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Transportation rating systems and social sustainability: A comprehensive analysis

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Transportation Rating Systems and Social Sustainability: A Comprehensive Analysis

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EXECUTIVE SUMMARY

The purpose of this study is to explore the social sector of sustainability in transportation design and engineering. Along with establishing a definition for social sustainability in transportation from existing literature, this document also includes a comprehensive analysis of current sustainability rating systems based on their evaluation of social sustainability metrics. The goal of this thesis is to inform transportation professionals about the existing social sustainability gaps in transportation literature and sustainability rating systems.

Social sustainability in transportation is comprised of two fundamental concepts: social equity and sustainability of community (Bramley and Power, 2009; Dempsey, 2009; McKenzie, 2004; Magis, 2010; Vallance, 2011). Social equity includes accessibility, safety, and health, and sustainability of community includes cohesion, participation, and awareness. A coding system based on a hierarchical representation of social sustainability terminology was developed to categorize the credits of six sustainable transportation rating systems: Greenroads, I-LAST, Envision, INVEST, GreenPaths, and STARS. The results of this study indicate that gaps exist between the definition and application of social sustainability in transportation. Since research in this sector of sustainability is underdeveloped compared to economic and environmental sustainability, social objectives were largely underrepresented in Envision, Greenroads, and I-LAST. Using a qualitative framework was helpful in understanding where gaps exist since the credits were interpreted based on interrelated themes and descriptions. After evaluating how each rating system quantifies social sustainability objectives, it was determined that GreenPaths and STARS are most inclusive of social credits.

I. INTRODUCTION AND BACKGROUND

Take a moment to think about what you did today. Did you go to work? Did you go to the grocery store? Did you go to school? If so, how did you get there? Transportation plays an integral role in our everyday lives. It provides us with the opportunity to travel locally, regionally, nationally, and even internationally with efficiency and ease. Transportation infrastructure has historically shaped our geography, economy, and society through the spread of new ideas, innovations, and opportunities. It has the ability to connect cultures and regions by creating access beyond an individual's immediate surroundings (Golub, 2014). As Bill Shuster, chairman of the US House Committee on Transportation and Infrastructure, stated, "Transportation is important. It's about people and how they live their lives…Our national transportation system binds us together" (CTI, 2013). *But could it also tear us apart?*

Background

According to the Congressional Budget Office, Federal spending on transportation in 2016 is estimated to total $98.7 billion, approximately 2% of the total federal budget (Congressional Budget Office, 2015). This is only a fraction of the total $1,723 billion investment needed to improve the surface transportation infrastructure rating to a 'B' by the year 2020 (ASCE Infrastructure Report Card, 2013). These federal dollars are being invested to repair aging infrastructure and expand existing networks to meet 21st Century needs (LCEF, 2011). But what exactly are those 21st Century needs? On October 5, 2009, President Obama signed Executive Order (EO) 13514 titled *Federal Leadership Environmental, Energy, and*

Economic Performance to set sustainability goals and performance metrics for federal agencies (White House, 2015). This Executive Order was eventually revoked on March 19, 2015 by EO 13693, *Planning for Federal Sustainability in the Next Decade,* which more specifically outlines sustainability and emission goals (White House, 2015).

It is evident that the federal government is committed to pursuing 21st Century sustainability goals, and this change in policy may appear to be a progressive measure towards a better future. However, sustainability is more than just a trendy concept. Rather, it is a complex area of study that requires an understanding of systems thinking and impact analysis. The idea of "sustainable development" became popularized in the 1980s, where it was used in the International Union for the Conservation of Nature's *World Conversion Strategy* (1980) and defined in the Brundtland Report as "*meeting the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED, 1987; Pisani, 2007). This concept was later revised and more broadly defined by the US Environmental Protection Agency (EPA) as "*the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations*" (USEPA, 2016). The EPA definition of sustainability illustrates the idea of the "Triple Bottom Line" (Figure 1), or the concurrent pursuit of social, environmental, and economic interests (Slaper, 2011; Oster, 2015). In this Venn Diagram model, ultimate sustainability is achieved when each sector is optimized, thus at the intersection of all three sectors, as indicated by the star on Figure 1 (Flint, 2004). It should be noted that other models have been developed to demonstrate different relationships between the three sectors of sustainability, but all agree that economy, society, and environment are interconnected and interdependent.

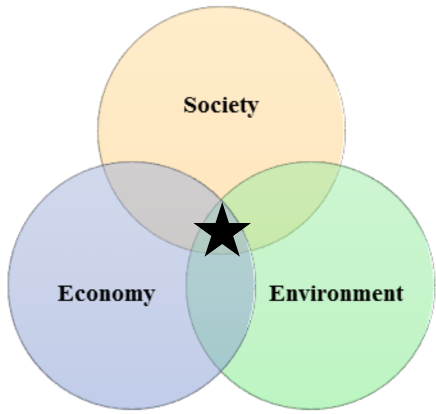


Figure 1: Venn Diagram Model of Sustainability (Flint, 2004)

The emergence of these definitions of sustainability has led to a new multidisciplinary design approach to transportation problems that converges sustainability science, social science, and engineering to achieve a balance between economic, environmental, and societal objectives (Mihelcic, 2003). The U.S. Department of Transportation (DOT) has developed their own *Strategic Sustainability Performance Plan*, which outlines sustainability goals and objectives for transportation expenditures to "*reduce the Department's direct and indirect energy and environmental impact and to protect our natural resources*" (U.S. DOT, 2011). While there is currently no universally accepted definition of sustainable transportation, there are a few frequently cited definitions, including the Centre for Sustainable Transportation, which defines it as,

> "*[A system that] allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations; is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy; and limits emissions and waste within the planet's ability to absorb them*" (CST, 2001).

Figure 2 highlights several other widely accepted definitions of sustainable transportation.

"A sustainable transport system is one that is accessible, safe, environmentally-friendly and affordable." *(European Conference of Ministers of Transport)* "The goal of sustainable transportation is to ensure that the environment, social and economic considerations are factored into decisions affecting transportation activity." *(Transport Canada)* "Sustainability is not about threat analysis; sustainability is about systems analysis. Specifically, it is about how environmental, economic, and social systems interact to their mutual advantage or disadvantage at various space-based scales of operation." *(Transportation Research Board)*

Figure 2: Existing definitions of transport sustainability (VTPI, 2014)

One reason why there is no universally accepted definition of sustainable transportation is due to the relative newness of this term. Figure 3 graphically depicts the growth of sustainability in transportation literature between the years 1950-2014.

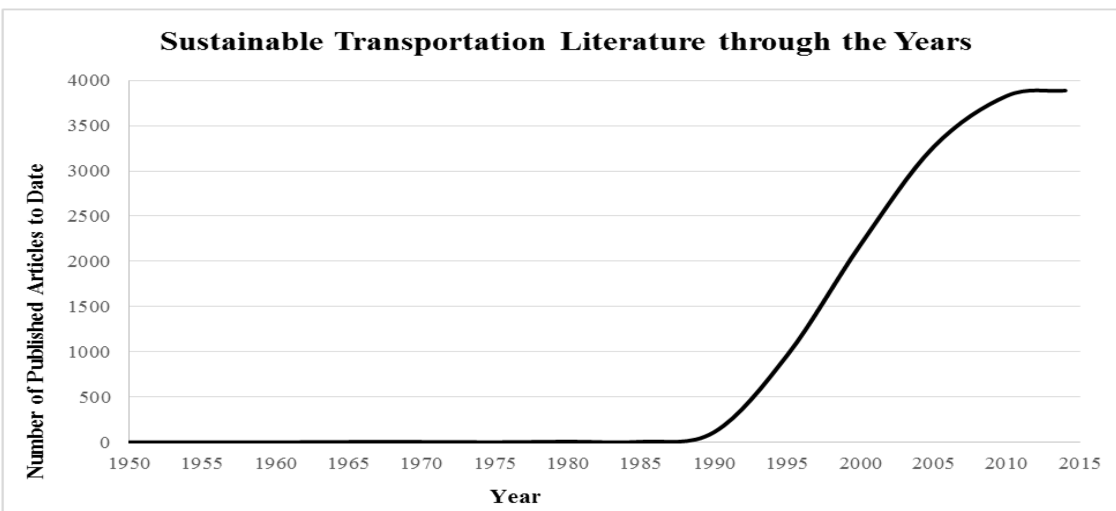


Figure 3: Published Sustainable Transportation Literature, 1950-2014 (trid.trb.org)

The data used to generate this graph was collected from the Transportation Research Board (TRB) Database (National Academy of Sciences, 2016). This graph indicates that sustainability was first introduced in the transportation sector around the time of the Brundtland Report publishing. Since then, the number of published transportation articles regarding sustainability has grown by nearly 800%. Some of these publications have focused on definitions and theoretical frameworks, while others present practical applications.

A more interesting finding from this data, however, suggests that each sector of sustainability (Economic, Environmental, Social), as outlined in the triple bottom-line approach, is not equally represented in transportation literature. Figure 4 graphically displays the occurrence of each sustainability sector in transportation literature between the years 1950-2014.

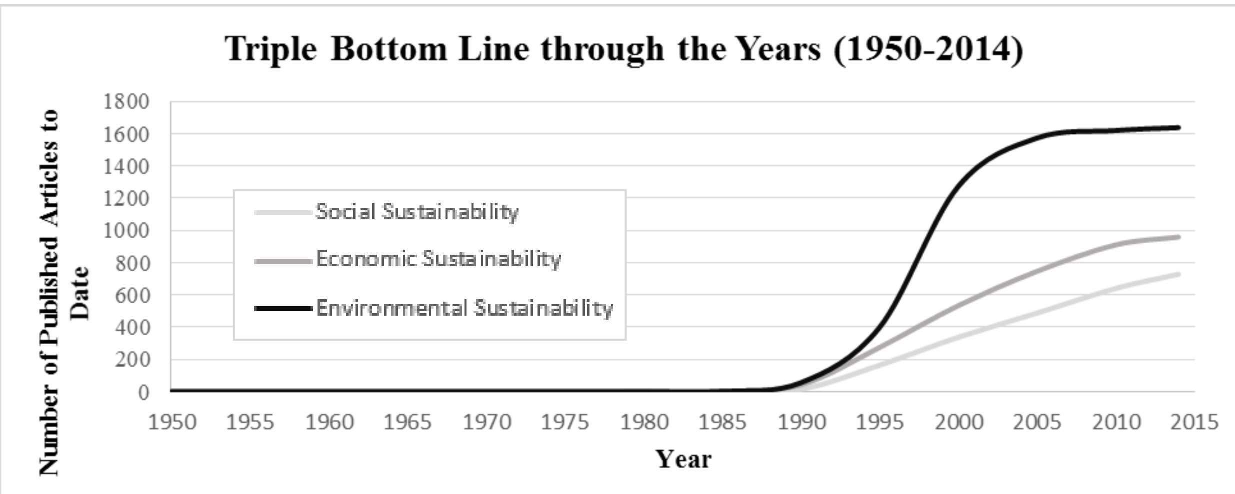


Figure 4: Triple Bottom Line in Transportation Literature, 1950-2014 (trid.trb.org)

This graph displays that the majority of TRB sustainability research has had an environmental focus, although the gap appears to be narrowing. Does this suggest that the environmental sector of sustainability is more important than the other two sectors? According to the triple bottom-line model, each sector is equal to one another, and sustainability is achieved only through the optimization of each sector. As previously stated, other models of sustainability exist, including the “nested-dependency model” (Figure 5), which suggests that each sector is nested and dependent upon one another (Doppelt, 2008; Senge, 2008).

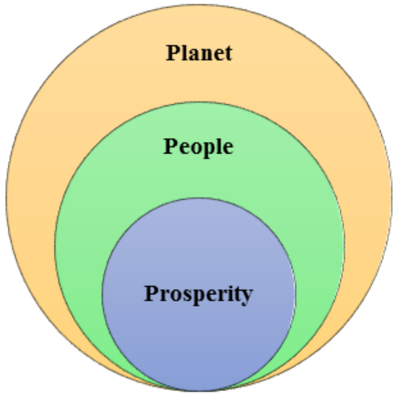


Figure 5: Nested-Dependency Model of Sustainability

As Figure 5 displays, the nested-dependency model demonstrates that environmental sustainability encompasses the other two sectors of sustainability; thus, without environmental sustainability, the other two sectors cannot exist. Perhaps this explains why so much attention has been directed towards the environmental sector in transportation literature throughout the last quarter century. Why then has there been such a comparatively small focus on social sustainability in transportation research through the years?

Objectives

This paper aims to explore the social sector of sustainability in transportation design and engineering. The overarching research questions for this study include:

1. How does existing literature define social sustainability in transportation design?

2. How do existing rating systems include social sustainability objectives?

The goal of this thesis is to inform transportation professionals about the existing social sustainability gaps in transportation literature and sustainability rating systems to ensure that “no community is left behind” (LCEF, 2011).

II. METHODOLOGY

Figure 6 outlines the methodology developed for this research project. This section introduces each stage of the process and provides references to where each corresponding section can be located in the report.

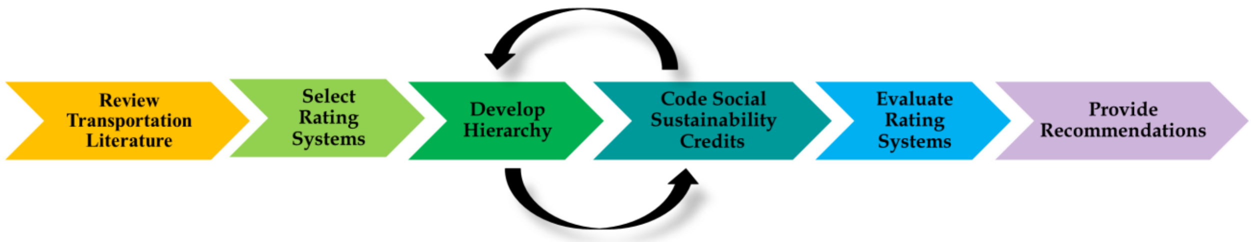


Figure 6: Methodology

The first stage in this process involved reviewing existing transportation literature to develop a better understanding of the research that has been completed in this field. Key research questions that were addressed during this stage included:

What is social sustainability in transportation design and why is it important?

How is social sustainability quantified for transportation projects?

Researching these questions provided insight into the work that has been completed in this field, as well as any current gaps and limitations. Section III: Social Sustainability and Transportation (pg. 16), answers these questions through a comprehensive review of existing social sustainability transportation literature.

The second stage was to select sustainable transportation rating systems to evaluate for their inclusion of social sustainability credits. The sustainable rating systems selected included: Greenroads, Illinois-Livable and Sustainable Transportation Rating System (I-LAST), Envision, Infrastructure Voluntary Evaluation Sustainability Tool (INVEST), GreenPaths, and Sustainable

Transportation Analysis and Rating System (STARS). Section IV: Transportation Rating Systems (pg. 20) provides an overview of each rating system.

The third stage of this process was to develop a social sustainability terminology hierarchy to code credits. This hierarchy is intended to provide a graphical representation of the information derived during the literature review process. A qualitative research method was utilized in order to analyze the literature and develop the hierarchy. The six steps of data analysis used to perform this qualitative study are as follows (Creswell, 2009):

1. *Organize and prepare* the data to be analyzed.
2. *Read through the data* to develop a general understanding of the information.
3. *Code the data*. (Coding is the "process of organizing material into chunks or segments of text before bringing meaning to information" (Rossman & Rallis, 1998)).
4. Use the coding process to *generate themes and descriptions*.
5. *Interrelate* the themes and desciptions.
6. *Interpret the meaning* of the themes and descriptions to capture the overall lessons learned from the study (Lincoln & Guba, 1985).

This process was used to organize and code information from the literature and selected rating systems to develop a complete hierarchy (Figure 7, pg. 36).

The forth stage of this process involved coding the social sustainability credits of each rating system based on the hierarchy. This was an iterative process, as indicated by the feedback arrow in Figure 6. Ultimately, each social credit was coded corresponding to the hierarchy and the results are included in Section VI: Coding of Transportation Rating Systems (pg. 37).

The fifth stage involved evaluating each rating system based on the coding results. Key questions evaluated during this process included:

What percentage of the total points/credits encompass social sustainability objectives?

How does each system quantify social sustainability?

Could certification be achieved without the implementation of any social credits?

The evaluation process of each rating system is located in Section VII: Evaluation of Transportation Rating Systems, (pg. 42). This section also includes an overview of how applying the GreenPaths rating system to a proposed transportation design in Harrisonburg, VA can measure the sustainability of a project.

The final stage is a discussion on the research conclusions and recommendations. Further information on this stage can be found in Section VIII: Conclusions and Recommendations (pg. 49).

III. SOCIAL SUSTAINABILITY AND TRANSPORTATION

On December 1, 1955, Rosa Parks was arrested for refusing to give up her seat to a boarding white passenger in Montgomery, Alabama (Sanchez, 2010). The 20th Century civil rights movement was integral to the evaluation of social equity in transportation systems, and eventually led to the 1961 Interstate Commerce Commission's ban on segregation of all interstate transportation facilities (LCEF, 2011; Sanchez, 2010). Social concerns in transportation did not stop there, however, and according to Angela Glover Blackwell--founder and CEO of PolicyLink-- "Transportation is back as a major civil rights issue. Today's focus is not on getting a seat at the front of the bus, but on making sure the bus takes us where we need to go" (LCEF, 2011).

Adequate transportation systems are necessary for individuals to fully participate in a society (VTPI, 2014; Golub, 2014). *But what if adequate systems do not exist within a community?* Transportation planning has historically "incentivized geographic expansion rather than improving infrastructure to accommodate larger, more densely populated areas" (LCEF, 2011). This has led to the decentralization of cities, or sprawl. As the demand for motorized travel increases, land use patterns and transportation systems are becoming more automobile dependent, thus limiting travel options for non-drivers, such as children, elders, disabled and low-income individuals (VTPI, 2014). Geographic expansion effects more than just the mobility of these people. It also creates barriers for disadvantaged groups to have equal access to health care, affordable housing, and economic opportunities (Sanchez, 2010; Mercier, 2009; Litman, 2012; Litman, 2015). This section explores the social sector of sustainability in transportation design by developing a definition for it based on existing literature.

Social sustainability is the least defined sector of sustainability and sustainable development (Dempsey, 2009). It is a dynamic concept that is indirect and difficult to measure (Dempsey, 2009; VTPI, 2014). There is a need to develop a better understanding of this concept and how it can be applied to sustainable transportation development; however, existing research in this area is limited and disjointed. Although social sustainability is a broad and multi-dimensional idea, research suggests that it is comprised of two foundational concepts: "social equity" and "sustainability of community" (Bramley and Power, 2009; Dempsey, 2009; McKenzie, 2004; Magis, 2010; Vallance, 2011).

Social equity is "the fairness in distribution of resources and opportunities" (Litman, 2012; VTPI, 2014). With a foundation in social justice, environmental justice, and distributive justice, social equity in an urban environment, such as transportation infrastructure, is related to social and environmental exclusion (Burton, 2000; Dempsey, 2009). Transportation projects that reduce social and environmental exclusion are considered equitable and, therefore, socially sustainable. Research suggests that social equity objectives can be measured by several key indicators, including accessibility, safety, and health (Barton, 2000; Manaugh, 2015; Litman, 2012).

Accessibility is a fundamental measurement of social equity (Barton, 2000). It refers to an individual's ability to attain goods, services, and activities based on factors including mobility, transportation options, system connectivity, mobility substitutes and land use patterns (Litman, 2012; Alba, 2003). Common accessibility indicators include the quality of available transport options, average trip distances, and costs per trip (Litman, 2016; Zietsman et al., 2011). It is important to note that in regards to equity, mobility is not an independent entity, but rather encompassed in accessibility. Conventional transportation planning tends to focus on improved mobility, or vehicle travel (Litman, 2016; Handy, 2002). Mobility indicators include traffic speeds, roadway Level of Service, and costs per vehicle-mile (Litman, 2016; Litman, 2002). Unfortunately, by designing systems that only move vehicles faster and further, non-motorists become socially excluded due to reduced access and increased safety concerns. When evaluating social equity in transportation, “basic mobility” refers to travel that provides basic access to goods, services, and activities (Litman, 2016). Basic mobility is not limited to only vehicular travel. In fact, when evaluating accessibility, mobility is encompassed in multimodal transport alternatives, including active transportation, mass transportation, vehicular transportation, or any combination of the three. Another fundamental concept of accessibility is users. As previously discussed, individuals with social, economical, physical, or cultural barriers face exclusion when it comes to travel (Fan and Huang, 2011; Jiao and Dillivan, 2013). It is important that transportation systems are designed to accommodate users of all ages and abilities. Land usage is another indicator of accessibility. Mixed-use and high density areas allow individuals to have increased access to different amenities, such as employment, education, and retail.

Research indicates that safety and health impacts related to transportation infrastructure are not distributed evenly across the population (Botchwey, 2009; Ross, 2012). According to Transportation for America’s report, *Dangerous by Design*, “Pedestrian crashes are becoming deadlier, with the probability of a collision resulting in the death of a pedestrian increasing by more than one-third in just ten years. Children, older adults, and racial ethnic minorities are disproportionately represented in this figure” (Ernst, 2011). Research also suggests that as bicycle and pedestrian trips increase, bicyclists and pedestrians are less likely to be involved in a motor vehicle collision (Jacobsen, 2003). Therefore, by designing transportation systems that increase physical activity through multimodal design, both health and safety can improve.

Improved health and safety conditions create a more equitable transportation system, and, thus, increase its social sustainability.

The second underlying concept of social sustainability is “sustainability of community”, or “the ability of society…to sustain and reproduce itself at an acceptable level of functioning”. Sustainability of community is related to a “prevailing social order in neighborhoods and the support of social interaction and networks between all residents” (Dempsey, 2009). This concept is built on three fundamental components: Cohesion, Participation, and Awareness. Cohesion refers to the “ongoing integration of behaviors of residents in a given neighborhood” (Dempsey, 2009). Participation is the inclusion of “as many social groups as possible in decision-making processes” (Murphy, 2012). When individuals are involved in the decision-making process, societies are able to build consensus, develop legitimacy, and resolve potential conflicts (Toke, 2008). By increasing public engagement, social cohesion and social sustainability goals can be met (Goodland, 2002). Awareness is associated with raising public attention to sustainability issues with a “view to encouraging alternative, sustainable consumption patterns”. Indicators of awareness include advertising campaigns, sponsored events, and educational outreach programs. As previously stated, “awareness for sustainability receives relatively less treatment in the social sustainability literature”, therefore education is a key objective to obtaining social sustainability (Murphy, 2012).

IV. TRANSPORTATION RATING SYSTEMS

Rating systems aid in achieving sustainability goals by quantifying sustainability objectives through metrics, evaluation methods, and best practices models. LEED (Leadership in Energy and Environmental Design) was a pioneering point-based certification system for sustainable building design, and it has since expanded to include other methods of evaluation including: Interior Design and Construction, Building Operations and Maintenance, Neighborhood Development, and Homes (LEED, 2015). Although this rating system has received criticism, including its focus on maximizing economic benefits to users, LEED has also served as a prominent model for developing assessment tools to evaluate the sustainability of transportation projects (Curz, 2012). Sustainability rating systems allow users to incorporate sustainable practices into transportation processes and programs by evaluating existing infrastructure or informing design decisions. The extent to which each rating system analyzes social equity, economic prosperity, and environmental health varies; however, literature suggests that transportation frameworks disproportionately benefit the evaluation of economic and environmental impacts over those of social concerns (Litman, 2012; Dondero, 2012; Curz, 2012). This incomplete sustainability analysis calls for a more comprehensive and systematic approach to defining, measuring, and evaluating social impacts to encourage communities to incorporate social sustainability objectives into transportation design (Mercier, 2009; Manaugh, 2015; Litman, 2012). This section provides an overview of the six sustainable transportation analysis tools that were selected for this study: Greenroads, I-LAST, Envision, INVEST, GreenPaths, and STARS.

Greenroads

Greenroads is an award-based, third-party certified, sustainability rating system with a fundamental goal of changing the way transportation projects are built. Developed in 2007 at the University of Washington, Greenroads has been used in over 80 transportation projects around the world (Greenroads, 2016). A "greenroad" is defined as a "roadway project that has been designed and constructed to a level of sustainability that is substantially higher than current common practices" (Greenroads, 2016). Submitted projects are evaluated and awarded with a credit system. The credits are organized into two categories: Project Requirements (PR) and Voluntary Credits (VC). There are 11 PRs that every Greenroads project must satisfy (Table 1).

Project Requirements (PR)	
PR-1	Environmental Review Process
PR-2	Lifecycle Cost Analysis (LCCA)
PR-3	Lifecycle Inventory (LCI)
PR-4	Quality Control Plan
PR-5	Noise Mitigation Plan
PR-6	Waste Management Plan
PR-7	Pollution Prevention Plan
PR-8	Low Impact Development (LID)
PR-9	Pavement Management System
PR-10	Site Maintenance Plan
PR-11	Educational Outreach

Table 1: Project Requirements (PR) for Greenroads

The PRs are intended to encompass the most fundamental levels of sustainability, including:

- Environmental and economic decision-making
- Public engagement

- Design for long-term environmental performance
- Construction planning
- Planning for lifetime monitoring and maintenance.

Additionally, there are 37 VCs and two Custom Credits (CC), cumulatively totaling 118 points. The VCs are divided into five categories: Pavement Technologies, Materials & Resources, Construction Activities, Environment & Water, and Access & Equity. A complete listing of the Voluntary Credits can be located in Table 2. After completing the 11 PRs, projects can complete VCs to earn certification awards. The certification levels and corresponding point values include: Bronze/Certified (32-42), Silver (43-53), Gold (54-63), and Evergreen (64+).

Voluntary Credits (VC)			
Environment & Water (EW)		Construction Activities (CA)	
EW-1	Environmental Management System	CA-1	Quality Management System
EW-2	Runoff Flow Control	CA-2	Environmental Training
EW-3	Runoff Quality	CA-3	Site Recycling Plan
EW-4	Stormwater Cost Analysis	CA-4	Fossil Fuel Reduction
EW-5	Site Vegetation	CA-5	Equipment Emissions Reduction
EW-6	Habitat Restoration	CA-6	Paving Emissions Reduction
EW-7	Ecological Connectivity	CA-7	Water Tracking
EW-8	Light Pollution	CA-8	Contractor Warranty
Access & Equity (AE)		Materials & Resources (MR)	
AE-1	Safety Audit	MR-1	Life Cycle Assessment
AE-2	Intelligent Transportation Systems (ITS)	MR-2	Pavement Reuse
AE-3	Context Sensitive Solutions	MR-3	Earthwork Balance
AE-4	Traffic Emissions Reduction	MR-4	Recycled Materials
AE-5	Pedestrian Access	MR-5	Regional Materials
AE-6	Bicycle Access	MR-6	Energy Efficiency
AE-7	Transit Access	Pavement Technologies (PT)	
AE-8	Scenic Views	PT-1	Long-Life Pavement
AE-9	Cultural Outreach	PT-2	Permeable Pavement
Custom Credits (CC)		PT-3	Warm Mix Asphalt (WMA)
CC-1	Custom Credit 1	PT-4	Cool Pavement
CC-2	Custom Credit 2	PT-5	Quiet Pavement
Greenroads Total Points: 118		PT-6	Pavement Performance Tracking

Table 2: Voluntary Credits (VC) for Greenroads

I-LAST

The goal of the I-LAST (Illinois- Livable and Sustainable Transportation) Rating System and Guide is to incorporate sustainable practices into the development and completion of state highway projects (I-LAST, 2010). This sustainability performance metric system was developed by the Joint Sustainability Group of the Illinois Department of Transportation (IDOT), the American Council of Engineering Companies (ACEC), and the Illinois Road and Transportation Builders Association (IRTBA). I-LAST contains a checklist of sustainable practices with corresponding point values to evaluate the sustainable measures included in a state highway project. Unlike other rating systems, I-LAST does not award certification levels based upon cumulative point values. Since all state highway projects are unique and have different needs, projects are evaluated based only on their inclusion of practices that were applicable to the project. Projects can be evaluated for sustainability at the beginning of the project to determine which metrics are applicable, at the end of the design phase to determine which credits were met, and during the construction phase. Table 3 displays the I-LAST Rating System and Guide categories and subcategories.

Category	Subcategory	
Planning	P-1	Context Sensitive Solutions
	P-2	Land Use/Community Planning
Design	D-1	Alignment Selection
	D-2	Context Sensitive Design
Environmental	E-1	Protect, Enhance or Restore Wildlife and its Habitat
	E-2	Trees and Plant Communities
	E-3	Noise Abatement
Water Quality	W-1	Reduce Impervious Area
	W-2	Stormwater Treatment
	W-3	Construction Practices to Protect Water Quality
Transportation	T-1	Traffic Operations
	T-2	Transit
	T-3	Improve Bicycle & Pedestrian Facilities
Lighting	L-1	Reduced Electrical Consumption
	L-2	Stray Light Reduction
Materials	M-1	Materials
Innovation	I-1	Innovation

Table 3: I-LAST Rating System and Guide Credits

Envision

Envision is a project assessment tool and design guide intended to "foster a dramatic and necessary improvement in the performance and resiliency of our physical infrastructure across the full dimensions of sustainability" (Envision, 2014). Envision was created by the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure (ISI). This tool is comprised of 60 sustainability credits intended to provide industry-wide sustainability metrics for all infrastructure types, including: Energy, Water, Waste, Transport, Landscape, and Information. This tool is not intended to evaluate buildings or facilities. The credits are organized into five categories (Table 4): Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Risk.

Category	Subcategory	
Quality of Life	QL1	Purpose
	QL2	Wellbeing
	QL3	Community
Leadership	LD1	Collaboration
	LD2	Management
	LD3	Planning
Resource Allocation	RA1	Materials
	RA2	Energy
	RA3	Water
Natural World	NW1	Siting
	NW2	Land and Water
	NW3	Biodiversity
Climate and Risk	CR1	Emissions
	CR2	Resilience

Table 4: Envision Credits

The Envision assessment tool can be used to help stakeholders make design decisions or to assist infrastructure projects in becoming Envision verified. The assessment tool measures project outcomes, not intentions, and is comprised of a yes/no questionnaire based on the Envision rating system. Projects pursuing certification must receive at least 20% of the applicable points to receive a Bronze Award, 30% for a Silver Award, 40% for a Gold Award, and 50% for a Platinum Award.

INVEST

INVEST (Infrastructure Voluntary Evaluation Sustainability Tool) is a web-based self-evaluation tool developed by the Federal Highway Association (FHWA) to allow transportation agencies to assess and enhance the sustainability of their projects and programs (INVEST, 2015). The tool is comprised of sustainability best practices, or criteria, which are divided into four modules to cover the full lifecycle of transportation services. The modules include: System Planning for States (SPS), System Planning for Regions (SPR), Project Development (PD), and Operations and Maintenance (OM). Each module is evaluated separately and contains 14-33 criteria. The criteria are intended to assist transportation planners in achieving sustainability goals within that module. SPS credits are geared towards states, tollways, and local agencies; SPR credits focus on metropolitan planning organizations and government councils; PD credits cover project-specific planning, design, and construction goals; and OM credits evaluate an agency's internal administration and operations. For the purpose of comparison to other rating systems, only the PD and OM modules will be evaluated in this study. Table 5 displays the criteria for these two modules. A list SPS and SPR criteria can be located at www.sustainablehighways.org.

Project Development (PD)	Operations and Maintenance (OM)
1. Economic Analyses 2. Lifecycle Cost Analyses 3. Context Sensitive Project Development 4. Highway and Traffic Safety 5. Educational Outreach 6. Tracking Environmental Commitments 7. Habitat Restoration 8. Stormwater Quality and Flow Control 9. Ecological Connectivity 10. Pedestrian Facilities 11. Bicycle Facilities 12. Transit and HOV Facilities 13. Freight Mobility 14. ITS for System Operations 15. Historic, Archaeological, and Cultural Preservation 16. Scenic, Natural, or Recreational Qualities 17. Energy Efficiency 18. Site Vegetation, Maintenance and Irrigation 19. Reduce, Reuse and Repurpose Materials 20. Recycle Materials 21. Earthwork Balance 22. Long-Life Pavement 23. Reduced Energy and Emissions in Pavement Materials 24. Permeable Pavement 25. Construction Environmental Training 26. Construction Equipment Emission Reduction 27. Construction Noise Mitigation 28. Construction Quality Control Plan 29. Construction Waste Management 30. Low Impact Development 31. Infrastructure Resiliency Planning and Design 32. Light Pollution 33. Noise Abatement	1. Internal Sustainability Plan 2. Electrical Energy Efficiency and Use 3. Vehicle Fuel Efficiency and Use 4. Reduce, Reuse and Recycle 5. Safety Management 6. Environmental Commitments Tracking System 7. Pavement Management System 8. Bridge Management System 9. Maintenance Management System 10. Highway Infrastructure Preservation and Maintenance 11. Traffic Control Infrastructure Maintenance 12. Road Weather Management Program 13. Transportation Management and Operations 14. Work Zone Traffic Control

Table 5: INVEST Project Development (PD) and Operations & Maintenance (OM) Criteria

GreenPaths

GreenPaths is a transportation rating system designed to evaluate social, environmental, and economic sustainability objectives of shared-use paths (Beiler, 2015). Created by transportation professionals, GreenPaths utilizes an analytical hierarchy process (AHP) to establish sustainability criteria and weightings that objectively evaluate the design and construction of shared-use paths. The criteria are organized into five categories (Table 6): Planning and Location (PL), Green Construction (GC), Infrastructure and Amenities (IA), Continuing Practices (CP), and Project Specific (PS). Each criteria (credit) has a maximum achievable point value based on the results from the AHP model. Points are awarded to projects based on whether or not they meet the performance metric of each credit. The maximum achievable point value in the GreenPaths rating system is 182. Projects are then assigned a certification level based on their performance. The certification levels and corresponding point values are as follows: Certified (66-82), Silver (83-99), Gold (100-132), and Platinum (133-182). It is important to note that as of 2016, GreenPaths is still in development.

Category	Credit
Planning and Location (PL)	1. Project Goals 2. Context Sensitive Solutions 3. Lifecycle Cost Analysis 4. Local, diverse Project Team 5. Repurposed Land Use 6. Agricultural Land & Wetland Conservation 7. Scenic, Historic, and Cultural Enhancement 8. Compact Development 9. Mixed Land Uses 10. Diverse Communities 11. Access Points 12. Multimodal Connectivity 13. ADA Accessibility
Green Construction (GC)	1. Waste Management Strategy 2. Minimize Site Disturbance 3. Recycled Materials 4. Regional Materials 5. Trail Mix Material 6. Permeable Surface 7. Cool Surface 8. Stormwater Management 9. Site Vegetation 10. Protection from Steep Slopes & Waterways
Infrastructure and Amenities (IA)	1. Historical Outreach 2. Wildlife Protection 3. Rest Areas 4. Restroom Accessibility 5. Green Restrooms 6. Hydration Stations 7. Trailhead Lighting 8. Path and Intersection Lighting 9. Energy Efficient Lighting 10. Bicycle Parking 11. Bicycle Friendly Attractions 12. Trailhead Surveillance 13. Emergency Call Boxes 14. Locational Signage 15. Multimodal Intersection Safety
Continuing Practices (CP)	1. Seasonal Maintenance 2. Waste Management Plan 3. Recycling Facilities 4. Waste Facilities 5. Art Connection 6. Public Outreach 7. Shared-use Path Watch Program
Project Specific (PS)	1. Innovation 2. Sustainability Expert

Table 6: GreenPaths Criteria

STARS

The Sustainable Transportation Analysis and Rating System (STARS) was developed and piloted by the North American Sustainable Transportation Council (STC) from 2009-2015. This integrated planning framework was developed to “help planners, communities, and decision makers evaluate the impacts of transportation plans and projects, identify innovative strategies and improve decision making” (STC, 2010). Distinguishing features of STARS is its “upstream” approach to improving access, and its flexible framework that encourages projects to achieve multiple sustainability goals. STARS does not award certification levels based on points. Instead, each credit is weighted equally, allowing users to optimize shared benefits across all credit categories. STARS includes a framework for both transportation projects and transportation planning. For comparative reasons, only the STARS Project credits will be evaluated in this study (Table 7).

Category	Subcategory	
Collaboration	CO1	Develop an interdisciplinary team
	CO2	Workshop(s)
	CO3	Multi-agency collaboration
Community Engagement	C1	Engagement Plan
Access	A1	Establish access goals and objectives
	A2	Evaluate expanded transportation demand management strategies
	A3	Evaluate expanded transportation system management strategies
	A4	Evaluate expanded transportation supply and service
Climate and Energy	CE1	Establish climate and energy goals and objectives
	CE2	Evaluate (infrastructure and service) vehicle mile reduction strategies
	CE3	Evaluate improving vehicle flow
	CE4	Evaluate construction materials and methods
	CE5	Evaluate renewable energy and energy efficiency
Cost Effectiveness Analysis	CEA1	Cost estimation and cost-effectiveness calculations
	CEA2	Selecting cost-effective projects and programs
Safety and Health	SH1	Improve multimodal safety, especially for the most vulnerable users
	SH2	Improve health by increasing physical activity
	SH3	Improve air quality
Equity	E1	Reduce disparities in healthy, safe access to key destinations for transportation disadvantaged
	E2	Demonstrate that investments do not disproportionately impact transportation disadvantaged
Economic Benefit	EB1	Re-invest in the local economy
	EB2	Improve economic access
	EB3	Improve travel time reliability and speed consistency for high value trips
Innovation	IV1	Additional actions resulting in more access and/or GHG Reductions
	IV2	Actions improving STARS effectiveness

Table 7: STARS Project Credits

V. OVERVIEW OF CODING SYSTEM

A coding system was developed from the hierarchy in Figure 7 to effectively organize and communicate the social sustainability credits of each rating system. Figure 7 organizes the literature reviewed for this study and is a graphical representation of social sustainability in transportation. This hierarchy also plays a dominant role in evaluating each rating system based on their inclusion of social credits.

The hierarchy is organized from top to bottom, with the top members representing "big picture" concepts (i.e. "Social Sustainability"), and each subsequent layer representing more specific concepts. The lowest level represents transportation performance measures. Performance measures are "indicators that enable decision-makers and other stakeholders to monitor changes in system condition and performance against established visions, goals, and objectives" (Herbel et al., 2009). The hierarchy includes both "Process Measures" (Blue) and "Outcome Measures" (Orange). Outcome measures, or "core measures", measure overall progress and how effectively policies, plans, or projects achieve desired results (Herbel et al., 2009; Amekudzi et al., 2010). Process measures, or "activity measures", measure actions taken to develop transportation plans and programs (Herbel et al., 2009; Amekudzi et al., 2010). This level includes specific and measurable programs and processes that can be implemented in a project to improve the social sustainability of the design. The rating systems most often included credits that could be linked to this level of the hierarchy.

Rating systems were coded based on the credit categories (alphabetic categorization) and corresponding credit subcategories (numeric categorization). The coding process was inductive and involved working upward from the lowest level of the hierarchy in order to reach the credit category level (Green). Credits that could be linked to the hierarchy were organized into a separate spreadsheet and coded based on the alphabetic and numeric system (Table 8).

Credit Categories		Credit Subcategories	
AC	Accessibility	**1**	Access Management Plan
		2	Diverse Users
		3	Land Usage
		4	Multimodal
S	Safety	**1**	Programs
		2	Amenities
H	Health	**1**	Physical
		2	Physiological
		3	Psychological
C	Cohesion	**1**	Community
		2	Social Resources
		3	Goals & Objectives
P	Participation	**1**	Engagement
		2	Leadership
A	Awareness	**1**	Education

Table 8: Credit Coding System

Table 9 shows an example of how a credit from I-LAST was coded based on this system.

ID	Credit	Subcategory	Category	Code
P2-b	Accommodate multi-modal transportation uses	Multi-modal (4)	Accessibility (AC)	AC.4

Table 9: Credit Coding Example

During the coding process, it was important to maintain consistency across each of the rating systems. This was an iterative process, and each rating system was reviewed multiple times to ensure that the coding was applied only to credits achieving social objectives. Many credits applied to multiple sustainability categories, which made it difficult to determine whether or not they should be included in the analysis. Ultimately, credits were selected based on their name and description, as well as any supplemental information provided by the rating system. Credits that applied to multiple sustainability sectors were not included if they appeared to have a greater economic or environmental focus, and this was carried over through all the rating systems that included similar credits. Exceptions to this rule were made if the supplemental information referenced a direct societal benefit.

In order to ensure qualitative reliability, an additional coder will be selected to evaluate each rating system for social credits based on the developed coding system. It is important that the coding system provides repeatability and interrater reliability to ensure that information can be interpreted similarly by different raters. Section VIII. Conclusions and Recommendations (pg. 49) contains additional information on the reliability procedures of this study.

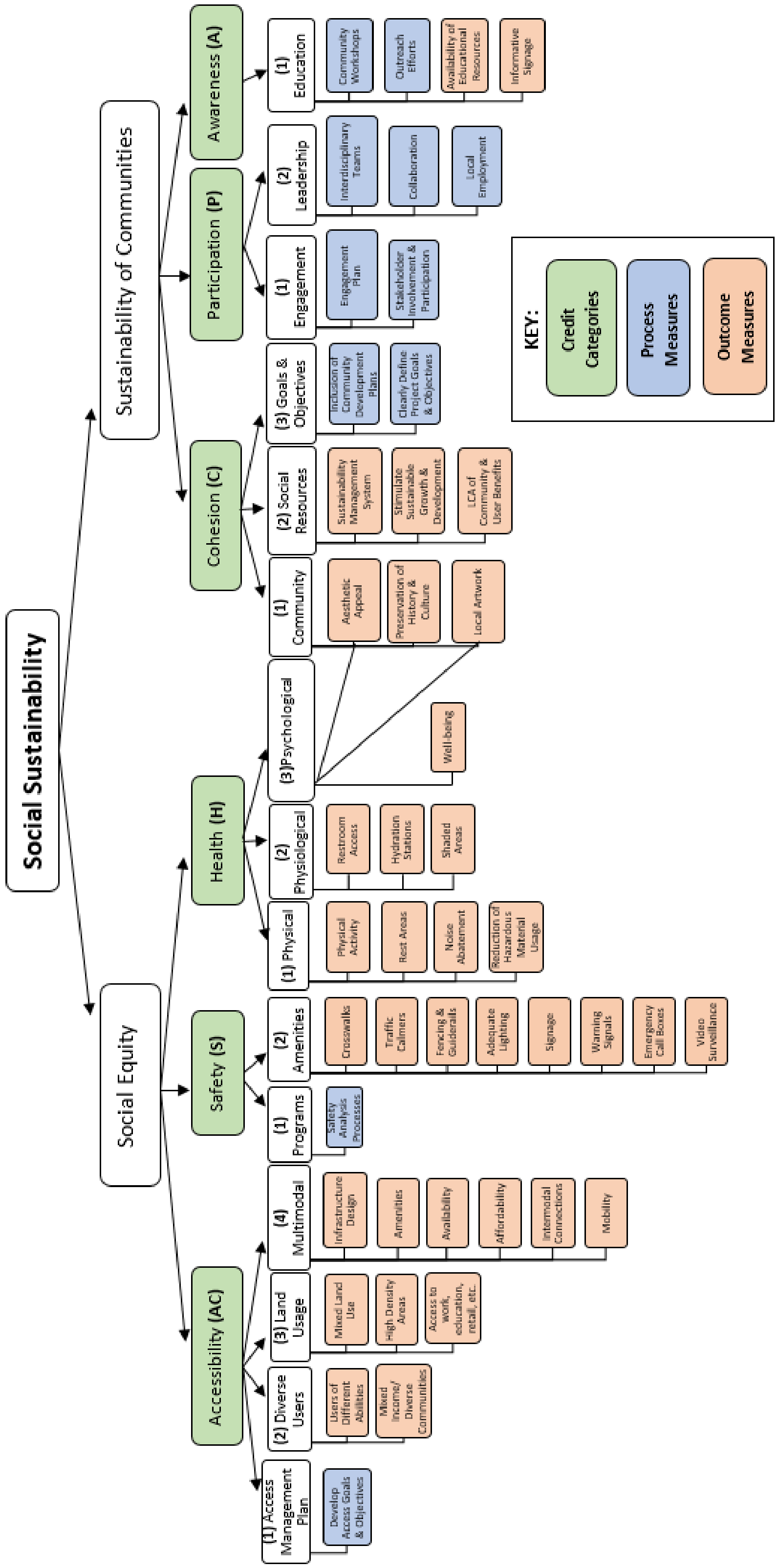


Figure 7: Social Sustainability Hierarchy

VI. CODING OF TRANSPORTATION RATING SYSTEMS

This section outlines the credits of each rating system that encompass social sustainability objectives. Table 10 organizes the following information: rating system, credit category, identification number, credit name, available points (if applicable), and hierarchy code.

Rating System	Category	ID	Credit	Points	Code
Greenroads	Project Requirements	PR-5	Noise Mitigation Plan	N/A	H.1
		PR-11	Educational Outreach	N/A	A.1
	Access & Equity	AE-1	Safety Audit	2	S.1
		AE-2	Intelligent Transportation Systems (ITS)	5	AC.4
		AE-3	Context Sensitive Solutions	5	C.3
		AE-5	Pedestrian Access	2	AC.4
		AE-6	Bicycle Access	2	AC.4
		AE-7	Transit Access	5	AC.4
		AE-8	Scenic Views	2	C.1
		AE-9	Cultural Outreach	2	C.1
I-LAST	Context Sensitive Solutions	P-1a	Identify stakeholders & develop stakeholders involvement plan	2	P.1
		P-1b	Engage stakeholders to conduct Context Audit and develop project purpose	2	P.1
		P-1c	Involve stakeholders to develop and evaluate alternatives	2	P.1
		P-1d	Employ stakeholder involvement techniques to achieve consensus for preferred project alternative	2	P.1
	Land Use/ Community Planning	P-2a	Promote reduction in vehicle trips by accommodating increased use of public transit	2	AC.4
		P-2b	Accommodate multi-modal transportation uses	2	AC.4
		P-2e	Project is consistent with regional plans & local managed growth-based Master or Comprehensive Plans	2	C.3
		P-2f	Project is compatible with local efforts for Transit Oriented Design	1	C.3
	Alignment Selection	D-1d	Avoid impacts to socioeconomic resources	3	SE
	Context Sensitive Design	D-2c	Visual enhancements	2	C.1
		D-2d	Items fit context of surroundings	1	C.1
		D-2e	Bridge aesthetics	1	C.1
	Noise Abatement	E-3a	Construction of noise barriers	3	H.1
		E-3b	Incorporate traffic system management techniques to reduce existing noise levels	2	H.1
		E-3c	Provide a buffer zone for adjacent receptors	2	H.1
		E-3d	Provide sound insulation to public or non-profit institutional structures	1	H.1
		E-3e	Tining of pavement to reduce noise levels	2	H.1
		E-3f	Provide plantings or sight screens to separate	1	C.1

			receptors from roadway		
	Transit	T-2a	Provide new Park-and-Ride lots	2	AC.4
		T-2b	Operational improvements of an existing Park-and-Ride lot	1	AC.4
		T-2c	Provide bike accommodations at Park-and-Ride lot	1	AC.4
		T-2d	Improved shading through vegetation at Park-and-Ride lots	1	H.2
		T-2e	Provide new multi-modal connections	1	AC.4
		T-2f	Include bus stops with shelters or pads and pedestrian access	1	AC.4
		T-2g	Installation of a transit express system	3	AC.4
	Improve Bicycle & Pedestrian Facilities	T-3a	Assess Conditions- Perform bicycle and pedestrian level of service analysis within the roadway corridor	1	AC.4
		T-3b	Improve intersection designs for pedestrians	2	AC.4
		T-3c	Provide new or rehabilitate existing sidewalks or bikeways	3	AC.4
		T-3d	Sidewalk or bikeway widening	2	AC.4
		T-3e	Designated space for cyclists (shared lanes)	1	AC.4
		T-3f	Striped bike lanes within roadway	2	AC.4
		T-3g	Restore or pave shoulders for bicycling	2	AC.4
		T-3h	Create parallel bike routes	1	AC.4
		T-3i	Align the roadway to facilitate the development of future multiuse paths & facilities	1	AC.4
		T-3j	Provide new grade-separated bike/pedestrian crossing structure	3	AC.4
		T-3k	Install bikeway signs	1	S.2
		T-3l	Install bicycle racks	1	AC.4
Envision	Purpose	QL1.1	Improve Community Quality of Life	2-25	H.3
		QL1.2	Stimulate Sustainable Growth & Development	1-16	C.2
		QL1.3	Develop Local Skills & Capabilities	1-15	P.2
	Wellbeing	QL2.1	Enhance Public Health & Safety	2-16	H,S
		QL2.2	Minimize Noise and Vibration	1-11	H.1
		QL2.4	Improve Community Mobility & Access	1-14	AC.4
		QL2.5	Encourage Alternative Modes of Transportation	1-15	AC.4
		QL2.6	Improve Accessibility, Safety, & Wayfinding	3-15	AC
	Community	QL3.1	Preserve Historic & Cultural Resources	1-16	C.1
		QL3.2	Preserve Views & Local Character	1-14	C.1
		QL3.3	Enhance Public Space	1-13	AC.3
	Collaboration	LD1.1	Provide Effective Leadership & Commitment	2-17	P.2
		LD1.2	Establish a Sustainability Management System	1-14	C.2
		LD1.3	Foster Collaboration & Teamwork	1-15	P.2
		LD1.4	Provide for Stakeholder Involvement	1-14	P.1
INVEST	Project Development	PD-03	Context Sensitive Project Development	10	C.3
		PD-04	Highway and Traffic Safety	10	S.1
		PD-05	Educational Outreach	2	A.1
		PD-10	Pedestrian Facilities	3	S.2, AC.2
		PD-11	Bicycle Facilities	3	S.2, AC.2
		PD-12	Transit and HOV Facilities	5	AC.4
		PD-15	Historic, Archaeological, and Cultural Preservation	3	C.1
		PD-16	Scenic, Natural, or Recreational Qualities	3	C.1, H.1,

					H.3
		PD-27	Construction Noise Mitigation	2	H.1
		PD-33	Noise Abatement	5	H.1
	Operations and Maintenance	OM-1	Internal Sustainability Plan	15	C.2
		OM-5	Safety Management	15	S.1
		OM-11	Traffic Control Infrastructure Maintenance	15	S.2
		OM-12	Road Weather Management Plan	15	AC.4
		OM-14	Work Zone Traffic Control	15	S.2
STARS	Collaboration	CO1	Develop an interdisciplinary team	N/A	P.2
		CO2	Workshop(s)	N/A	A.1
		CO3	Multi-agency collaboration	N/A	P.2
	Community Engagement	C1	Engagement Plan	N/A	P.1
	Access	A1	Establish Access Goals and Objectives	N/A	AC.1
		A4	Evaluate Expanded Transportation Supply and Service	N/A	AC.4
	Safety & Health	SH1	Improve multimodal safety, especially for the most vulnerable users	N/A	S.2
		SH2	Improve health by increasing physical activity	N/A	H.1
	Equity	E1	Reduce disparities in health, safe access to key destinations for transportation disadvantaged	N/A	AC
		E2	Demonstrate that investments do not disproportionately impact trans disadv	N/A	AC
	Economic Benefit	EB2	Improve economic access	N/A	AC.3
GreenPaths	Planning & Location (PL)	PL-1	Identify opportunities for sustainable development through clearly defined project goals and objectives	5	C.3
		PL-2	Identify and address the needs and concerns of stakeholders and community members by holding public meetings throughout the planning process.	8	P.1
		PL-3	Complete a life cycle cost analysis based on the projected life of the path and provide justification for the costs with evidence of the community and user benefits	4	C.2
		PL-4	Promote the local economy by employing local firms and workers with a variety of backgrounds to complete the project.	4	P.2
		PL-7	Enhance the community by means of project placement along significant scenic, historic, or cultural sites	7	C.1
		PL-8	Maximize the number of potential path users by establishing the path and or trailheads in a high density area	8	AC.3
		PL-9	Ensure path users have access to destinations for work, education, retail, recreation, etc. along the pathway	10	AC.3

		PL-10	Maximize the accessibility of the path to mixed income/diverse communities	5	AC.2
		PL-11	Provide access to the path with periodically spaced trailheads with vehicular parking in addition to frequent, safe, easy and public access points.	6	AC.4
		PL-12	Increase transportation access options by providing connections to other sustainable transportation modes (bus, rail, ferry, etc.) from the path and/or trailhead	7	AC.4
		PL-13	Provide access for all users by adhering to ADA accessibility guidelines in path design (width, grade, trailhead access, etc), amenity design (benches, water fountains, restrooms, etc) as well as the design of all access facilities connected to the path	8	AC.2
	Green Construction (GC)	GC-5	Improve the quality and reduce the quantity of stormwater and increase pedestrian comfort by using crushed aggregate surface material for, at minimum, a portion of the path.	2	H.1
		GC-10	Protect path users from steep slopes or waterways along the path with fencing or guiderails	2	S.2
	Infrastructure and Amenities (IA)	IA-1	Increase public knowledge of the history of the shared-use path right-of-way with informative signage along the path	1	A.1
		IA-3	Provide stopping points for path users through periodically spaced rest areas with benches along the path	2	H.1
		IA-4	Provide restroom access along the path with permanent facilities at trailheads and permanent or portable facilities periodically spaced along the path	3	H.2
		IA-6	Ensure adequate hydration for path users with periodically spaced, human and pet accessible water fountains	2	H.2
		IA-7	Increase path safety through adequate lighting at path trailheads	3	S.2
		IA-8	Increase path safety through adequate lighting along undeveloped/remote sections and at all road or railroad crossings along the path	3	S.2
		IA-10	Promote bicycling through secure bicycle racks at all path trailheads.	3	AC.4
		IA-11	Promote bicycling through secure bicycle racks in view of the front door at retail, business, school, and transit locations along the path	2	AC.4

		IA-12	Increase path safety with video surveillance at path trail heads.	1	S.2
		IA-13	Increase path safety with emergency call boxes periodically spaced along remote path areas	2	S.2
		IA-14	Provide path users with a sense of location and distance traveled through signage (mile markers, street labels, and nearby attractions)	3	AC.4
		IA-15	Ensure safe intersections at road or railroad crossings with cautionary measures including signage and crosswalks	5	S.2
	Continuing Practices (CP)	CP-1	Ensure proper path maintenance with a management plan for seasonal maintenance (vegetation upkeep, leaf removal, snow removal)	6	AC.4
		CP-5	Promote the arts and the community by incorporating locally produced artwork into the path project	2	H.3 C.1
		CP-6	Increase public awareness of sustainable activities by incorporating a public education program and community events into the path product	4	A.1
		CP-7	Increase path safety through an organized path watch program	4	S.1

Table 10: Coding of Sustainability Credits

VII. EVALUATION OF TRANSPORTATION RATING SYSTEMS

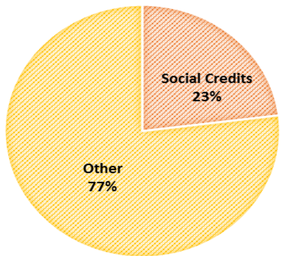
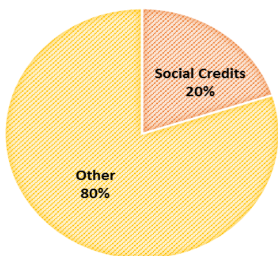
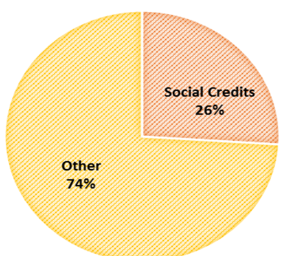
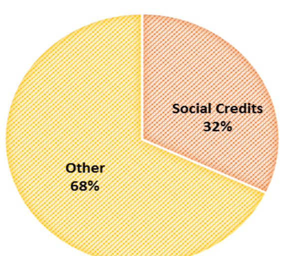
This section aims to further evaluate each transportation rating system based on its inclusion of social sustainability credits. The primary objective of this evaluation is to:

A) Quantify the percentage of social sustainability points (or credits) of each system

B) Qualify how each system measures social sustainability

C) Determine if implementation of social credits is necessary for certification

The percentage of social sustainability points (or credits) for each system was determined by dividing the number of social points (credits) by the total number of points (credits). This percentage is important because it allows for comparison among each rating system based on its inclusion of social objectives and credits. Qualifying how each system measures social sustainability was completed by determining which credit categories from the hierarchy (Accessibility, Safety, Health, Cohesion, Participation, Awareness) are represented. This qualification is important because it shows what social evaluation gaps exist within each system based on the literature's definition of social sustainability. Determining whether or not certification can be achieved without the implementation of social credits brings attention to any ambiguity that may exist within the rating system. A project that strategically accumulates points without implementing any social credits should not be able to receive any sustainability certifications, since it does not encompass all three sectors of sustainability. This method of evaluation is not applicable to all of the rating systems, because several systems do not incorporate a certification level process based on accumulated points. Table 11 summarizes the results of this evaluation.

Rating System	Percentage of social sustainability points (or credits)	Credit categories used to measure social sustainability	Is implementation of social credits necessary for certification?
Greenroads		✓ Accessibility ✓ Safety ✓ Health ✓ Cohesion Participation ✓ Awareness	✗
I-LAST		✓ Accessibility ✓ Safety ✓ Health ✓ Cohesion ✓ Participation Awareness	N/A
Envision		✓ Accessibility Safety ✓ Health ✓ Cohesion ✓ Participation Awareness	✗
INVEST		✓ Accessibility ✓ Safety ✓ Health ✓ Cohesion Participation ✓ Awareness	N/A

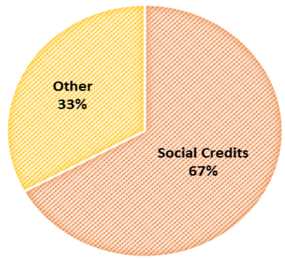
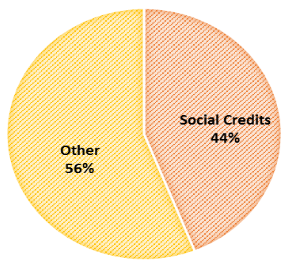
GreenPaths		✓Accessibility ✓ Safety ✓ Health ✓ Cohesion ✓ Participation ✓ Awareness	✓
STARS		✓ Accessibility ✓ Safety ✓ Health Cohesion ✓ Participation ✓ Awareness	✓

Table 11: Summary of Rating System Evaluation

Greenroads contains 11 Project Requirements (PR) that are mandatory for each project using this system. These PRs are intended to encompass the "most fundamental levels of sustainability"; however, only 18% of the required credits focus on sustainability. These required social credits address the following categories: Health and Awareness. It is important to note that of the 37 Voluntary Credits (VC), totaling 118 points, Evergreen certification is awarded to projects that achieve 64 or more points. This means that projects can earn the highest level of achievement by fulfilling only 54% of the VCs. Furthermore, only 21% of the VCs encompass social sustainability objectives. Therefore, a transportation project using Greenroads has the potential to achieve the highest level of sustainability without achieving any social credits. Cumulatively, social credits account for 23% of the total available points within the system. The categories addressed in the VCs include: Accessibility, Cohesion, and Safety. Overall, Greenroads does encompass a wide range of social sustainability objectives (Accessibility, Safety, Health, Cohesion, Awareness), and it includes multiple credits focused on improving accessibility, which is a primary indicator of social equity. Greenroads, however, is not equally representative of all three sectors of sustainability, and this is illustrated in the ambiguity of the certification level requirements.

I-LAST has a total available point value of 321, with 63 points, or 20%, encompassing social objectives. In theory, projects could choose to address only social sustainability credits; however, when evaluated cumulatively, the social credits are largely underrepresented compared to the other sustainability sectors. The social credits of I-LAST address the following areas of social sustainability: Accessibility, Safety, Health, Cohesion, and Participation. The social credits have a large focus on accessibility, specifically multimodality. Health is also largely represented in the social credits through noise abatement practices; however, besides improved shading, I-LAST fails to address any other physical, physiological, or psychological health factors. Similarly to Greenroads, I-LAST does not provide an equal representation of all three sectors of sustainability.

Envision certification is awarded based on the percentage of achieved applicable points. It is important to note that Platinum certification--the highest level--only requires a 50% achievement level of applicable credits. As seen in Table 12, the points received for each credit vary depending on the extent to which they were achieved. Points are awarded based on the following achievement levels: Improved, Enhanced, Superior, Conserving, and Restorative, with Improved being the minimum point value and Restorative being the maximum point value. This weighting system allows projects to achieve more points based on their level of achievement within each criteria. A complete description of how points are awarded to projects can be referenced in the Envision manual.

Achievement	Social Points	Total Points	% Social
Improved	17	79	22%
Enhanced	42	178	24%
Superior	91	355	26%
Conserving	202	700	29%
Restorative	140	514	27%

Table 12: Envision Points based on Achievement Level

On average, points awarded to social sustainability credits account for approximately 26% of the total available points. Although in theory, a project could choose to address only social sustainability credits; this indicates that the social sector of sustainability is not as equally represented as the other sectors of sustainability in this rating system. The social credits of Envision address the following areas of social sustainability: Accessibility, Safety, Health, Cohesion, and Safety. Strengths of this rating system include the flexible scoring system and the ability of projects to evaluate only the credits applicable to their project. On average, over 25% of the weighted points encompass social objectives. This is greater than the previous two rating systems discussed in this section. Since Envision is developed to be applied to a variety of infrastructure projects, a weakness of this system is its lack of specificity to sustainable transportation objectives. The social objectives in this rating system are general and do not provide as specific of metrics.

INVEST does not award certification levels to projects, but rather is used as a benchmark to enhance the sustainability of a project. Approximately 32% of the INVEST credits encompass social sustainability objectives. Based on the triple-bottom line approach to sustainability, it makes sense that approximately 1/3 of the credits are oriented towards enhancing the social sector of sustainability. The social credits of INVEST address the following categories: Accessibility, Safety, Health, Cohesion, and Awareness. Overall, INVEST equally represents social objectives compared to the other two sectors of sustainability.

STARS is also used as a benchmark to enhance the sustainability of a project. Approximately 44% of the STARS credits encompass social sustainability objectives. This may indicate that social objectives represented more than the other two sectors of sustainability. Since the credits in STARS are intended to allow planners to achieve multiple sustainability goals at once, there are likely credits included in that percentage that encompass more than just social sustainability objectives. The social credits of STARS address the following categories: Accessibility, Safety, Health, Participation, and Awareness. Overall, STARS equally represents all three sectors of sustainability.

GreenPaths has a high percentage of social credits (67%) and this is in part due to the nature of the rating system. GreenPaths is intended to evaluate shared-use paths, and therefore has a stronger social orientation than rating systems designed to evaluate vehicular transportation. GreenPaths incorporates all six credit categories: Accessibility, Safety, Health, Cohesion, Participation, and Awareness. The lowest level of certification in this system is "Certified", and the minimum point value to achieve this level is 66 points. There are only 60 points in that do not encompass social sustainability objectives; therefore, this system requires that social objectives be met in order to become certified. The following case study illustrates how applying this rating system can improve social sustainability outcomes.

GreenPaths Case Study

This case study was completed in conjunction with the Senior Engineering Greenway Capstone Project. The team designed a greenway system for Harrisonburg, VA intended to alleviate transportation inequity within the city by providing a safe mode of active transportation. During the testing and refinement stage of the design, the team implemented GreenPaths to determine whether the path met the sustainability objectives outlined in the system requirements.

The team chose to implement GreenPaths due to its specificity in evaluating social, environmental, and economic objectives in shared-use paths. The team would use the results of GreenPaths to help inform future design decisions that enhanced the sustainability of the path. The team used different analysis techniques to determine whether the proposed route satisfied the requirements of each credit. These techniques included: spatial analysis from ArcGIS maps, data extractions from the City of Harrisonburg government website, and community feedback results. The first time GreenPaths was applied to the design, 70 out of 122 available social sustainability points were satisfied. Since the implementation of GreenPaths was intended to inform design decisions, refinements were made to the design to fulfill additional sustainability credits. The second time GreenPaths was applied to the design, 104 out of 122 available social sustainability points were satisfied. The application of GreenPaths has led to the development of a signage, maintenance, and lighting plan. These credits increase the social sustainability of the path by encompassing accessibility and safety objectives. This case study demonstrates how the implementation of a rating system with social sustainability credits can have a positive impact on society. At the completion of the capstone project, the team was able to achieve Gold Level Certification.

VIII. CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate that gaps exist between the definition and application of social sustainability in transportation. Research in this sector of sustainability is underdeveloped compared to economic and environmental sustainability, and this is evident in the underrepresentation of social sustainability objectives in Envision, Greenroads, and I-LAST. GreenPaths contained the largest percentage of social credits. It can be argued that GreenPaths is more socially sustainable than the other rating systems largely due to it being designed to evaluate only shared-use paths. Since STARS credits are intended to achieve multiple sustainability goals, this rating system also ranked high on its inclusion of social sustainability objectives.

This study has limitations due to reduced qualitative reliability. Qualitative reliability indicates that the research approach is consistent across different users and applications (Gibbs, 2007). The results outlined in this report were concluded based on the qualitative analysis of one researcher; therefore, prior to future publication, a second coder will be used to evaluate the repeatability and interrater reliability of this research. The second coder will follow the reliability procedures recommended by Gibbs (2007) by doing the following:

1. Checking rating systems to verify that they do not contain any social credits that were not included in the study.
2. Making sure that the coding is consistent among the different rating systems.
3. Communicating and documenting results with the original researcher.

The results of this study conclude that gaps exist within the social sustainability evaluation of transportation projects. The rating systems were more inclusive of social equity goals than sustainability of community goals. All six of the rating systems included credits focused on improving accessibility and health, and all but Envision included credits focused on safety objectives. Overall, the rating systems were inclusive of social equity goals and objectives. However, only GreenPaths included all three sustainability of community categories: cohesion, participation, and awareness. Using a qualitative framework was helpful in understanding where gaps exist since the credits were interpreted based on interrelated themes and descriptions. If I were to recommend a rating system to a city that was not designing a shared-use path, I would recommend STARS due to its focus on improving accessibility rather than just mobility. STARS is a flexible framework that is designed to allow planners to achieve goals in all three sectors of sustainability.

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