA 3.1
				Prevent Surface+Groundwater Contamination: over operation	NW 2.3
			Stormwater runoff quality		
			Volume	Manage Stormwater	NW 2.1
			Quality		
				Protect Fresh Water Availability	RA 3.1
			Groundwater quality	Avoid Adverse Geology	NW 1.4
			Drinking water	Reduce Potable Water Consumption	RA 3.2
		Clean Land		Preserve Prime Farmland	NW 1.3

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Envision V2.0	Credit
			Contaminated soil-brownfield development Land use (don't take land more than use)	Preserve Greenfields	NW 1.7
				Reduce Excavated Materials Taken Off Site	RA 1.6
				Preserve Floodplain Functions	NW 1.5
			Steep Slopes ***Floodplain***	Avoid Unsuitable Development on Steep Slopes	NW 1.6
			Waste Management/Minimization ***site selection***	Divert Waste from Landfills	RA 1.5
		Ecosystem Preservation - wetland - forest - coastal zone, Marine environment -Biodiversity	Ecological connectivity (Avoid/Minimize/Mitigate)	Maintain Wetland & Surface Water Functions: maintained and restored ecosystem functions	NW3.4
		Forest area (Biodiversity)	- Deforestation - Wildlife Population Habitat creation		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Envision V2.0	Credit
			Habitat preservation/conservation	Preserve Prime Habitat	NW1.1
				Preserve Species Biodiversity	NW 3.1
			Minimize footprints	Control Invasive Species	NW 3.2
			noise pollution/reduction	Minimize noise and vibration	QL2.2
			Light pollution/reduction	Minimize Light Pollution	QL 2.3
			Vibration		
	Natural resources				
		Non- renewable material (recycle/reuse/local) - pavement, wood, metals, minerals	Material reuse		
			Minimize materials (reduce)		
				Use Recycled Materials	RA 1.3
			Material recycling	Use Recycled Materials	RA 1.3
			Fuel use		
		Water availability	Water use	Monitor Water Systems	RA 3.3
			Minimum water use	Reduce Potable Water Consumption	RA 3.2
			Renewable water resources (potable water conservation)		
	Climate &Energy	**Greenhouse gas emission**	Greenhouse gas emission LCA	Reduce Greenhouse Gas Emissions: life-cycle carbon assessment	CR 1.1

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Envision V2.0	Credit
				Minimize Light Pollution	QL 2.3
				Use Recycled Materials	RA 1.3
				Lighting and signal fixtures, Renewable energy	
		Renewable energy	Renewable energy use (encourage)	Use Renewable Energy	RA 2.2
		Energy consumption	Non-renewable energy use (discourage)	Reduce Net Embodied Energy: reduction	RA 1.1
				Reduce Energy Consumption	RA 2.1
			LCA	Reduce Net Embodied Energy: Life cycle energy assessment	RA1.1
Economy (Economic Wellbeing)	**Prepare for the future**	**Material Consumption (reuse/recycling/local)**	Materials reuse		
			Material recycling		
			Minimize materials		
			Local Materials		
		Organic Farming			
		Genuine Saving			

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	Envision V2.0	Credit
	Economy	**Public debt** (Economic Vitality GDP)	LCCA and or cost-benefit Durable structures Quality construction control	 Extend Useful Life	 LD 3.3
		Employment	Local employment ***Regional workers***	Stimulate Sustainable Growth and Development Develop Local Skills and Capabilities	QL1.2 QL1.3
		Economic Vitality (Gross Domestic Product (GDP))	Local economy **Improved economy** Access to view scenery (same as above) **Freight Mobility**	Stimulate Sustainable Growth and Development	QL1.2

Infrastructure Sustainability (IS)

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	IS (not include Management Systems/Procurement)	Credit
Equity (Human Wellbeing)	**Basic Needs**	**Sufficient food**	Access to food		
		Sufficient to drink	Access to drinking water Utilities include water Access to clean energy (table1)		
		Safe Sanitation	Utilities include sanitation		
	Personal Development	**Healthy life**	Access and mobility to hospitals and health places Clean air (human) livability (location and quality of transportation facilities, TIS, quite pavement, travel demand management)	Community health and well-being	Hea-1

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	IS (not include Management Systems/Procurement)	Credit
				Crime prevention (CPTED guidelines)	Hea-2
			Noise reduction		
		Safety	safety - worker/ jobsite safety		
			- traffic/road user safety		
			(clean roadside hazards, Horizontal realignment of dangerous curves, Improved realignment)	Community and user safety	Hea-3
			roundabout		
		Education Opportunities	Access to school Training		
			Mobility (More mode choice, public transportation access, bicycle)		
			Access to workplaces Local jobs		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	IS (not include Management Systems/Procurement)	Credit
		Cultural and historic	Cultural and Cultural heritage preservation	Heritage assessment and management Monitoring of heritage	Her-1 Her-2
		Aesthetics	Aesthetics Access to view scenery		
		Public Participation	Public Participation	Stakeholder engagement strategy Level of engagement Effective communication Addressing community concerns	Sta-1 Sta-2 Sta-3 Sta-4
		Equality	Environmental justice/gender diversity all people including women, the poor, the rural, and the disabled (well measured)		
		Social Impact			
	Well-balanced Society	**Good Governance** **Income Distribution**	Anti-corruption/collusion		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	IS (not include Management Systems/Procurement)	Credit
		Population Growth Security in the community Decent work			
Ecology **(Environmental Wellbeing)**	**Healthy Environment**	Clean Air	Construction equipment emissions and construction activity emissions Material Transport Emissions Material Production Emissions Traffic Emissions	Air quality	Dis-4
		Clean water	Clean water Stormwater runoff quality Volume Quality ***Groundwater quality*** ***Drinking water***	Receiving water quality Replace potable water	Dis-1 wat-3
		Clean Land	Contaminated soil-brownfield development	Contamination and remediation	Lan-3

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	IS (not include Management Systems/Procurement)	Credit
			Land use (don't take land more than use)	Previous land use	Lan-1
				Conservation of onsite resources	Lan-2
				Flooding Design	Lan-4
			Steep Slopes		
			Floodplain		
			Waste Management/Minimization	Diversion from landfill	Was-2
				Waste Management	Was-1
				Deconstruction/Disassembly/Adaptability	Was-3
			site selection		
		Ecosystem Preservation - wetland - forest - coastal zone, Marine environment -Biodiversity	Ecological connectivity (Avoid/Minimize/Mitigate)	Ecologically Sensitive sites Habitat connectivity Ecological value Biodiversity	Eco-1 Eco-4 Eco-2 Eco-3
		Forest area (Biodiversity	- Deforestation		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	IS (not include Management Systems/Procurement)	Credit
			- Wildlife Population Habitat creation		
			Habitat preservation/conservation		
			Minimize footprints		
			noise pollution/reduction	Noise	Dis-2
			Light pollution/reduction	Light pollution	Dis-5
			Vibration	Vibration	Dis-3
	Natural resources	material (recycle/reuse/local) - pavement, wood, metals, minerals	Material reuse	Materials Lifecycle impact measurement and reduction	Mat-1
			Minimize materials (reduce)		
			Material recycling		
			Fuel use		
		Water availability	Water use	Water use monitoring and reduction	Wat-1
			Minimum water use	Water saving opportunities	Wat-2
			Renewable water resources (potable water conservation)		
				Replace potable water	Wat-3
	Climate &Energy			Climate change risk assessment	Cli-1
				Adaptation measures	Cli-2
		Greenhouse gas emission	Greenhouse gas emission	Energy and carbon monitoring and reduction	Ene-1

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	IS (not include Management Systems/Procurement)	Credit
			LCA	Energy and Carbon reduction opportunities	Ene-2
		Renewable energy	Renewable energy use (encourage)	Renewable Energy	Ene-3
		Energy consumption	Non-renewable energy use (discourage)	Energy and carbon monitoring and reduction	Ene-1
			LCA	Energy and Carbon reduction opportunities	Ene-2
Economy **(Economic Wellbeing)**	**Prepare for the future**	**Material Consumption (reuse/recycling/local)**	Materials reuse		
			Material recycling		
			Minimize materials		
			Local Materials		
		Organic Farming			
		Genuine Saving			
	Economy	**Public debt** (Economic Vitality GDP)	LCCA and or cost-benefit		
			Durable structures		
			Quality construction control		
		Employment	Local employment		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	IS (not include Management Systems/Procurement)	Credit
		Economic Vitality (Gross Domestic Product (GDP))	***Regional workers*** local economy **Improved economy** Access to view scenery (same as above) **Freight Mobility**		

LEED_ND

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	LEED_ ND	Credit
Equity (Human Wellbeing)	**Basic Needs**	**Sufficient food**	Access to food	Walkable streets	NPDp1
				Bicycle facilities	SLLc4
				Access to quality transit	SLLc3
				Connected and open community	NPDc1
				Access to civic and public spaces	NPDc9
				Access to recreation facilities	NPDc10
		Sufficient to drink	Access to drinking water Utilities include water Access to clean energy (table1)		
		Safe Sanitation	Utilities include sanitation		
	Personal Development	**Healthy life**	Access and mobility to hospitals and health places		
			Clean air (human)		
			Livability (location and quality of transportation facilities, TIS, quite pavement, travel demand management)	Smart Location	SLLp1
				Preferred locations	SLLc1

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	LEED_ ND	Credit
				Compact development	NPDp2
				Connected circulation network	NPDc6
				Transit facilities	NPDc7
				Transportation demand Mgmt	NPDc8
		Safety	Noise reduction safety - worker/ jobsite safety - traffic/road user safety (clean roadside hazards, Horizontal realignment of danagerous curves, Improved realignment) Roundabout		
		Education Opportunities	Access to school Training Mobility (More mode choice, public transportation access, bicycle)	Neighborhood schools	NPDc15
			Access to workplaces Local jobs	Housing and jobs proximity	SLLc5
		Cultural and historic	Cultural and Cultural heritage preservation	Historic resource preservation and adaptive use	GIBc6
		Aesthetics	Aesthetics Access to view scenery		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	LEED_ ND	Credit
		Public Participation	Public Participation	Community outreach and involvement	NPDc12
		Equality	Environmental justice/gender diversity all people including women, the poor, the rural, and the disabled (well measured)	Visitability and univeral design	NPDc11
		Social Impact			
	Well-balanced Society	**Good Governance** **Income Distribution** **Population Growth** Security in the community Decent work	Anti-corruption/collusion		
Ecology **(Environmental Wellbeing)**	**Healthy Environment**	Clean Air	Construction equipment emissions and construction activity emissions Material Transport Emissions Material Production Emissions Traffic Emissions		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	LEED_ ND	Credit
		Clean water	Clean water		
			Stormwater runoff quality	Rainwater Management	GIBc8
				Construction Activity Pollution Prevention	GIB Prerequisite
			Volume		
			Quality		
			Groundwater quality		
			Drinking water	Wastewater Management	GIB
		Clean Land	Contaminated soil-brownfield development	Brownfield remediation	SLLc2
			Land use (don't take land more than use)		
			Steep Slopes	Steep slope protection	SLLc6
			Floodplain		
			Waste Management/Minimization		
				Solid waste Management	GIBc16
			site selection		
		Ecosystem Preservation	Ecological connectivity (Avoid/Minimize/Mitigate)	Imperiled species and ecological communities	SLLp2

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	LEED_ ND	Credit
		- wetland		Wetlands and water body conservation	SLLp3
		- forest		Agricultural land conservation	SLLp4
		- coastal zone, Marine environment		Floodplain avoidance	SLLp5
		-Biodiversity		Heat Island reduction	GIBc9
		Forest area (Biodiversity)	- Deforestation - Wildlife Population	Minimized site disturbance (existing noninvasive trees, native plants and pervious surface)	GIBc7
			Habitat creation	Site design for habitat or wetland and water body conservation	SLLc7
			Habitat preservation/conservation	Restoration of habitat or wetlands and water bodies	SLLc8
			Minimize footprints	Long-term conservation Mgmt of habitat or wetlands and water bodies	SLLc9
				Reduced parking footprint	NPDc5
			noise pollution/reduction Light pollution/reduction	Light pollution reduction	GIBc17
			Vibration		

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	LEED_ ND	Credit
	Natural resources	non- renewable material (recycle/reuse/local) - pavement, wood, metals, minerals	Material reuse	Building reuse	GIBc5
			Minimize materials (reduce)	Recycled and reused infrastructure	GIBc15
			Material recycling	Recycled and reused infrastructure	GIBc15
			Fuel use		
		Water availability	Water use	Indoor water use reduction	GIBc3
			Minimum water use	Outdoor water use reduction	GIBc4
			Renewable water resources (potable water conservation)	Wastewater Mgmt	GIBc14
	Climate &Energy	**Greenhouse gas emission**	Greenhouse gas emission	Minimum building energy performance	GIBp2
			LCA	Optimize building energy performance	GIBc2
				Infrastructure energy efficiency	GIBc13
		Renewable energy	Renewable energy use (encourage)	Solar orientation	GIBc10

SSI Dimension	SSI Category	SSI Indicator	Roadway Topic	LEED_ ND	Credit
				Renewable energy production	GIBc11
		Energy consumption	Non-renewable energy use (discourage) LCA		
Economy (Economic Wellbeing)	**Prepare for the future**	**Material Consumption (reuse/recycling/local)**	Materials reuse Material recycling Minimize materials Local Materials		
		Organic Farming **Genuine Saving**			
	Economy	**Public debt** (Economic Vitality GDP)	LCCA and or cost-benefit Durable structures Quality construction control		
		Employment	Local employment ***Regional workers***		
		Economic Vitality (Gross Domestic Product (GDP))	local economy **Improved economy** Access to view scenery (same as above) **Freight Mobility**	Local food production	NPDc13

Appendix B: The Master Table

Results of an analysis of Greenroads by using the international framework from five analysts in Chapter 5.

			Environmental Review Process	Lifecycle Cost Analysis	Lifecycle Inventor	Quality Control Plan	Noise Mitigatio n Plan	Waste Management Plan	Pollution Preventio n Plan	Low-Impact Development
		Greenroads scores	5	5	5	5	5	5	5	5
		New scores	5	5	5	5	5	5	5	5
Dimension	**Category**	**Indicator**	PR-1	PR-2	PR-3	PR-4	PR-5	PR-6	PR-7	PR-8
Human	Basic Needs	Access	5	0	0	0	0	0	0	0
	Health	Healthy Life	5	0	0	5	5	5	5	5
		Safety	5	0	0	5	5	0	0	0
		Culture and History	5	0	0	0	0	0	0	0
		Aesthetics	5	0	0	0	5	0	0	0
	Personal and social development	Education	0	0	0	0	0	0	0	0
		Equality	0	0	0	0	0	0	0	0
		Good Governance	5	0	0	0	0	0	0	0
		Income Distribution	0	0	0	0	0	0	0	0
Environment	Nature & Environment	Clean Air	5	0	0	0	0	0	5	0
		Clean Water	5	0	0	0	0	5	5	5
		Clean Land	5	0	0	0	0	5	5	5
		Ecological Resources	5	0	0	0	0	5	5	5
	Climate & Energy	Renewable Energy	0	0	0	0	0	0	0	0
		GHG Emissions	5	0	5	5	0	0	5	0
	Natural Resources	Water Resources	5	0	0	0	0	0	5	5
		Consumption	5	5	5	5	0	5	0	0
Economy	Transition	Transition	0	0	0	0	0	0	0	0
	Economy	Financial impact	0	0	0	0	0	0	0	0
		Employment	0	0	0	0	0	0	0	0
		Cost-Benefit	0	5	0	5	0	5	0	0
		Total Points for the Credit	65	10	10	25	15	30	35	25
		# of Indicators Applicable	13	2	2	5	3	6	7	5

			Pavement Management System	Site Maintenance Plan	Educational Outreach	Environmental Management System	Runoff Flow Control	Runoff Quality	Stormwater Cost Analysis	Site Vegetation
		Greenroads scores	5	5	5	2	3	3	1	3
		New scores	5	5	5	2	5	5	1	3
Dimension	**Category**	**Indicator**	PR-9	PR-10	PR-11	EW-1	EW-2	EW-3	EW-4	EW-5
Human	Basic Needs	Access	0	0	0	0	0	0	0	0
	Health	Healthy Life	5	5	5	2	5	5	0	3
		Safety	5	5	0	0	0	0	0	0
		Culture and History	0	0	0	0	0	0	0	0
		Aesthetics	5	5	0	0	0	0	0	3
	Personal and social development	Education	0	0	5	0	0	0	0	0
		Equality	0	0	0	0	0	0	0	0
		Good Governance	0	0	0	0	0	0	0	0
		Income Distribution	0	0	0	0	0	0	0	0
Environment	Nature & Environment	Clean Air	0	0	0	2	0	0	0	0
		Clean Water	0	5	0	2	5	5	0	0
		Clean Land	0	5	0	2	5	5	0	3
		Ecological Resources	0	0	0	2	5	5	0	3
	Climate & Energy	Renewable Energy	0	0	0	0	0	0	0	0
		GHG Emissions	0	0	0	2	0	0	0	3
	Natural Resources	Water Resources	0	0	0	2	5	5	0	3
		Consumption	5	0	0	2	5	0	0	0
Economy	Transition	Transition	0	0	0	0	0	0	0	0
	Economy	Financial impact	0	0	0	0	0	0	0	0
		Employment	0	0	0	0	0	0	0	0
		Cost-Benefit	5	5	0	0	0	0	1	0
		Total Points for the Credit	25	30	10	16	30	25	1	18
		# of Indicators Applicable	5	6	2	8	6	5	1	6

			Habitat Restoration	Ecological Connectivity	Light Pollution	Safety Audit	Intelligent Transportation Systems	Context Sensitive Solutions	Traffic Emissions Reduction	Pedestrian Access
		Greenroads scores	3	3	3	2	5	5	5	2
		New scores	3	3	3	5	5	5	5	5
Dimension	**Category**	**Indicator**	EW-6	EW-7	EW-8	AE-1	AE-2	AE-3	AE-4	AE-5
Human	Basic Needs	Access	0	0	0	0	0	5	0	5
	Health	Healthy Life	3	0	3	5	5	5	5	5
		Safety	0	3	3	5	5	5	0	5
		Culture and History	0	0	0	0	0	5	0	0
		Aesthetics	3	0	3	0	0	5	0	0
	Personal and social development	Education	0	0	0	0	0	0	0	0
		Equality	0	0	0	0	0	0	0	5
		Good Governance	0	0	0	0	0	5	0	0
		Income Distribution	0	0	0	0	0	0	0	0
Environment	Nature & Environment	Clean Air	0	0	0	0	5	0	5	5
		Clean Water	0	0	0	0	0	0	0	0
		Clean Land	0	0	0	0	0	0	0	0
		Ecological Resources	3	3	3	0	0	0	0	0
	Climate & Energy	Renewable Energy	0	0	0	0	0	0	0	0
		GHG Emissions	0	0	3	0	5	0	5	5
	Natural Resources	Water Resources	0	0	0	0	0	0	0	0
		Consumption	0	0	3	0	5	0	5	5
Economy	Transition	Transition	0	0	0	0	0	0	0	0
	Economy	Financial impact	0	0	0	0	0	0	0	5
		Employment	0	0	0	0	0	0	0	0
		Cost-Benefit	0	0	0	0	5	0	5	0
		Total Points for the Credit	9	6	18	10	30	30	25	40
		# of Indicators Applicable	3	2	6	2	6	6	5	8

			Bicycle Access	Transit & HOV Access	Scenic Views	Cultural Outreach	Quality Management System	Environmental Training	Site Recycling Plan	Fossil Fuel Reduction
		Greenroads scores	2	5	2	2	2	1	1	2
		New scores	5	5	2	2	2	1	1	5
Dimension	**Category**	**Indicator**	AE-6	AE-7	AE-8	AE-9	CA-1	CA-2	CA-3	CA-4
Human	Basic Needs	Access	5	5	0	0	0	0	0	0
	Health	Healthy Life	5	5	2	2	2	1	0	5
		Safety	0	0	0	0	2	0	0	0
		Culture and History	0	0	0	2	0	0	0	0
		Aesthetics	0	0	2	2	0	0	0	0
	Personal and social development	Education	0	0	0	0	0	1	0	0
		Equality	0	0	0	0	0	0	0	0
		Good Governance	0	0	0	0	0	0	0	0
		Income Distribution	0	0	0	0	0	0	0	0
Environment	Nature & Environment	Clean Air	5	5	0	0	0	1	1	0
		Clean Water	0	0	0	0	0	1	1	0
		Clean Land	0	0	0	0	0	1	1	0
		Ecological Resources	0	0	0	0	0	0	1	5
	Climate & Energy	Renewable Energy	0	0	0	0	0	0	0	0
		GHG Emissions	5	5	0	0	0	1	0	5
	Natural Resources	Water Resources	0	0	0	0	0	0	0	0
		Consumption	5	5	0	0	0	1	1	5
Economy	Transition	Transition	0	0	0	0	0	0	0	0
	Economy	Financial impact	5	0	0	0	0	0	0	0
		Employment	0	0	0	0	0	0	0	0
		Cost-Benefit	0	0	0	0	0	0	1	5
		Total Points for the Credit	30	25	4	6	4	7	6	25
		# of Indicators Applicable	6	5	2	3	2	7	6	5

			Equipment Emission Reduction	Paving Emission Reduction	Water Use	Contractor Warranty	Lifecycle Assessment	Pavement Reuse	Earthwork Balance	Recycled Material
		Greenroads scores	2	1	2	3	2	5	1	5
		New scores	5	5	2	3	2	5	1	5
Dimension	**Category**	**Indicator**	CA-5	CA-6	CA-7	CA-8	MR-1	MR-2	MR-3	MR-4
Human	Basic Needs	Access	0	0	0	0	0	0	0	0
	Health	Healthy Life	5	5	0	0	0	0	0	5
		Safety	0	0	0	0	0	0	0	0
		Culture and History	0	0	0	0	0	0	0	0
		Aesthetics	0	0	0	0	0	0	0	0
	Personal and social development	Education	0	0	0	0	0	0	0	0
		Equality	0	0	0	0	0	0	0	0
		Good Governance	0	0	0	0	0	0	0	0
		Income Distribution	0	0	0	0	0	0	0	0
Environment	Nature & Environment	Clean Air	5	5	0	0	2	5	1	5
		Clean Water	0	0	0	0	0	0	1	0
		Clean Land	0	0	0	0	0	5	1	5
		Ecological Resources	0	0	0	0	0	0	1	5
	Climate & Energy	Renewable Energy	0	0	0	0	0	0	0	0
		GHG Emissions	5	5	0	0	0	5	1	5
	Natural Resources	Water Resources	0	0	2	0	0	0	0	0
		Consumption	0	0	0	3	0	5	1	5
Economy	Transition	Transition	0	0	0	0	0	0	0	0
	Economy	Financial impact	0	0	0	0	0	0	0	0
		Employment	0	0	0	0	0	0	0	0
		Cost-Benefit	0	0	0	3	0	5	1	5
		Total Points for the Credit	15	15	2	6	2	25	7	35
		# of Indicators Applicable	3	3	1	2	1	5	7	7

			Regional Material	Energy Efficiency	Long-Life Pavemen	Permeable	Warm Mix	Cool Pavement	Quiet Pavemen	Pavement Performance Tracking
		Greenroads scores	5	5	5	3	3	5	3	1
		New scores	5	5	5	3	3	5	3	1
Dimension	**Category**	**Indicator**	MR-5	MR-6	PT-1	PT-2	PT-3	PT-4	PT-5	PT-6
Human	Basic Needs	Access	0	0	0	0	0	0	0	0
	Health	Healthy Life	0	0	0	3	3	5	3	0
		Safety	0	0	0	0	3	0	0	0
		Culture and History	0	0	0	0	0	0	0	0
		Aesthetics	0	0	0	3	0	5	3	0
	Personal and social development	Education	0	0	0	0	0	0	0	0
		Equality	0	0	0	0	0	0	0	0
		Good Governance	0	0	0	0	0	0	0	0
		Income Distribution	0	0	0	0	0	0	0	0
Environment	Nature & Environment	Clean Air	5	5	5	0	3	5	0	0
		Clean Water	0	0	0	3	0	0	0	0
		Clean Land	0	0	5	0	0	0	0	0
		Ecological Resources	0	0	0	3	0	0	0	0
	Climate & Energy	Renewable Energy	0	0	0	0	0	0	0	0
		GHG Emissions	5	5	5	0	3	5	0	0
	Natural Resources	Water Resources	0	0	0	3	0	0	0	0
		Consumption	5	5	5	0	3	5	0	1
Economy	Transition	Transition	0	0	0	0	0	0	0	0
	Economy	Financial impact	0	0	0	0	0	0	0	0
		Employment	0	0	0	0	0	0	0	0
		Cost-Benefit	5	5	5	0	3	0	0	1
		Total Points for the Credit	20	20	25	15	18	25	6	2
		# of Indicators Applicable	4	4	5	5	6	5	2	2

			Transportation Professional (STP)	Work zone	Pavement Smoothess	Roadside Revegetation (pilot Credit)	Electric vehicle Infrastrure	Alternative Energy	Fright Access	Design for Disassembly
		Greenroads scores	2	2	5	3	5	5	5	5
		New scores	2	5	5	3	5	5	5	5
Dimension	**Category**	**Indicator**	CC-1	CC-2	CC-3	CC-4	CC-5	CC-6	CC-7	CC-8
Human	Basic Needs	Access	0	0	0	0	0	0	5	0
	Health	Healthy Life	2	0	0	3	0	0	5	0
		Safety	0	5	0	0	0	0	0	0
		Culture and History	0	0	0	0	0	0	0	0
		Aesthetics	0	0	0	0	0	0	0	0
	Personal and social development	Education	2	0	0	0	0	0	0	0
		Equality	0	0	0	0	0	0	0	0
		Good Governance	0	0	0	0	0	0	0	0
		Income Distribution	0	0	0	0	0	0	0	0
Environment	Nature & Environment	Clean Air	0	0	0	0	0	0	0	0
		Clean Water	0	0	0	0	0	0	0	0
		Clean Land	0	0	0	0	0	0	0	0
		Ecological Resources	0	0	0	3	0	0	0	0
	Climate & Energy	Renewable Energy	0	0	0	0	5	5	0	0
		GHG Emissions	0	0	5	3	5	5	0	5
	Natural Resources	Water Resources	0	0	0	3	0	0	0	0
		Consumption	0	0	5	3	5	5	0	5
Economy	Transition	Transition	0	0	0	0	5	0	0	0
	Economy	Financial impact	0	0	0	0	0	0	0	0
		Employment	0	0	0	0	0	0	0	0
		Cost-Benefit	0	0	5	0	0	0	0	5
		Total Points for the Credit	4	5	15	15	20	15	10	15
		# of Indicators Applicable	2	1	3	5	4	3	2	3

			VOC reduction	Infrastructure resiliency +flooding	Anti-corruptio	Prevailin g wages	Year round	Regional Employment	Job Training	Dust Control	Environmenal Justice/gender diversity
		Greenroads scores	2	0	0	0	0	0	0	0	0
		New scores	2	4	5	1	2	2	1	2	2
Dimension	**Category**	**Indicator**	CC-9	CC-10	CC-11	CC-12	CC-13	CC-14	CC-15	CC-16	CC-17
Human	Basic Needs	Access	0	4	0	0	2	0	0	0	0
	Health	Healthy Life	2	0	0	0	0	0	0	0	2
		Safety	0	4	0	0	0	0	0	0	0
		Culture and History	0	0	0	0	0	0	0	0	0
		Aesthetics	0	0	0	0	0	0	0	0	0
	Personal and social development	Education	0	0	0	0	0	0	1	0	0
		Equality	0	0	0	0	2	0	0	0	2
		Good Governance	0	0	5	0	0	0	0	0	0
		Income Distribution	0	0	0	1	0	0	0	0	0
Environment	Nature & Environment	Clean Air	2	0	0	0	0	2	0	2	0
		Clean Water	2	0	0	0	0	0	0	2	0
		Clean Land	0	0	0	0	0	0	0	2	0
		Ecological Resources	2	0	0	0	0	0	0	2	0
	Climate & Energy	Renewable Energy	0	0	0	0	0	0	0	0	0
		GHG Emissions	2	0	0	0	0	2	0	0	0
	Natural Resources	Water Resources	2	0	0	0	0	0	0	0	0
		Consumption	2	0	5	0	0	0	0	0	0
Economy	Transition	Transition	0	0	0	0	0	0	0	0	0
	Economy	Financial impact	0	0	0	0	0	0	0	0	0
		Employment	0	0	0	0	0	2	0	0	0
		Cost-Benefit	0	0	5	0	0	0	0	0	0
		Total Points for the Credit	14	8	15	1	4	6	1	8	4
		# of Indicators Applicable	7	2	3	1	2	3	1	4	2

		Greenroads scores	maximun points dealing with item	total points dealing with SSI Category	Number of Credits dealing with item	% of total points for this indicator	Ordered List (high to low) of all indicators		
		New scores	187						
Dimension	**Category**	**Indicator**							
Human	Basic Needs	Access	36	36	8	3.5%	Healthy Life	156	15.0%
	Health	Healthy Life	156		39	15.0%	Consumption	140	13.4%
		Safety	65		15	6.2%	GHG Emissions	130	12.5%
		Culture and History	12		3	1.2%	Clean Air	91	8.7%
		Aesthetics	49	282	13	4.7%	Cost-Benefit	90	8.6%
	Personal and social development	Education	9		4	0.9%	Clean Land	60	5.8%
		Equality	9		3	0.9%	Ecological Resources	66	6.3%
		Good Governance	15		3	1.4%	Safety	65	6.2%
		Income Distribution	1	34	1	0.1%	Aesthetics	49	4.7%
Environment	Nature & Environment	Clean Air	91		24	8.7%	Clean Water	47	4.5%
		Clean Water	47		14	4.5%	Water Resources	40	3.8%
		Clean Land	60		16	5.8%	Access	36	3.5%
		Ecological Resources	66	264	19	6.3%	Culture and History	12	1.2%
	Climate & Energy	Renewable Energy	10		2	1.0%	Good Governance	15	1.4%
		GHG Emissions	130	140	31	12.5%	Education	9	0.9%
	Natural Resources	Water Resources	40		11	3.8%	Financial Impact	10	1.0%
		Consumption	140	180	34	13.4%	Equality	9	0.9%
Economy	Transition	Transition	5	5	1	0.5%	Income Distribution	1	0.1%
	Economy	Financial impact	10		2	1.0%	Renewable Energy	10	1.0%
		Employment	2		1	0.2%	Transition	5	0.5%
		Cost-Benefit	90	102	22	8.6%	Employment	2	0.2%
		Total Points for the Credit	1043	1043				Mean	4.8%
		# of Indicators Applicable						Median	3.8%

Appendix C: The Results of Weighing the Dimensions of SSI 2012 Data of 151 Countries

$$\text{Human wellbeing} = 10.00 - \text{Score}_{HW} = \text{Dis10}_{HW} \quad \text{(C.1)}$$

$$\text{Environmental wellbeing} = 10.00\text{-Score}_{EW} = \text{Dis10}_{EW} \quad \text{(C.2)}$$

$$\text{Economic wellbeing} = 10.00\text{-Score}_{ECW} = \text{Dis10}_{ECW} \quad \text{(C.3)}$$

$$\text{The lowest result (LOW)} = \text{MIN}(\text{Dis10}_{HW}, \text{Dis10}_{EW,} \text{Dis10}_{ECW}) \quad \text{(C.4)}$$

$$\text{Final}_{HW} = \text{Dis10}_{HW} / \text{LOW} \quad \text{(C.5)}$$

$$\text{Final}_{EW} = \text{Dis10}_{EW}/\text{LOW} \quad \text{(C.6)}$$

$$\text{Fianl}_{ECW} = \text{Dis10}_{ECW}/\text{LOW} \quad \text{(C.7)}$$

Country	**Dis10_{HW}**	**Dis10_{EW}**	**Dis10_{ECW}**	**Final_{HW}**	**Final_{EW}**	**Fianl_{ECW}**
Albania	2.03	3.86	6.78	1	2	3
Algeria	2.77	5.97	5.96	1	2	2
Angola	5.52	2.56	8.22	2	1	3
Argentina	2.77	6.17	3.42	1	2	1
Armenia	3.21	5.90	6.86	1	2	2
Australia	1.62	8.00	2.70	1	5	2
Austria	0.79	5.53	2.96	1	7	4
Azerbaijan	3.55	6.17	5.70	1	2	2
Bangladesh	4.58	5.08	6.50	1	1	1
Belarus	2.47	6.68	5.25	1	3	2
Belgium	1.15	7.52	4.91	1	7	4
Benin	5.36	2.10	6.42	3	1	3
Bhutan	4.42	4.59	6.88	1	1	2
Bolivia	4.74	4.44	6.11	1	1	1
Bosnia-Herzegovina	2.43	7.41	7.28	1	3	3
Botswana	4.61	5.33	5.47	1	1	1
Brazil	3.41	4.45	5.95	1	1	2
Bulgaria	1.86	6.59	5.26	1	4	3
Burkina Faso	5.36	2.48	6.69	2	1	3
Burundi	5.08	3.59	8.57	1	1	2
Cambodia	4.62	1.76	6.33	3	1	4
Cameroon	4.75	3.03	6.35	2	1	2

Country	**$Dis10_{HW}$**	**$Dis10_{EW}$**	**$Dis10_{ECW}$**	**$Final_{HW}$**	**$Final_{EW}$**	**$Fianl_{ECW}$**
Canada	1.07	7.79	6.08	1	7	6
Central African Republic	6.03	2.20	7.63	3	1	3
Chad	6.21	3.45	8.25	2	1	2
Chile	3.03	6.65	5.74	1	2	2
China	4.16	5.99	5.50	1	1	1
Colombia	3.94	3.74	6.22	1	1	2
Congo	5.69	4.01	7.99	1	1	2
Congo. Dem. Rep.	6.40	2.09	7.72	3	1	4
Costa Rica	3.37	3.08	5.39	1	1	2
Cote d'Ivoire	5.34	1.61	8.16	3	1	5
Croatia	1.93	6.14	4.54	1	3	2
Cuba	2.53	6.39	6.12	1	3	2
Cyprus	1.34	7.60	5.02	1	6	4
Czech Republic	1.30	7.19	2.02	1	6	2
Denmark	1.26	7.31	2.24	1	6	2
Dominican Republic	4.00	3.98	4.90	1	1	1
Ecuador	3.22	4.91	5.58	1	2	2
Egypt	2.55	7.07	6.04	1	3	2
El Salvador	3.72	5.17	6.25	1	1	2
Estonia	1.72	7.75	2.52	1	5	1
Ethiopia	5.46	1.56	7.48	3	1	5
Finland	0.60	6.57	2.47	1	11	4
France	1.03	6.46	5.32	1	6	5
Gabon	4.37	3.74	6.75	1	1	2
Gambia	5.36	4.37	7.67	1	1	2
Georgia	3.49	4.71	6.94	1	1	2
Germany	1.03	6.64	4.20	1	6	4
Ghana	4.81	2.84	7.07	2	1	2
Greece	1.53	7.16	7.05	1	5	5
Guatemala	4.38	2.58	6.11	2	1	2
Guinea	5.36	3.45	8.64	2	1	3
Guinea-Bissau	5.25	1.60	7.38	3	1	5
Guyana	4.30	6.27	6.91	1	1	2
Haiti	6.12	4.27	7.47	1	1	2
Honduras	4.36	3.51	5.76	1	1	2
Hungary	1.34	6.52	5.27	1	5	4
Iceland	0.55	6.35	7.75	1	11	14
India	4.88	5.25	6.97	1	1	1
Indonesia	3.57	4.65	6.04	1	1	2
Iran	3.16	7.04	6.26	1	2	2
Iraq	4.28	7.68	8.01	1	2	2
Ireland	0.99	7.82	6.57	1	8	7

Country	$Dis10_{HW}$	$Dis10_{EW}$	$Dis10_{ECW}$	$Final_{HW}$	$Final_{EW}$	$Fianl_{ECW}$
Israel	2.05	7.99	4.96	1	4	2
Italy	1.43	6.07	4.64	1	4	3
Jamaica	3.32	5.83	7.44	1	2	2
Japan	0.88	6.63	6.61	1	8	8
Jordan	2.97	7.85	7.29	1	3	2
Kazakhstan	2.84	7.66	6.34	1	3	2
Kenya	5.13	2.51	7.52	2	1	3
Korea, North	3.97	6.31	7.25	1	2	2
Korea, South	1.41	7.32	4.12	1	5	3
Kuwait	2.38	8.78	4.76	1	4	2
Kyrgyz Republic	3.47	4.80	6.76	1	1	2
Laos	4.01	3.10	6.71	1	1	2
Latvia	2.35	4.62	3.41	1	2	1
Lebanon	2.77	7.11	7.27	1	3	3
Liberia	5.27	4.34	7.94	1	1	2
Libya	2.72	8.13	7.31	1	3	3
Lithuania	1.91	6.30	3.63	1	3	2
Luxembourg	1.24	7.09	2.75	1	6	2
Macedonia	3.12	6.49	4.96	1	2	2
Madagascar	5.52	4.39	6.67	1	1	2
Malawi	4.60	2.25	7.61	2	1	3
Malaysia	2.92	6.08	5.48	1	2	2
Mali	5.12	4.59	7.36	1	1	2
Malta	2.33	7.83	6.69	1	3	3
Mauritania	5.20	5.66	8.34	1	1	2
Mexico	3.71	5.93	4.06	1	2	1
Moldova	3.13	6.53	5.17	1	2	2
Mongolia	3.83	7.19	7.60	1	2	2
Montenegro	2.15	4.63	6.39	1	2	3
Morocco	3.39	6.82	6.42	1	2	2
Mozambique	5.75	1.97	7.58	3	1	4
Myanmar	5.21	3.89	7.11	1	1	2
Namibia	4.91	5.80	6.77	1	1	1
Nepal	5.39	1.83	7.48	3	1	4
Netherlands	0.93	7.23	3.93	1	8	4
New Zealand	1.09	5.94	4.32	1	5	4
Nicaragua	4.74	2.90	6.93	2	1	2
Niger	5.95	4.54	7.26	1	1	2
Nigeria	5.64	2.50	7.20	2	1	3
Norway	0.56	6.30	1.95	1	11	3
Oman	2.69	8.28	7.27	1	3	3
Pakistan	4.86	5.05	6.76	1	1	1

Country	$Dis10_{HW}$	$Dis10_{EW}$	$Dis10_{ECW}$	$Final_{HW}$	$Final_{EW}$	$Fianl_{ECW}$
Panama	3.62	5.10	5.45	1	1	2
Papua New Guinea	5.52	5.52	6.61	1	1	1
Paraguay	4.37	4.57	5.88	1	1	1
Peru	3.78	5.51	4.95	1	1	1
Philippines	3.13	4.79	5.80	1	2	2
Poland	1.50	6.63	3.89	1	4	3
Portugal	1.37	6.05	6.24	1	4	5
Qatar	3.50	8.78	5.39	1	3	2
Romania	2.63	6.01	4.34	1	2	2
Russia	2.95	7.36	5.61	1	2	2
Rwanda	5.34	2.67	7.54	2	1	3
Saudi Arabia	2.88	7.88	6.59	1	3	2
Senegal	4.48	3.02	7.43	1	1	2
Serbia	2.19	6.27	7.39	1	3	3
Sierra Leone	5.96	3.52	6.75	2	1	2
Slovak Republic	1.28	6.24	3.08	1	5	2
Slovenia	1.30	6.21	2.58	1	5	2
South Africa	3.78	7.04	7.04	1	2	2
Spain	1.75	6.85	5.02	1	4	3
Sri Lanka	2.96	3.51	5.79	1	1	2
Sudan	5.85	4.80	8.01	1	1	2
Sweden	0.59	5.80	1.74	1	10	3
Switzerland	0.92	4.64	1.37	1	5	1
Syria	3.13	7.58	7.23	1	2	2
Taiwan	1.63	7.55	5.80	1	5	4
Tajikistan	4.09	5.47	7.22	1	1	2
Tanzania	5.31	1.66	7.54	3	1	5
Thailand	3.20	4.78	5.32	1	2	2
Togo	5.45	2.25	8.33	2	1	4
Trinidad and Tobago	2.96	6.83	7.31	1	2	2
Tunisia	2.58	6.99	5.34	1	3	2
Turkey	3.15	6.87	4.79	1	2	2
Turkmenistan	3.49	8.50	6.74	1	2	2
Uganda	5.04	3.16	5.44	2	1	2
Ukraine	2.97	7.17	5.67	1	2	2
United Arab Emirates	2.50	8.46	4.86	1	3	2
United Kingdom	1.22	6.22	5.14	1	5	4
United States	1.78	7.29	6.95	1	4	4
Uruguay	2.34	6.46	3.26	1	3	1
Uzbekistan	4.01	7.65	7.56	1	2	2
Venezuela	3.53	5.72	5.87	1	2	2
Vietnam	3.53	5.02	6.16	1	1	2
Yemen	5.13	7.56	8.12	1	1	2

Country	**$Dis10_{HW}$**	**$Dis10_{EW}$**	**$Dis10_{ECW}$**	**$Final_{HW}$**	**$Final_{EW}$**	**$Fianl_{ECW}$**
Zambia	5.65	3.62	7.66	2	1	2
Zimbabwe	5.33	2.91	8.72	2	1	3