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Qualitative Analysis of Sustainable Indicators: An Approach to Correlate Sustainable Indicators with Transportation Practices

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Strictly as per the compliance and regulations of:

Qualitative Analysis of Sustainable Indicators: An Approach to Correlate Sustainable Indicators with Transportation Practices

Hariharan Naganathan [α], Aaron D Sauer [σ], Oswald Chong [ρ] & Jonghoon Kim [ω]

Abstract- Transportation sustainability is centered on being the linchpin to cultivate innovations and enhance safer environmental standards. The public and private agencies adopt sustainable practices integrating their policies in order to elevate sustainability performances. There is an advent need of developing a tool for quantifying the transportation policies and practices. This paper explains (1) the fundamental practices adopted by different transportation agencies; (2) the impacts of three pillars on developing the sustainable indicators; (3) the selection of indicators and their grouping; and (4) the statistical relationship between indicators with the real-time variables population and GDP. This performance benchmark aims to quantify the sustainability practices of the state and its transportation agencies by assessing their environmental, social, and economic practices. The paper examines the relationship between the selected sustainable indicators and establishes the framework for the sustainability of transportation. This framework is a starting point for adding more relevant indicators to measure the sustainability of transportation when data become available.

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I. Introduction

The transportation sector is the bloodline of the U.S economy, and the sustainability of this sector has an enormous impact on its growth. Alternatives for nonrenewable resources are looked upon by the researchers to enhance transportation sustainability. Transportation influences all aspects of the economy, environment, and society and generates long-term impacts on humanity (Dearing, 2000). Sustainability in transportation addresses the basic needs of societies such as safety and is in a manner consistent with the health of humans and the ecosystem through transportation infrastructure (CH2M HILL, 2009). The active structure of transportation planning and management relies entirely on sustainability. Federal and state transportation agencies perform a pivotal role in implementing sustainability in the transportation sector. The ever increasing demand for nonrenewable resources has forced decision-makers of the transportation sector to look for alternatives that can satisfy or improve our living environment, economy, and society. The purpose of incorporating sustainability into the transportation sector is to alleviate the environmental and social impacts caused by the sector while sustaining its contributions to the economy. A knowledge platform integrates different policies, practices, and technologies in order to reflect sustainability in different situations and conditions (Andrea, 2013). These knowledge platforms of these sustainable practices adopted by different transportation agencies are not promulgated wisely (Daniel, 2011). The Departments of Transportation (DOTs) do not clearly understand the relationships between sustainable practices and their ability to create jobs, reduce carbon emissions and pollution, and provide social benefits to their residents. Also, many of these sustainability initiatives implemented by the states are not appropriately quantified. Thus, the level of sustainability adopted by different state agencies cannot be quantified and measured. These policies and practices can be quantified using sustainable indicators, which is selected with the available data from reliable sources.

The Transportation Demand Management (TDM) program is used to develop strategies and policies that help in reducing the traffic loads and other transportation-related issues (U.S DOT, 2008). It is adopted by various state transportation agencies but not utilized at the fullest. Some of the agencies incorporated this program later dropped it due to its strategies and policies that can be adopted only at local levels and often at the project level (Alameda County Transportation comission, 2009). The need for demand management is critically high since oil prices, and publicly owned vehicles are increasing rapidly (U.S DOT, 2008). The transportation research board stated that some of the factors influencing sustainability in transportation include nonrenewable fuel depletion, global climatic change, local air quality, fatalities and injuries, congestion, greenhouse gas emissions, and

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noise pollution (TRB, 2005). There are several other organizations like American Public Transportation Association (APTA), American Public Works Administration (APWA), Energy Information Administration (EIA), and Energy Protection Agency (EPA) that adopts different policies and strategies in order to achieve transportation sustainability. These organizations have quantified several sustainable indicators, which are derived from the policies and strategies they have adopted. Most of these indicators are quantified through regular data collection, while other indicators have not yet been quantified.

II. Impacts of Three Pillars on Sustainability

Sustainability is sometimes defined narrowly. For example, some focus on resource depletion and air pollution problems, while others identify it as the most significant long-term ecological risk. These focuses are prone to be neglected by engineers, planners, and architects alike. The most common approach to tackle various sustainability issues is the triple bottom line approach. The triple bottom line approach relates between vibrant community (people), healthy environment (planet), and firm profitability (profit). According to Litman (2011), this approach to sustainability can be represented by a Venn diagram, which identifies the interrelationship between social, economic, and environmental issues.

III. Social Issues

Social variables refer to the social dimensions of community, society, or region and include education, equity, and access to social resources, health and well-being, quality of life, and social capital (Flaper, 2009). Social indicators measure the impacts of an action on the community. It includes population size, composition and growth, life expectancy, and literacy (UNSDa, 2012). Some of the factors, according to Flaper (2009), are unemployment rate, female labor force participation rate, median household income, relative poverty, percentage of the population with a post-secondary degree or certificate, average commute time, violent crimes per capita and health-adjusted life expectancy.

The U.S. Government Accountability Office (GAO) has developed a set of social indicators (called national key indicators) that measure the U.S. social impact performance. The indicators are divided into different stages and include factors like health, macroeconomics, education, crime, safety, social support, community, governance, sustainability, and transparency. These indicators also overlapped some economic indicators. Economic indicators are often intimately associated with social indicators as the economy is often closely tied to the welfare of the community and society (Riche, 2010).

IV. Economic Issues

Economic health is a critical component of any nation. A monetary system influences the wealth of the nation and its citizens. The economic variables include income, climatic factors, and expenditures (Riche, 2010). Regional and global economic and political instability threatens the supply of critical resources, and often create commodity price shocks (Gelos & Ustyugova, 2011). Right in between, the supply and demand of these resources lay in the transportation system that ties both together. Increases in the price of energy push up the cost of various commodities, which elevates the general prices (inflation). The responses towards prices of different commodities vary among different countries, as Gelos & Ustyugova (2011) suggested that drivers of the prices include market openness, trends of import and export, the share of food and transport on consumer price index, fuel use in a country, financial development, and the health of the labor market and financial institutions. Increase in gas prices reduce disposable income and affect economic growth as a result. The economic sustainability of transportation should focus on the efforts of transportation systems on various economic factors.

V. Environmental Issues

Environmental indicators measure the effects of human activity on the environment and ecosystems. There are national, regional, and local laws that target these environmental impacts. Example of these agencies includes the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Agency (NOAA). These regulations target to eliminate the environmental impact of product manufacturing and from various other economic activities. These agencies focus on enhancing the water and air quality, reducing energy use, eliminating radiation and toxicity, improving land quality, reversing climate change, controlling chemical use, etc. These indicators are often used to quantify the environmental impact of products, policies, and systems (UNSD, 2011).

Air pollution, noise, water pollution, depletion of nonrenewable resources, landscape degradation, heat island effects (increased ambient temperature resulting from the pavement), and ecological degradation (Litman, 2011) are some of the environmental impacts created by the transportation systems. Some of the other environmental impacts are caused by the high concentration of sulfur dioxide and nitrogen oxides, pollutants, and excessive nutrients, fossil fuel and electricity consumption, improper solid and hazardous waste management, and change in land use and land cover.

VI. Prior Research on Sustainable Transportation

Transportation influences all aspects of the economy, environment, and society and generates long-term impacts on humanity (Dearing, 2000). Sustainability in transportation addresses the basic needs of societies such as safety and is in a manner consistent with the health of humans and the ecosystem through transportation infrastructure (AASHTO, 2009). The Bruntland report published by the World Commission on environment and development defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Oswald, 2008). There is numerous research on sustainable transportation developed by different researchers, particularly on sustainable indicators and its development. Since sustainable development became an international priority in the 1980s and 1990s, infrastructure sustainability has become a growing area of interest in practice, research, and education (AdjoAmekudzi, 2005). Examples of researchers who did intense work on sustainable indicators of transportation include Litman (2011), Adjo (2005), Gudmundsson (2000), Meyers (2000), Cortese(2003), Wheeler(2003), etc.

According to AdjoAmekudzi (2005), the frameworks found in the literature can be placed into three categories which linkages-based, impact-based, and influence oriented (Adjo Amekudzi, 2005). Similarly, Litman (2011) includes various indicators based on the three pillars, which include economic, social, and environmental activities. This research moves a step forward from this level to prove the positive correlation between these indicators, which is considerably used by researchers for performance analysis of sustainable transportation.

VII. Sustainable Transportation Policies

Sustainable strategies and policies are adopted under the banner of sustainable initiatives by most cities (Goldman, 2006). The purpose of sustainable policies optimizes the environmental, economic, and social benefits of the transportation systems (OECD, 2000). Measurable outcomes are needed in order to determine the success of the actual sustainability policies.

The funding for public transportation has increased over the last two decades (D. Banister, 2007). Many innovations in transportation practice occurred and continue to take place in the transportation sector, and many of these innovations may serve the goal of a more sustainable transportation system (Goldman, 2006). The New York State Department of Transportation (NYSDOT) sustainable mission is to integrate sustainability into different transportation practices that include the planning, constructing and maintaining of the transportation system, and the optimizing of internal resources of DOT. (NYSDOT, 2013).

One of the most extensive sustainable frameworks is the performance planning process defined by the Government Performance and Results Act (GPRA). GPRA is adopted as a U.S. legislation in 1993 and with bi-partisan support. This framework, the GPRA, and the other "Sustainable Policy" framework will be the main focus in this section (Henrik Gudmundssun, 2001). Most of the transportation agencies align themselves with the framework and concepts of sustainable transportation that are more relevant to their states. Department of Transportation (DOTs), American Association of State Highway and Transportation Officials (AASHTO), Federal Highway Administration (FHWA), Federal Transit Administration (FTA), United States Department of Transportation (USDOT) and various regional transportation agencies have initiated numerous sustainable transportation programs and initiatives that target the transportation sustainability of the states, counties, cities, and communities. It in turn elevated the standards of transportation through the integration of sustainable practices to a certain extent.

VIII. Sustainable Practices

USDOT encourages the state DOTs to initiate sustainable practices and implement measures to develop that green transportation. DOT has defined five strategic goal areas. There have not been changes between 1997 and the revised 2000 Strategic Plan. The five-goal areas cover Safety, Mobility, Economic Growth and Trade, Human and Natural Environment, and National Security (Henrik Gudmundssun, 2001). Many DOTs attempted to implement many sustainable practices based on the state population and the budget on their sustainable practices.

Examples of these sustainable practices include 1. Renewable energy: The California Department of Transportation (Caltrans) installation of a large number of wind turbines and the development of many renewable energy production facilities across the state of California (Caltrans, 2013), and the Texas Department of Transportation (TxDOT) initiative to develop and utilize of renewable and natural resources (mostly ethanol) as the alternative fuel in the state (TxDOT, 2013), and the Iowa Department of Transportation provides extensive supports for the development of ethanol (renewable energy) program in the state; 2, Green Transportation and Highway System: The New York State Department of Transportation (NYSDOT) developed the green and blue highways initiatives, which can provide green transportation throughout the state (NYSDOT, 2013), the Washington Department of Transportation (WSDOT) developed the standards for green highway design and

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initiated several green highway projects (e.g. the Electric Highways, Smarter Highways and Sustainable Transportation projects), the New Mexico Department of Transportation (NMDOT) and the Pennsylvania Department of Transportation (PENDOT) invests their growth through Smart transportation system for roadways (NMDOT, 2013).; 4. Recycling and Use of Low-Emission Vehicles: The Oregon Department of Transportation (ODOT) started various e-recycling and low emission vehicle programs (ODOT, 2013); 5. Use of "green" materials: The Florida Department of Transportation (FDOT) and Georgia Department of Transportation (GDOT) developed research facilities in order to elevate the green material technology in transportation infrastructure and focused on Asphalt pavement (Jim Warren, 2013).

Similarly, the Illinois Department of Transportation focuses on alternative fuel and electric vehicle initiatives (IDOT, 2013); and 6. Other initiatives: States with a smaller population and budget have also implemented numerous sustainable initiatives that enhance the state's green efficiency. The Wisconsin Department of Transportation (WIDOT) constructed a historical museum on transportation to educate people about the importance of sustainable transportation. Also, they have implemented an air quality program that focuses on reducing toxic generated from fuels. The West Virginia Department of Transportation (WVDOT) runs a tire-recycling program and plants wildflower (WVDOT, 2013).

IX. Sustainability Rating System

Sustainability rating systems are generally designed to perform a specific function, for specific projects and repairs, and to achieve specific goals. The rating systems can also be categorized into the region(s) of application, namely, international and national (Table 1), state (Table 2), and community levels (Table 3).

Table 1: National level rating systems and their developers

Sustainability rating system	Developers
Envision	Institute of Sustainable Infrastructure (ISI)
Sustainable highway self-evaluation tool	Federal Highway Administration (FHWA)
LEED	US Green Building Council (USGBC)
SITES	American Society of Landscape Architects (ASLA)
Green highway partnerships	U.S. Environmental Protection Agency (EPA)
CEEQUAL	Institution of Civil Engineers (ICE)

Table 2: State level rating system and their developers

Sustainability rating system	Developers
Green roads certification	Washington Department of Transportation and the University of Washington
GreenLITES certification	New York Department of Transportation
I- Last	Illinois Department of Transportation
BE2ST	Wisconsin Department of Transportation and the University of Wisconsin.

Table 3: Local, sustainable rating systems and their developers

Sustainability rating system	Developers
Sustainable transportation and analysis rating systems(STAR)	Portland Department of Transportation, Oregon
PEACH Roads	Cobb County, Georgia

Table 4: Categories of various rating systems Source: (Hirsch, 2011)

	Rating Systems				
	STAR	GreenLITES	Envision	I-LAST	Greenroads
Categories	Integrated Process	Sustainable sites	Project pathway/siting	Planning	Basic program requirements
	Access	Water quality	Project strategy	Design	Environment &water
	Climate	Material resources	Communities	Environmental	Access & equity
	Ecological function	Energy and atmosphere	Land use and restoration	Water quality	Construction activities
	Cost-effectiveness	Innovation	Landscaping	Transportation	Materials and resources
	Innovation	Planning	Ecology	Lighting	Pavement

X. Limitations of the Rating Systems

There are easily over 200 sustainable rating systems globally. Each rating system targets specific markets, regions, and products. Many rating systems are the products of public and private collaborations and are designated for different purposes at the national, state, and local levels. The rating systems categorize indicators into different technical areas. These areas target different environmental and social impacts such as habitat protection and enhancement, storm water management, material use, and reuse, context-sensitive design, light pollution, noise abatement, public outreach, land use compatibility, and construction waste reduction (Dondero, George, 2012). The rating system is one of the most common approaches for benchmarking and quantifying sustainability practices (for example, LEED and Envision). The output of the rating systems can be used to measure the different levels of sustainability, and thus speed up the process of sustainability implementation and adoption among the states with quantitative numbers and published examples.

The use of the systems depends on the market; the systems are designed. The systems can be generic, regionally specific, and even corporate specific. These systems are generally driven by the following:

a) *Cost efficiency and effectiveness of the rating system*

The rating systems are developed by pioneers either in the civil engineering field or by external agencies. Cost-effectiveness and sustainability are not correlated, and the results are still debatable with high investments on the rating systems. Most of the decision-makers ignore the sustainable factors unless they realize there are some cost savings out of it (Hirsch, 2011). The developers of rating systems should focus on the cost-effectiveness of their rating systems and has to develop a framework to analyze the cost-effectiveness (Hirsch, 2012).

b) *Level of complexity in the rating system*

This is an essential factor for the shortfall of the rating system. Rating systems are developed in order to certify, enhance, and encourage humans to adopt and achieve sustainability in various infrastructures. However, there are conventional approaches to appraising or valuing land/ buildings and analyzing property values in each country, although it appears that rating tools have not followed similar approaches; they are complex systems that are not easily accessible by the general public (Reed, 2009).

c) *Specification of the rating system and their integration with the transportation projects*

There are numerous rating systems developed in different parts of the world according to their specific climate change and business objectives. The rating systems have similar specifications with different categorizations with the project requirements. This, in turn, has created complications for stakeholders, including property investors. An understanding of the many differences between each market has been increasing difficulty (Reed, 2009).

Many sustainability-rating systems have become irrelevant, while others continue to thrive. Many of the thriving programs that have been developed specific to an organization's operations, environmental needs, local context, and sustainability philosophy, and thus they are still being used extensively (Hirsch, 2011). While these systems give more weight to the environmental credits (such as stormwater, habitat, vegetation, material use), they focus less on the equity and economic benefits. The key reason for this is that the cost-effectiveness of sustainability often overwhelms social relevance (Dondero, George, 2012). Economic decisions are far more important drivers of choices than what the public and private sectors make.

These rating systems often face a dilemma like:

1. Justify the weights and allocates points of the indicators.
2. Ensure the consistency of the evaluation process; and
3. Neglect the use of reliable information and data.

According to AASHTO, FHWA's self-evaluation tool (Invest) for sustainable highways does not focus on all three sustainable pillars. One particular critique noted that several concepts and modules overlapped one another, and the tools failed to clarify the intended linkages between the modules. The overlapping and unclear linkages result in potential double-counting of credits. (Eisenman, 2012).The table shows different points on traffic-related activities. The table shows that these systems allocate the emissions factor less weight. Also, the "multi transit factors" that involves ridership has very low weightage (as shown in the following table). In summary, points allocated in the rating systems only reflect the compliances of the rating systems, and compliance with systems does not necessarily mean achieving the intended sustainability goals of the systems. One of the purposes of this research is to examine the approaches that could better align with sustainability goals with various sustainability policies and practices.

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Table 5: Traffic-related points on different rating systems Source: (Bockisch, 2012)

Category	Invest (%)	Envision (%)	Green Roads (%)	PEACH Roads (%)
Transportation planning	12	13	5	6
ITS	4	5	5	19
Multi Transit	4	4	8	3
Intermodal	6	0	0	2
Safety	9	2	2	0
Emissions	0	5	4	2
Total	35	29	24	32

XI. Issues in Sustainable Transportation

Sustainability in transportation addresses the basic needs of societies such as safety and is in a manner consistent with the health of humans and the ecosystem through transportation infrastructure. Sustainability aims to build up the social and environmental equity within and between generations. (AASHTO, 2009). The nature and scope of the issues and their implications for transportation planning and policy are only beginning to be explored in recent decades by scientists (Litman, 2006). The development of sustainable transport policies implies reconciling environmental, social, and economic objectives and will require further improvements to a wide range of fronts for inland transport (ECMT, 2000). The critical issues of policy-making include accidents, employment rates, accessibility, congestion, traffic growth, nature, emission, and air quality issues (ECMT, 2000). Land use pattern is also a significant barrier in achieving sustainability in transportation.

There is a significant relationship between transportation modes and energy consumptions per capita. Railways carry more goods and people and use less energy than trucks and planes (Lewis , 2009). Sea freights can carry much more loads and uses less fuel than railways, while air transportation consumes the most substantial amount of energy per ton of goods carried (UNCTAD, 2006). While public transportation consumes a lower energy footprint per capita compared with private transportation, availability and convenience often force people to rely on private transportation and results in lower ridership of transportation in many parts of the country, which increases energy use of such modes (Turtenwald, 2013).However, the economy cannot function properly without any of the above transportation modes. Perishable cannot rely on sea freight while shipping large quantities of electronics can be expensive using air freight. The decision to use the different types of transportation modes is often driven by economic needs rather than the sustainability of the modes.

XII. Sustainable Indicators

Sustainability indicators have to represent and measure the social, economic, and environmental status or condition of a transportation system. Indicators simplify the measurement of sustainability and to overcome the complexities of quantifying sustainability (Bossel, 1999). Sustainability indicators also simplify the process of answering the question of how to reduce human impact and conserve for future generations (Oswald, 2008). The indicators must be selected according to the rigor of any research process, and any models generated from the research have to be based on reliable information. According to Bossel (1999), the indicators are selected based on four steps: 1.Understand the requirement and the total system; 2.Identify the potential indicators; 3. Quantify the indicators; and 4.Construct a participative process. Sustainability policies and practices will be evaluated into the next level if a set of measurable indicators can be used to track trends, compare areas and activities, evaluate particular policies and planning options, and set performance targets (Litman, 2011).

The indicators adopted for measuring sustainability are determined by their level of importance to their purposes. A progress report prepared by the U.S. Interagency Working Group (IAWG) on Sustainable Development Indicators highlighted that the approaches of developing these indicators. The report includes: (1) a proposed framework for measuring progress towards sustainable development; (2) a set of 40 specific indicators for the U.S. within that framework; and (3) time-series data and graphs of each indicator. (Henrik Gudmundssun, 2001). Significant elements in the report are from the 17 indicators listed in the report indicate favoritism towards Sustainable Development, 13 indicators showed the opposite, and ten indicators had unclear interpretations (Henrik Gudmundssun, 2001). Some of the indicators are treated separately, and new indicators are developed to reflect the needs.

XIII. Level of Importance

There are many conditions in the transportation system that influences sustainable indicators. The indicators for the preliminary analysis are selected based on the eight principles of a good rating system that Litman (2011) indicated. These indicators include Budget, Ridership, Emission, Consumption, and Energy efficiency (BRECE). Each of these indicators includes a wide range of sub-indicators that influences sustainability and is interrelated and interdependent on one other. Table 4.8 lists the various sub-indicators that come under the BRECE indicators.

The level of importance of each indicator used by the system is determined by; (1) the availability and reliability of information and data sources; (2) the impact of the indicators on the state sustainability; (3) how the indicators influence states' decisions to implement them; and (4) the impact of the indicators on the transportation sector. The sustainable indicators are ranked high, medium, and low based on various factors such as availability of the data, and their importance to the research. For example, budget is an essential indicator with the focus since it involves many relations with other indicators like population and population density of the state. Similarly, ridership on-demand response has very fewer data and can be neglected. Hence, it is of low importance. The bicycle path program is one crucial sustainable initiative that is implemented almost in every state, but the data availability of the bicycle program is qualitative rather than quantitative, hence it is considered of medium importance. The table shows the various indicators and their grouping, respectively.

Table 6: Budgets on transportation (Sunshine review, 2010)

Budget		
Sustainable indicators	Data sources	Importance
Total state budget	Sunshine Review	High to Medium
Total budget on transportation	Sunshine Review	High to Medium
The budget on public transportation	Sunshine Review	High to Medium
The budget on sustainable programs	Sunshine Review	High to Medium
The budget for sustainable research	Sunshine Review	High to Medium

Table 7: Ridership on public transit(APTA, 2011)

Public transportation		
Sustainable indicators	Data sources	Importance
Ridership of public transport	American Public transit Association (APTA)	High to Medium
Ridership on high-speed rail	American Public transit Association (APTA)	High to Medium
Ridership on commuter rail	American Public transit Association (APTA)	High to Medium
Ridership on buses	American Public transit Association (APTA)	High to Medium
Ridership on carpool/vanpool	American Public transit Association (APTA)	High to Medium
Ridership on trolleybuses	American Public transit Association (APTA)	High to Medium
Ridership on streetcars	American Public transit Association (APTA)	Medium to Low
Ridership on bicycle	American Public transit Association (APTA)	Medium to Low
Ridership on demand response	American Public transit Association (APTA)	Low

Table 8: Emissions and fuel consumption indicators(EIA, 2010)

Emissions and fuel consumption		
Sustainable indicators	Data sources	Importance
Carbon emissions by public transportation	Energy Information Administration (EIA)	High to Medium
Carbon emissions by state buildings	Energy Information Administration (EIA)	High to Medium
Gasoline consumption	Energy Information Administration (EIA)	High to Medium
Ethanol consumption	Energy Information Administration (EIA)	High to Medium
Biofuel productions	Energy Information Administration (EIA)	High to Medium

Table 9: Energy use and efficiency indicators(FHWA, 2010)

Energy use and efficiency		
Sustainable indicators	Data sources	Importance
Transportation energy	Energy Information Administration (EIA)	High to Medium
Operational energy	Environmental Protection Agency (EPA)	High to Medium
Embodied energy	Environmental Protection Agency (EPA)	High to Medium
State vehicles on alternative fuels	Energy Information Administration (EIA)	High to Medium
State vehicles on electricity	Federal Highway Administration (FHWA)	High to Medium

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Number of alternative fuel stations	Energy Information Administration (EIA)	High to Medium
Number of electric charging stations	Energy Information Administration (EIA)	High to Medium
Renewable energy in public transit	Energy Information Administration (EIA)	High to Medium
Public buses running on electricity	Energy Information Administration (EIA)	Medium to Low

Table 10: State agencies' commitments and goals

Commitment by state agencies		
Sustainable indicators	Data sources	Importance
Sustainability targets	DOT/Survey	High to Medium
Participation in livability programs	DOT/Survey	Medium to Low
Public involvement and educational programs	Survey	Highto Medium
Environment management systems by state DOTs	Survey	High to Medium
Green highway initiatives	DOT/Survey	High to Medium

Table 11: Other important indicators

Proposed other important indicators		
Sustainable indicators	Data sources	Importance
Land used on highways	Web sources	High to Medium
Recycling and reuse of materials	Survey	Medium to Low
Recycling rate by state agencies	Survey	Low
State Water Quality	Web sources	Low
Water use by the state transportation agency	Web sources/Survey	Medium to Low
Total number of OSHA violations	Web sources/Survey	High to Medium
State overall air quality	Web sources/Survey	Low
Vehicle toxicity emission	Web sources	High to Medium
Construction pollutants	Web sources/Survey	Medium to Low
Vehicle emissions inspection	EIA/Survey	High to Medium
Particulate emissions	EIA/Survey	High to Medium
Productivity loss due to injury	Survey	High to Medium
Productivity loss due to death	Survey	High to Medium
Project delay	Survey	High to Medium

XIV. Selection of Indicators

Several vital indicators were dropped from the framework due to (1) the lack of available and reliable data, and (2) information for those indicators are difficult to verify or that the government agencies are not able to provide such data for the Survey. Examples of the "drop-out" indicators include "the impact of transportation on the standard of living,""quality of life,""health and crime,"and "how the community felt about various transportation projects."For example, the overall funding allocated for sustainability-related initiatives is not available in most of the states and dropped as a factor at this time. The research team needs to focus on other important indicators. Data availability of the embodied and operational energy of state buildings is also not available and has to be omitted. Carbon emissions from the state buildings require time to collect; hence the indicator is neglected at this time. Instead of tracking health statistics (were establishing a link between transportation and health can be very difficult), the research team targets pollutant emissions. It is challenging to correlate health issues with transportation issues. The research team also included the ridership on-demand response as a sub-indicator because of the availability of data for all fifty states though it has very less quantifiable values.

The Environmental Protection Agency has not established procedures to track the entire transportation indicator sets continuously. Some of the examples of environmental indicators related to transportation are criteria air pollutants, toxic pollutants, greenhouse gases, chlorofluorocarbons, and stratospheric ozone depletion, habitat and land use, water quality, hazardous materials incidents, noise and solid waste (Henrik Gudmundssun, 2001).There are many conditions in the transportation system that influences sustainable indicators. The indicators for the preliminary analysis are selected based on the eight principles of the excellent rating system mentioned in Litman(2011)that fits the research at its best at this point. These indicators can be presented as Budget, Ridership, Emission, Consumption, and Energy efficiency (BRECE). Each of these indicators includes a wide range of sub-indicators that influences sustainability and is interrelated and interdependent. Table 12 lists the various sub-indicators that come under the BRECE indicators.

Table 12: Selection of Indicators (BRECE)

Sustainable indicators	Importance
Total state budget	High to Medium
Total budget on transportation	High to Medium
The budget on public transportation	High to Medium
The budget on sustainable programs	High to Medium
The budget for sustainable research	High to Medium
Ridership of public transport	High to Medium
Ridership on high-speed rail	High to Medium
Ridership on commuter rail	High to Medium
Ridership on buses	High to Medium
Ridership on carpool/vanpool	High to Medium
Ridership on trolleybuses	High to Medium
Ridership on streetcars	Medium to Low
Ridership on bicycle	Medium to Low
Ridership on demand response	Low
Carbon emissions by public transportation	High to Medium
Transportation energy	High to Medium
Gasoline consumption	High to Medium
Ethanol consumption	High to Medium
Biofuel productions	High to Medium
Number of electric charging stations	High to Medium

BRECE indicators comprise of sub-indicators that are selected based on the reliability of information sources, data availability, and the importance of the indicator as analyzed by the preliminary analysis on sustainable transportation. These indicators are statistically proven to be positively correlated using different statistical concepts. The concepts include Karl Pearson's population coefficient correlation, p-value analysis, and Spearman's rank correlation. The correlation is determined manually and rechecked for accuracy using Minitab statistical software tool. Apart from the quantitative data, the research team focused on using qualitative information available online from reliable sources. These qualitative data include the documents, proposed plans and initiatives, and reports on environmental prevention strategies by DOTs.

XV. Statistical Analysis

Two adjustors, population and GDP, are used to adjust the indicators. Population influences the sustainability of transportation, at least on the level where public transportation becomes viable. It is used as a key adjuster with which the data collected from various trusted sources are adjusted to reflect the ranking of the states. The population of the state reflects the demand for public transport. States generally spend more money on transportation if it has a greater population density. Large states have more giant footprints, and thus it is necessary to present the sustainability after adjusting the size of the states. Population and budget are good adjustors. The various indicators that are used with population adjustors are the total number of vehicles registered, total transportation budget, the population density of state and most significant cities, and ethanol and gasoline consumption. Three different analyses are done with the population and GDP as an adjuster.

A data analysis framework is developed to lay out the relationship between the data and their intended output. The data are gathered from various trusted sources and then grouped under BRECE indicators. The adjustors used in this research are the population and GDP. Pearson's correlation and P-value are determined using the Minitab statistical tool.

The various equations used to determine the correlations are as follows

1. Pearson's population coefficient equation is given by (Source: Social science statistics)

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

2. Rank correlation is given by (Source: Social science statistics)

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}.$$

The correlation coefficients and P-value is determined through manual calculation and statistical package. The top ten states of each indicator are selected before and after adjustments for the correlation analysis. Pearson's correlation and P-value are determined before adjusting the indictors through the population, and the rank correlation is determined after adjustment. It is found that the values are in the range of -1 to +1, which proves the indicators grouped and adjusted are positively correlated. The level of an importance checkbox is also added to the table to explain how the indicators are treated with respect to population and GDP. The level is selected based on the impact of such indicators on sustainable transportation concerning real-time factors. Table 13 below shows the correlation values of indicators adjusted through the population.

Table 13: Correlation values of indicators adjusted through population

Statistical Analysis					Level of Importance		
S. No.	Indicators	Pearson's correlation	Rank correlation	P-value	High to Medium	Medium to Low	Low
1	Transportation Budget	0.462	0.81	0.179	☐	☒	☐
2	Automobiles	0.568	0.40	0.011	☒	☒	☐
3	Ridership	0.472	0.64	0.582	☒	☐	☐
4	Carbon emission	0.303	0.18	0.069	☒	☐	☐
5	Ethanol Consumption	0.311	0.93	0.035	☐	☒	☐
6	Gasoline consumption	0.314	0.36	0.020	☒	☐	☐
7	Transportation energy consumption	0.310	0.24	0.013	☒	☐	☐

The transportation budget does not directly relate to sustainability. The budget for the population is essential to understand the requirement of implementing policies and standards, Hence it of medium importance. Carbon emissions contribute to environmental safety to a greater extent, and hence it is of higher importance.

Gross Domestic Product plays a vital role and is considered to be the primary indicator of the economic health of a nation. Wealthier states tend to spend relatively more money on their investments than weaker states on GDP reflects the cost of living (Kimberly Amadeo, 2013). Similarly, the correlation values of the indicators are determined by adjusting through GDP. Since budget and GDP are in the same units, the budget is not adjusted through GDP. Table 2 shows the correlation values for the indicators adjusted through GDP. As population adjustment, the correlation values are positive. When looking at the importance of indicators, budget and ridership are not of high importance when adjusted through GDP, whereas consumption is of high importance. Hence the data adjustments are proved to be the right way for the data analysis to be continued.

Table 14: Correlation values for the indicators adjusted through GDP

Statistical Analysis					Level of importance		
S. No.	Indicators	Pearson's Correlation	Rank correlation	P-value	High to Medium	Medium to Low	Low
1	Budget	NA	NA	NA	☐	☐	☐
2	Automobiles	0.888	0.18	0.001	☐	☒	☐
3	Ridership	NA	NA	NA	☐	☐	☐
4	Carbon emission	0.056	0.18	0.743	☒	☐	☐
5	Ethanol Consumption	0.021	0.55	0.934	☒	☐	☐
6	Gasoline consumption	0.056	0.43	0.778	☒	☐	☐
7	Transportation energy consumption	0.871	0.23	0.001	☒	☐	☐

The table shows some interesting facts on the positive correlation and their importance. The level of importance varies when adjusted through population and GDP. The correlation with GDP and transportation budget cannot make any sense as both involve the same units, which is U.S dollars. Similarly, the ridership per GDP is not considered to be a better analysis by the authors. The P-values are used to determine the testing of significance between two indicators and thus lower the p-value, higher the chance of correlation to be negative. It is noted that automobiles by GDP have lesser P-value after adjustment, which can say the correlation and the performance analysis can hit different opinions on the outputs. The focus of this paper is to prove that sustainable indicators are positively correlated, which are grouped under BRECE, and this research has a more significant potential of performance analysis, including several indicators under different categories.

XVI. Conclusion

Sustainability requires more comprehensive and integrated planning, which accounts for a broad set of economic, social, and environmental impacts, including those that are difficult to measure (Litman, 2006). Sustainable development of a state mainly depends on how they conserve energy, land, and other natural resources. The social and economic status of the state varies often, and the energy use, consumption, and production depend on the population of the state. Thus, the strategy and combination of factors need to be developed as a sustainable rating framework in order to quantify the benefits rather than rating it through the point system that still has several questions unanswered. Figure 1 shows the positive correlation values of the indicators.

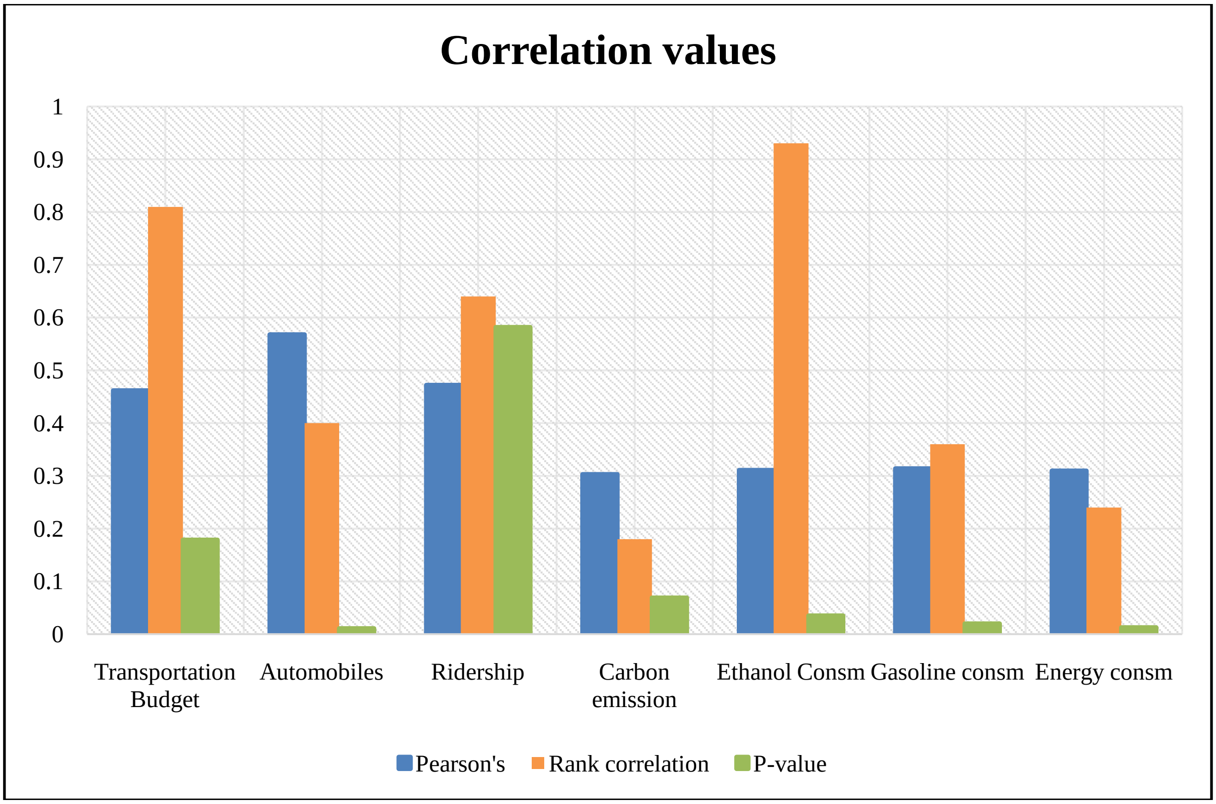

Figure 1: Correlation values of the indicators

The sustainable indicators are categorized into conventional, comprehensive, and straightforward patterns, which have their limitations with various real-time factors (time and population). There is no evidence of these indicators to be the right indicators of sustainability though it is environmentally related. This paper relates the sustainable indicators and proves statistically that these are the efficient indicators that can be used for analyzing the sustainable efficiency of the transportation sector.

The main objectives of this state are met along different sections of this paper, which includes fundamental practices, impacts of three pillars, sustainable indicators, and relationship among the sustainable indictors. The next step of this research is to understand more interrelationships of policies and sustainable transportation systems and to create a database technology where the user can populate the data values to understand the sustainable performances of their state. This can be further developed as a web-based system and can be implemented on states, counties, and cities for a more in-depth analysis of sustainable performances.

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