

PRELIMINARY ANALYSIS FRAMEWORK FOR STATE SUSTAINABLE  
TRANSPORTATION SYSTEM

BY

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Submitted to the graduate degree program in Civil, Environmental and Architectural Engineering  
and the Graduate Faculty of the University of Kansas in partial fulfillment of the requirement for  
the degree of Master of Science.

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## **Abstract**

Sustainable practices have become the cornerstone of the transportation sector, and widely adopted by many states' transportation agencies. The nerve center of the economic development today circles around resource utilization and energy use. The transportation sector is the bloodline of the U.S economy and sustainability of this sector affects the growth of the economy. Even though sustainable practices have now become the edifice of transportation sectors, the adoption of such practices cannot be quick enough to overcome the ever-increasing demand of resources from the global population. Benchmarking sustainability is the most appropriate method to determine the sustainability of transportation practices. There are numerous rating and benchmarking systems, and most of them follow similar approach and format that outline the sustainability factors (namely, energy, water, land use, air quality, pollution etc.). Such approaches and formats can be found on many sustainable standards and tools such as the Leadership for Energy and Environmental Design (LEED). The purpose of this research is to develop a framework that includes an alternative approach to benchmark the sustainable performances of state transportation systems. The framework focuses on measuring the actual sustainability rather than to develop standard compliance approach similar to LEED rating system. It also focuses on utilizing modified/adjusted quantitative data to determine the sustainability of transportation practices. Such an approach would allow transportation agencies and states to compare and compete with one another.

## Table of Contents

Abstract.....	III
Chapter 1-Introduction.....	1
1.1 Motivation.....	1
1.2 General problem statement.....	2
1.3 Objectives.....	4
1.4 Outline.....	4
Chapter 2 – Sustainability in transportation.....	6
2.1 Definitions of sustainability.....	6
2.2 Sustainable transportation.....	7
2.3 Transportation in united states.....	9
2.4 Impacts of tribble bottom line on sustainability.....	10
2.4.1 Social issues.....	11
2.4.2 Economic issues.....	12
2.4.3 Environmental issues.....	13
2.5 Focus of the project.....	14
Chapter 3-Sustainable rating systems and limitations.....	15
3.1 Sustainability rating system.....	15
3.1.1 STAR system.....	16
3.1.2 GreenLITES certification system.....	17
3.1.3 Envision.....	18
3.1.4 I-LAST.....	18
3.1.5 Greenroads.....	18
3.2 Limitations of the rating systems.....	21
Chapter 4 -Sustainable policies, practices and development of indicators.....	25
4.1 Sustainable practices.....	26
4.2 Factors influencing sustainable indicators.....	27
4.3 Sustainable indicators.....	28
4.3.1 Development of indicators.....	30
4.3.2 Level of importance of sustainable indicators.....	31

4.3.3 Selection of indicators .....	35
Chapter 5- Data analysis .....	37
5.1 Data collection .....	37
5.2 Survey form .....	38
5.3 Data analysis .....	38
5.4 Population as an adjustor .....	41
5.4.1 Budget and population density .....	41
5.4.2. Budget and population .....	43
5.4.3 Automobile ownership and population.....	45
5.4.4 Automobiles and population density .....	47
5.4.5 Ridership and population .....	49
5.4.6 Carbon emissions and population:.....	51
5.4.7 Energy consumption and population .....	54
5.5 Gross Domestic Product as an adjustor .....	61
5.5.1 Transportation energy and GDP .....	61
5.5.2 Automobile ownership and GDP.....	63
5.5.3 Gasoline and GDP .....	66
5.5.4 GDP and carbon emissions .....	67
Chapter 6-Results and discussions.....	69
6.1 Discussions .....	70
6.2 Scope of the project .....	72
References.....	74
Appendices.....	84
Appendix A.....	84
Survey form .....	84

## List of Tables

Table 3.1 National level rating systems and their developers .....	15
Table 3.2 State level rating system and their developers.....	16
Table 3.3 Local sustainable rating systems and their developers .....	16
Table 3.4 Categories of various rating systems Source: (Hirsch, 2011).....	20
Table 3.5 Traffic related points on different rating systems Source: (Bockisch, 2012) .....	24
Table 4.1 Sustainable rating indicators; Source: (Litman, 2011) .....	30
Table 4.2 Budgets on transportation .....	33
Table 4.3 Ridership on public transit.....	33
Table 4.4 Emissions and fuel consumption indicators.....	33
Table 4.5 Energy use and efficiency indicators .....	34
Table 4.6 State agencies' commitments and goals .....	34
Table 4.7 Other important indicators .....	34
Table 4.8 Selection of Indicators (BRECE).....	36
Table 5.1 Indicators adjusted by population .....	41
Table 5.2 Percentage of transportation budget to the total state budget, Source: (Sunshine review, 2010) .....	42
Table 5.3 Population of the state Source: (Sunshine review, 2010) .....	48
Table 5.4 Ridership values of the top states; Source: (APTA, 2011) .....	50
Table 5.5 Details on Gasoline consumption/capita , Source: (EIA, 2010) .....	59
Table 5.6 Total Number of vehicles using alternative fuels (Top 20 states); Source FHWA .....	63
Table 5.7 Total Number of Vehicles using Alternative Fuels per 1000 People (FHWA).....	64
Table 5.8 Total Number of Vehicles using Alternative Fuels per \$100 million of GDP .....	65
Table 6.1 Results and Outcomes.....	69

## List of Figures

Figure 2.1 Triple bottom line approach; Source: (Burwell, 2006) .....	11
Figure 2.2 Hierarchy of needs, Source: (Simons, 1987).....	11
Figure 5.1 Flow chart representing Research Focus and outcomes.....	40
Figure 5.2 Transportation budget of the states, Source: (Sunshine review, 2010).....	43
Figure 5.3 Transportation budget / Capita in US (2010); Source: (Sunshine Review, 2010) .....	44
Figure 5.4 States with high number of publicly owned vehicles .....	46
Figure 5.5 Public owned vehicles per 100 people, Source: (FHWA, 2010).....	46
Figure 5.6 Ridership values(Trips/Day/Capita) for the top states (APTA, 2011) .....	51
Figure 5.7 Details on carbon emission through transportation (million metric tons).....	53
Figure 5.9 Details on energy consumption by Transportation sector (EIA, 2010).....	55
Figure 5.10 Biofuel production (Trillion Btu); Source: (EIA, 2010) .....	56
Figure 5.11 Renewable energy production, Source: (EIA, 2010).....	57
Figure 5.12 Details on Gasoline consumption by state, Source: .....	58
Figure 5.13 Details on ethanol consumption (EIA, 2010) .....	60
Figure 5.14 Ethanol consumption per capita; Source: (EIA, 2010).....	60
Figure 5.15 Total transportation energy details by state (EIA, 2010) .....	62
Figure 5.16 Ranking on transportation energy (EIA, 2010).....	62
Figure 5.17 Gasoline per dollar GDP; Source: (EIA, 2010).....	66
Figure 5.18 Ethanol consumption per dollar GDP; Source: (EIA, 2010).....	66
Figure 5.19 Positive correlation between GDP and Energy use.....	67
Figure 5.20 Carbon emissions per dollar GDP; Source: (EIA, 2010) .....	68

## **Acknowledgement**

I would like to thank Dr. Oswald Chong, my advisor and committee chair for providing me support and guidance during this research work. Also, I am thankful to Dr. Steven Schrock and Dr. Daniel Tran for serving as members of my committee.

I would like to thank my parents for providing me all support to pursue my Masters at KU. I am thankful to my friends and family for encouraging me throughout my academics. A special thanks to the research team members for helping me out during the research work.



## **Chapter 1- Introduction**

Sustainability is defined as “A system of policies, beliefs, and best practices that will protect the diversity and richness of the planet’s ecosystems, foster economic vitality and opportunity and create a high quality of life for people” (CH2M HILL, 2009). It has its elevation from just a common word to reality, striving to ameliorate the standards of society, economy and environment. Recently, sustainability predominates almost every profession and impacts people’s thought process and decision-making abilities. Sustainable practices are emerging as a dynamic effort to combine human needs and environmental standards (Hannah Gould, 2013). Ubiquitous sustainability aims at formulating the policies and actions that integrate socio-economic issues.

### **1.1 Motivation**

The term “green” is commonly used to reflect the socially and environmentally friendly approaches adopted by the industries on their day-to-day activities. The more extensive sustainability is used to describe the efficient approaches commonly practiced through transportation to elevate the economic growth. Highways help to bring people together for work and play and thus generate jobs as a result (Mircea Serafim, 2010). Railways in the United States are used to supply coals from Wyoming to various power stations across the country (Economist, 2010). Airplanes are the drivers of globalized economies in which people can travel further to explore and find new opportunities. Marine transportation aims at transporting the essential and large quantity of goods required for the well-being of human resources. While transportation has pushed forward the development of the modern society, it has become the target for many special interest groups. Extensive networks of highways have resulted in a rapid increase in fossil fuel

consumption as the U.S depends on more fossil fuel (Worldwatch Institute, 2013). The time an average American spends on the roads today is far greater than what a decade before. Though the standards of life has widely elevated, study has suggested that the quality of life may be compromised.

Researchers and industrial practitioners have all agreed that the transportation sector needs to be more sustainable. The motivation of this research is driven by the need of the transportation sector to become more sustainable. There has not been yet a quantification method, which focuses on the measurement of sustainability. Compliance with sustainable standards (similar to LEED) is an approach to push forth sustainability practices. However, quantifying compliances cannot accurately reflect the differences in the level of sustainability. The purpose of this research is to (1) determine what transportation sustainability truly means; (2) identify the indicators of sustainability and (3) develop an alternative approach to quantify sustainability.

## **1.2 General problem statement**

Sustainability in transportation has become an important aspect of transportation system planning and management. Federal and state transportation agencies perform a pivotal role of implementing sustainability in the transportation sector. There are numerous rating systems developed through agencies and researchers to implement rate and sustainability of transportation and the transportation sector. These rating systems are similar to the rating systems developed for buildings such as Leadership in Energy and Environmental Design (LEED) and Building Research Establishment's Environmental Assessment Method (BREEAM) (Berardi, 2011). The rating systems are commonly based on regional transportation policy, sustainability factors and their importance. In addition, these rating systems allocate points for

each defined category where the allocations are still debatable. Keeping track of sustainability through the rating systems is a challenge given the significant differences among different regions and the inability of the systems to reflect such differences. A knowledge platform integrates different policies, practices and technologies in order to reflect the sustainability in different situations and conditions (Andrea, 2013). There is no clear definition and directions of sustainability and that point to what the transportation sector needs (MnDOT, 2011). It is difficult to quantify the effectiveness of sustainable policies, practices and technologies,

Transportation agencies are mostly responsible to introduce and implement practices and policies related to sustainable transportation. These agencies also influence how consumers make transportation decisions. Without access to public transport, consumers have to rely on private transportation (Bureau of Transportation Statistics, 2008). Public transportation agencies would be responsible to introduce and incorporate sustainable practices and technologies in their respective states (FHWA, 2007). Without efforts by these agencies, the spread of sustainable practices and technologies will be slower. Some of the states repeat these efforts with little or prior knowledge that other states had experiences implementing them. The support from other states would ease the process and make it more effective and with the support from other states that have experience in implementing them. For example, the concept of high occupancy vehicle (HOV) lanes was introduced in California to reduce the fuel consumption and to promote ride sharing and was later adopted by a few other states like Virginia, Minnesota and New Jersey. The sharing of knowledge was never thorough (Transport Canada, 2012). Similarly, the Green highway concepts are efficiently practiced at New York and Florida whereas adopted by smaller regions like the District of Columbia and Virginia. Knowledge was rarely been transferred from the states to the districts. Thus, there is a need of an online platform (search engines like Google

and Bing) where people can populate their queries to know about the sustainable efficiency of their state through transportation. With a centralized platform, these efforts and experiences could have been as widely disseminated and shared. The private sector is not directly involved in the development of such policies though they may be engaged by the public sector as a partner (Bureau of Transportation Statistics, 2008).

### **1.3 Objectives**

The key objective of this research is to develop a framework of the sustainable transportation knowledge platform that could effectively benchmark the sustainability of transportation. There are three research sub-objectives:

1. Understand what drives sustainability in transportation;
2. Identify and evaluate the sustainability rating systems and determine the sustainable indicators of transportation; and
3. Develop a preliminary framework for the transportation sector to evaluate their sustainable performance.

### **1.4 Outline**

The thesis is divided into six chapters, which outlines the following:

Chapter 2 emphasizes the basic understanding of sustainability and its impact on the triple bottom line theory. It focuses on understanding of sustainable transportation and its essentiality in the transportation industry.

Chapter 3 investigates various sustainability-rating systems such as models adopted and their implementation methods. This chapter also contains extensive literature review pertaining to sustainable transportation, sustainability rating systems, performance measurement, and the limitation of sustainable rating systems.

Chapter 4 explains about the transportation policies, their integration with sustainability, and sustainable practices implemented by state agencies. In addition, it demonstrates on how sustainable indicators quantifies these policies and practices and about selection of indicators for this research.

Chapter 5 documents the data collection and results of the data analysis. It also establishes the proposed preliminary framework of the sustainability index.

Chapter 6 outlines the outcomes of the research and identifies the future research directions.

## **Chapter 2 – Sustainability in transportation**

This chapter details various definitions of sustainability to gain a basic understanding on sustainability. It also explains about the basics of sustainable transportation and influence of triple bottom line dimensions on sustainable transportation.

### **2.1 Definitions of Sustainability**

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). Several industries readapt the Bruntland report for their own specific purpose and goals. There are numerous definitions for sustainability and there is no common definition adopted universally. Various sustainability definitions are developed by different organizations and agencies that are goal specific of their respective activities. Some of the definition includes:

1. "Long-term, cultural, economic and environmental health and vitality" with emphasis on long-term, "together with the importance of linking our social, financial, and environmental well-being” (Sustainable measures, 2010).
2. “Simultaneous pursuit of economic prosperity, environmental quality and social equity” (World Business council on sustainable development, 2009).
3. Real World Coalition (1996) and Globalfootprints (2009) highlighted that environment must be protected to preserve essential ecosystem functions and to provide for the wellbeing of future generations; environmental and economic policy must be integrated; the goal of policy should be an improvement in the overall quality of life, not just income growth; poverty must be ended and resources distributed more equally; and all sections of society must be involved in decision making.

In addition, Sustainable measures (2010) categorized sustainability into three different focus. It includes:

- *General definition*

There are numerous definitions for sustainability. In general, it is defined as the utilization of the resources without depleting it for the mere future.

- *Community and societal focus*

Sustainability in communal definition can refer to the entity itself or its relationship to outside influences and its position within the network of those influences (Joseph, 2012). Social sustainability is the idea that future generations should have the same or greater access to social resources as the current generation while there should also be equal access to social resources within the current generation (Ciesen, 2009).

- *Business and production*

Sustainable business is one that has a minimal negative impact on society, economy and environment. The business aims at meeting and elevating the standards of society, economy and environment (Keenan, 2008).

## **2.2 Sustainable transportation**

The transportation sector makes major contribution to an economy. Transportation consumes energy resources and land space. 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 human and ecosystem through transportation infrastructure (CH2M HILL, 2009). This helps in building up the social and environmental equity within and between generations (AASHTO, 2009). The aim to integrate sustainability into

transportation is to elevate the economic, environmental and societal performances of transportation infrastructure and to create awareness among humans about the impacts generated by the transportation sectors. Sustainability in transportation should concentrate on the quality of transportation system and the reduction of the use of critical and scarce resources such as fossil fuel, fresh air, potable water and farmland. Like sustainability, sustainability in transportation has numerous definitions adopted by different organizations. Some of these definitions are:

1. “One in which fuel consumption, emissions, safety, congestion, and social and economic access are of such levels that they can be sustained into the indefinite future without causing great or irreparable harm to future generations of people throughout the world” (Victoria Transport Policy Institute, 2011).
2. “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” (Environment Canada, 2010).
3. “The capacity to support the mobility needs of people, freight and information in a manner that is the least damageable to the environment” (Paul Rodrigue, 2013).
4. “Limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise” (Environment Canada, 2010).

The purpose of incorporating sustainability into the transportation sector is to reduce the environmental and social impacts caused by the sector while maintaining its contributions to the economy. Sustainability encourages people, society, government, and private entity to deviate



from the traditional transportation modes and designs that are energy intensive and move towards energy efficient practices (Victoria Transport Policy Institute, 2011).

Examples of sustainable transportation modes include bike path, alternative transportation systems (share a ride and public transport), use of recycled concrete and asphalt, encourage the use of electric cars and renewable energy through infrastructure development, and lower the energy use of various transportation agencies. Implementing sustainability in transportation requires the extensive collaborations between the federal, state, and local governments, private sectors, and citizens.

### **2.3 Transportation in United States**

The transportation system in the U.S. relies heavily on fossil fuel, with a small proportion of electric vehicles (EV) that consumes mainly coal-generated electricity (IPTV, 2004). The public sector influences the transportation development and guides the market that determines the transportation planning (Rodridge, 2013). People are forced to drive or fly if railways are not accessible. The energy intensity is greater and the life cycle of the energy and resource use is far more significant for private transportation and plane modes than railway modes. Huge amounts of concrete are required for airport runways, asphalt for highways, and steel for railways while energy consumption to construct these infrastructure are marginally high.

There is also a significant relationship between transportation modes and energy consumptions per capita. Railways carries more goods and people, and uses 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 largest 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 actually increase energy use of such modes (Turtenwald, 2013).

Government effort, policies, investment and plans, are the key components to ensure the success of sustainable transportation. The successes of the U.S. railway network, national interstate systems, and national scenic driveways clearly indicate the importance of solid government policies, programs and investment in sustainable transportation. The federal, state and regional governments have to provide the leadership to enhance sustainability in the transportation sector.

#### **2.4 Impacts of triple bottom line (3BL) on sustainability**

Sustainability is sometimes defined narrowly, For example, some focuses on resource depletion and air pollution problems while others identify it as the greatest 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 strong profitability (profit). According to Litman (2011), this approach to sustainability can be represented by a Venn diagram, which identifies the interrelationship between the social, economic and the environmental issues.

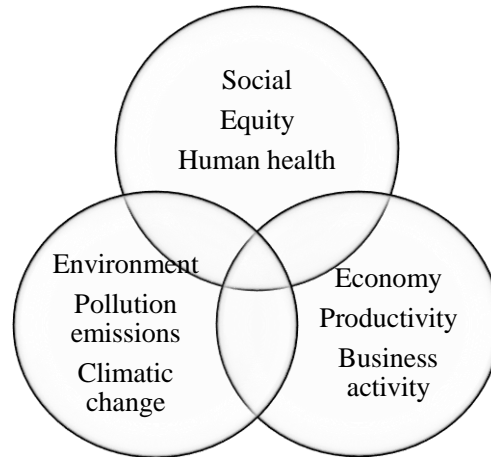


Figure 2.1 Triple bottom line approach; Source: (Burwell, 2006)

### 2.4.1 Social issues

Abraham Maslow, an American psychologist proposed a model to explain the hierarchy of the needs into five different stages. During the peacetime, the US citizens adopted three important levels, which include social, self-esteem and self-actualization (Simons, 1987).

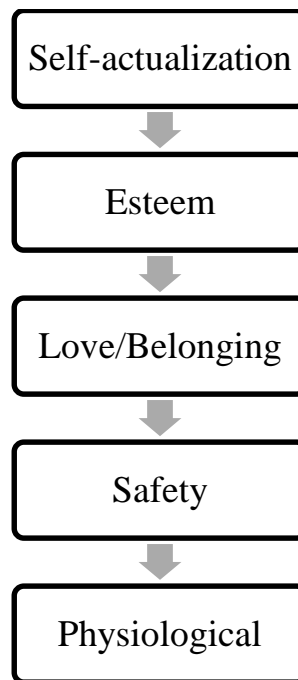


Figure 2.2 Hierarchy of Needs, Source: (Simons, 1987)

Social variables refer to the social dimensions of community, society or region and includes 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 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 community and society (Riche, 2010).

#### **2.4.2 Economic issues**

Economic health is a critical component of any nation. A monetary system influences the wealth of the nation and its citizens. The economy swirls along with investments and business activities, creating opportunities and wealth along the way. 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 varies among different countries, as Gelos & Ustyugova (2011) suggested that drivers of the prices include market openness, trends of import and export, 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 the economic growth as a result. Economic sustainability of transportation should focus on the efforts of transportation systems on various economic factors.

### **2.4.3 Environmental issues**

Environmental indicators measure the effects of the human activity on the environmental 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 from 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 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 di-oxide 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.

## **2.5 Focus of the research**

While the above discussion highlight the factors that should be included in sustainable benchmarking system, many of these data are not available in many regions. Unless there is an initiative to collect the data, researchers have to collect additional data for the factors in order to develop the relevant models. There will be issues if researchers are forced to develop their own dataset, as there will be incompatibility if others wish to duplicate the same models. As such, the project focuses only on selected environmental indicators that are readily available from reliable sources, and thus the framework and models have not included factors that do not have reliable dataset.

### Chapter 3-Sustainable rating systems and limitations

This chapter focuses on reviewing various sustainable rating systems and indicators pertaining to transportation. The review also includes various non-transportation sustainability-rating systems that are developed at the national, state and local levels.

#### 3.1 Sustainability rating system

Sustainability rating systems are generally designed to perform 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 3.1), state (Table 3.2) and community levels (Table 3.3).

Table 3.1 National level rating systems and their developers

<b>Sustainability rating system</b>	<b>Developers</b>
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	US Environmental Protection Agency (EPA)
CEEQUAL	Institution of Civil Engineers (ICE)

Table 3.2 State level rating system and their developers

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

Table 3.3 Local sustainable rating systems and their developers

<b>Sustainability rating system</b>	<b>Developers</b>
Sustainable transportation and analysis rating systems(STAR)	Portland Department of Transportation, Oregon
PEACH Roads	Cobb county, Georgia

### 3.1.1 STAR system

The Sustainable Transportation Analysis & Rating System (STARS) is an integrated planning framework for transportation plans and projects (STAR, 2012). Its design framework aims at evaluating the entire life cycle of transportation projects. This transportation rating system is a performance-based system where the users must accomplish the specified goals and objectives within a specific time limit (STAR, 2012). The rating system takes a non-traditional approach by encouraging mixture of transportation and land use strategies to meet transportation needs. The program is organized into 29 credits. There are five specific credit areas that are required to obtain certification (Hirsch, 2011). STAR has various rating categories, which



include integrated process, access, climate and energy, ecological function, cost effectiveness analysis and innovation (Hirsch, 2011).

STAR system is effectively applied in many States. The Santa Cruz county regional Transportation council adopted STAR system in its transportation plan and target to reduce the complexity of their planning process. The Santa Cruz County Regional Transportation Council also worked with Caltrans to evaluate alternatives for the primary travel corridor in the County using STAR system (STAR, 2012). The Unified Corridor Investment Plan consider policies, projects and programs that perform best on various sustainability outcomes, STAR system allowed them to compare the performance of various transportation alternatives for all modes of travel (STAR, 2012).

### **3.1.2 GreenLITES Certification system**

The Green Leadership in Transportation and Environmental Sustainability (GreenLITES) certification program is developed by the New York State Department of Transportation. It is used to evaluate the transportation projects and elevate the sustainable practices of various roadway projects of the state. The program is used only by NYSDOT and aims at reducing environmental impacts, and encourages the development of sustainable innovations in project design and planning (NYSDOT, 2012). It consists of four different levels of certification and a point system that are very similar to LEED (Hirsch, 2011). Its goals, policy are very similar to Greenroads and I-LAST. GreenLITES for sustainable planning is currently under development. It is a project solicitation tool that identifies projects that should be included into Transportation improvement program (Dondero, George, 2012). The major rating categories of GreenLITES includes sustainable sites, water quality, material resources, energy and atmosphere and innovation (Hirsch, 2012).

### **3.1.3 Envision**

Envision is developed by the Zofnass program for sustainable infrastructure at Harvard University. Envision is an infrastructure rating and recognition system that has a unique category of climate and risk that accounts for natural hazards, and climate change mitigation and adaptation (Envision, 2013). Envision addresses all infrastructure projects while the system does not contain a comprehensive rating system specific to transportation project. Some of the rating category includes project pathway, project strategy, communities, land use and restoration, landscaping, ecology and biodiversity, water resources and environment, energy and carbon, resource waste management and transportation (Hirsch, 2011).

### **3.1.4 I-LAST**

The Illinois Livable and Sustainable Transportation (I-LAST) Rating System was developed by the Joint Sustainability Group of the Illinois Department of Transportation (IDOT), the American Council of Engineering Companies–Illinois chapter, and the Illinois Road and Transportation Builders Association (IDOT, 2009). It is a point-based system and the results are mainly approximations. I-LAST is a voluntary system that is designed to provide a comprehensive list of sustainable practices to project managers and a simple project evaluation (Hirsch, 2011). It is also used to recognize the existing use of sustainable practices by the industry. Some of the criteria include planning, design, environmental, water quality, transportation, lighting, materials and innovation (Hirsch, 2011).

### **3.1.5 Greenroads**

Greenroads is a flexible rating system that is used to rank, score and compare road design and construction sustainability (Greenroads, 2012). It aims at rating sustainable practices of highways. The rating system comprises of 51 scoring criteria with a total of 118 points and four certification levels (Hirsch, 2011). Greenroads provides a range of credits applicable primarily at

the time of construction or immediately thereafter (Dondero, 2012). The credits most closely resemble those offered by GreenLITES and I-LAST, although Greenroads includes a life cycle assessment as part of the materials and resources category (Dondero, 2012). Greenroads is fully developed certification system that required the project reviewers to review projects independent of the project team (Greenroads, 2012). There are basic program requirements that include categories like environment and water, access and equity, construction activities, materials and resources, pavement technologies and custom credits (Hirsch, 2011).

The PEACH roads system used by Georgia department of transportation is similar to the Green LITES system. PEACH Roads is a tool for the assessment of environmental sustainability issues affecting transportation projects. Points are awarded based on criteria for each project before it bids for construction. Categories include promoting the use of recyclable materials, protecting and enhancing the environment, enhancing historic, scenic and aesthetic characteristics of the project site, among many others. In addition, the PEACH roads systems have four different type of certifications based on the points (Cobb County, 2013).

Life cycle analysis (LCA) of the highways is assessed through quantitative analysis method in BE2ST system. It includes mandatory screening and utilizes the judgment indicators to perform life cycle analysis (Hirsch, 2011). The Wisconsin Department of Transportation and University of Wisconsin developed Building Environmentally and Economically Sustainable Transportation Infrastructure Highways (BE2ST). The categories includes social, greenhouse gas emissions, energy use, waste reduction, water consumption, social carbon, cost savings, life cycle and hazardous waste (Hirsch, 2012).

The Sustainable Sites Initiative (SITES) is developed by the Lady Bird Johnson Wildflower Center at The University of Texas at Austin and the United States Botanic Garden

(Hirsch, 2011). It mainly concentrates on sustainable land design, maintenance and construction practices. SITES has 250 points and covers categories including materials, soil and vegetation, sustainable practices and maintenance (Hirsch, 2011). Other considerations for certification can be including projects like public parks and college campuses. The various categories include site selection, pre-design assessment and planning, water, soil and vegetation, human health and well-being, construction, operations and maintenance and monitoring and innovation (Hirsch, 2011).

Table 3.4 Categories of various rating systems Source: (Hirsch, 2011)

		<b>Rating Systems</b>				
		<b>STAR</b>	<b>GreenLITES</b>	<b>Envision</b>	<b>I-LAST</b>	<b>Greenroads</b>
<b>Categories</b>	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	

### **3.2 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). Rating system is one of the most common approaches for benchmarking and quantifying sustainability practices (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 for. The systems can be generic, regional specific and even corporate specific. These systems are generally driven by the following:

#### *1. 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 is 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 is some cost savings out of it (Hirsch, 2011). The developers of rating systems should focus on cost effectiveness of their rating systems and has to develop a framework to analyze on the cost effectiveness (Hirsch, 2012).

## 2. Level of complexity in the rating system

This is an important 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 common 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 which are not easily accessible by general public (Reed, 2009).

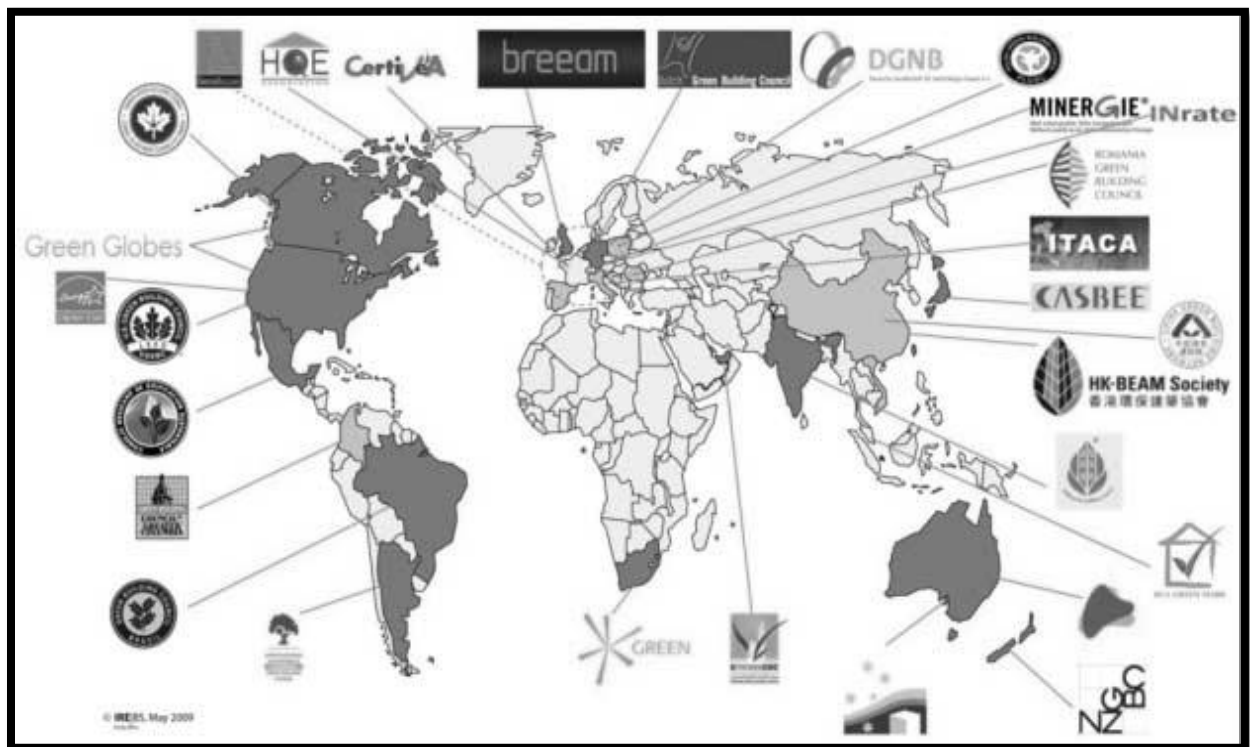


Figure 3.1 International tools on sustainable rating system, Source copied from Reed(2009)

## 3. 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 categorization 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 increasingly difficult (Reed, 2009).

Many sustainability-rating systems have faded away over the past decades, while the more relevant ones continue to thrive. However, many of the programs that have been developed specific to an organization's operations, environmental needs, local context and sustainability philosophy (Hirsch, 2011). While these systems give more weight to the environmental credits (such as storm water, habitat, vegetation, material use), they focus less on the equity and economic benefit. The key reason for this is that cost effectiveness of sustainability overwhelms social relevance (Dondero, George, 2012). Economic decisions are far more important drivers of choices than what the public and private sectors make. As a result, these rating systems often face 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).

Table 3.5 Traffic related points on different rating systems Source: (Bockisch, 2012)

<b>Category</b>	<b>Invest (%)</b>	<b>Envision (%)</b>	<b>Green Roads (%)</b>	<b>PEACH Roads (%)</b>
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

The table shows different points on traffic related activities. The table shows that the emissions factor is allocated less weight by these systems. In addition, the “multi transit factor” that involves ridership has very low weightage.

Greenroads roadway management system does not cover all aspects of transportation sustainability. Greenroads does not address the impact of a road’s life cycle even though life-cycle cost analysis (LCA) is an important part of any sustainability life cycle (Eisenman, 2012). Given the premise that Greenroads can be used to identify where better practices can be applied in project development, it is prudent to understand how the Greenroads system will ensure the contractor or owner is aware of such practices (Eisenman, 2012). Finally, Greenroads does not consider the financial impacts of projects even though it is an important sustainability issue.

GreenLITES is a self-certification program (Dondero, 2012) that shares many similarities with Greenroads and I-LAST. None of the systems provide programmatic elements such as Transportation Demand Management (TDM). I-LAST is a point based system similar to LEED and shares similar credits with GreenLITES and Greenroads.



## **Chapter 4 -Sustainable Policies, Practices and Development of Indicators**

The sustainable strategies and policies are rendered and adopted under the banner of sustainable initiatives in most of the cities (Goldman, 2006). The aim of integrating the sustainable policies with the transportation sector is to travel towards maximizing the economic and social benefits until optimization of costs (OECD, 2000). The success of actual sustainability relies on the measurable outcomes than on theoretical. Interestingly, the funding for public transportation had increased in last two decades (D. Banister, 2007). A number of the organic innovations in transportation practice that are occurring in the field may better serve the goal of sustainable transportation (Goldman, 2006). The New York State Department of Transportation (NYSDOT) sustainable mission is to integrate sustainability into practices, which include planning, constructing and maintaining of the transportation system, and to implement the same in managing the internal resource optimization. (NYSDOT, 2013). Similarly, most of the state agencies develop their transportation policies through which they implement their sustainable initiatives.

Most of the transportation agencies have generally adopted the framework for sustainable transportation that they have identified more relevant to them. 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. This in turn elevated the standards of transportation through the integration of sustainable practices to a certain extent.

#### **4.1 Sustainable practices**

USDOT encourages the state DOTs to initiate sustainable practices and implement measures to develop that green transportation. Many DOTs took this seriously and tried to implement many sustainable practices based on the state population and the budget on their sustainable practices.

The California Department of Transportation (Caltrans) installed a large number of wind turbines and developed many renewable energy production facilities across the state of California (Caltrans, 2013). The Texas Department of Transportation (TxDOT) aims to utilize the renewable and natural resources as the alternative fuel (TxDOT, 2013). 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 Oregon Department of Transportation (ODOT) started various e-recycling and low emission vehicle programs (ODOT, 2013). The Washington Department of Transportation (WSDOT) developed the standards for green highway design and initiated several green highway projects (e.g. the Electric Highways, Smarter Highways and Sustainable Transportation projects). The Iowa Department of Transportation supports the development of ethanol (renewable energy) program in the state.

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 focuses on Asphalt pavement (Jim Warren, 2013). Similarly, Illinois Department of Transportation focuses on alternative fuel and electric vehicle initiatives (IDOT, 2013). The New Mexico Department of Transportation (NMDOT) and the Pennsylvania Department of Transportation (PENNDOT) invests their growth through Smart transportation system for roadways (NMDOT, 2013).

States with smaller population and budget have also implemented numerous sustainable initiatives that enhance state's green efficiency. The Wisconsin Department of Transportation (WIDOT) constructed a historic museum on transportation to educate people about the importance of sustainable transportation. In addition, they have also implemented 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).

#### **4.2 Factors influencing sustainable indicators**

Despite these sustainable practices, the knowledge platforms of these sustainable practices adopted by different transportation agencies are not promulgated wisely. The DOTs are not able to have a clear picture if these practices actually create jobs, reduce carbon emissions and pollution, and provide social benefits to their states and communities. In addition, these environmental initiatives do not compose towards quantification of sustainability mostly. Thus, the policies and practices adopted by different state agencies do not exactly provide the level of sustainability of the state. 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 incorporate this program, later drop it due to lack of funding and initiatives from the state. 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 states that some of the factors influencing sustainability in transportation includes nonrenewable fuel depletion, global climatic change, local air quality, fatalities and injuries, congestion, greenhouse gas emissions and 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) 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. The research team focuses on the availability of information from similar reliable resources. The indicators are also developed from the literatures (Litman, 2011) and from the information collected through the state DOT websites.

### **4.3 Sustainable Indicators**

Indicators are the representation of the social, economic, and environmental information. Indicators provide orientation, or direction, for measuring sustainability amongst its many complexities (Bossel, 1999). Information on these three dimensional issues are plenty and hence these indicators are considered to be the best way of portraying the issue in a simplest form in terms of quantification. In terms of sustainability, indicators simplify the process of answering the question of how to reduce human impact and protect future generations (Oswald, 2008). The indicators must be selected according to the requirement of the research and based on reliable information. According to Bossel (1999), the indicators are selected based on four important steps. The steps include first, understand the requirement and the total system; second, identify the potential indicators; third, quantify the indicators and finally, construct a participative process.

It is possible to capture essential processes and relationships in a model and it can always be improved as new knowledge is gained about the system through the system life cycle (Bossel, 1999). Sustainability is evaluated using a set of measurable indicators to track trends, compare

areas and activities, evaluate particular policies and planning options, and set performance targets (Litman, 2011). The indicators adopted for measurement of sustainability are determined by their level of importance to their application. The use of a large number of indicators can improve the comprehensiveness of information and thus better reflects sustainability in reality. However, increasing the number of indicators may elevate the cost of operating the system, and it may not effectively represent sustainability if the data comes from unreliable sources.

According to Litman, the principle for a good system includes (Litman, 2011):

*1. Comprehensiveness of the system:* Indicators should reflect the required economic, social and environmental impacts, and transportation activities. The indicators selected have to cover all of the required impacts and measurements and have to reflect the sustainability intended.

*2. Data quality:* Data used by the indicator has to come from established and reliable sources.

The data has to be consistent with the output of the system.

*3. Comparability:* Data collection should be standardized so that the results are suitable for comparison under the given conditions (e.g. time and groups).

*4. Easy to understand and avoid double counting:* Indicators must be useful by decision-makers and understandable to the public. The more information condensed into a single index the less meaning it has for specific policy targets (for example, Ecological Footprint analysis incorporates many factors) and the greater the likelihood of double counting.

*5. Accessible and Transparent:* Indicators (and the data they are based on) and analysis details should be accessible to all stakeholders and the models adopted be transparent to the users.

*6. Cost effective:* Data collection should be more cost effective than the output the data generates. Users will stay away from indicators and data that cost a lot of money to use.

7. *Net Effects*: Indicators should differentiate between net (total) impacts and shifts of impacts to different locations and times and can be separated or integrated with indicators easily.

8. *Performance targets*: select indicators that are suitable for establishing usable performance targets.

The table below indicates the general indicators under social, economic and environmental categories.

Table 4.1 Sustainable rating indicators; Source: (Litman, 2011)

<b>Sustainable Rating Indicators</b>		
<b>Environmental</b>	<b>Economic</b>	<b>Social</b>
Climate change emissions	User satisfaction	User rating
Other air pollution	Commute time	Safety
Air pollution	Employment accessibility	Fitness
Noise pollution	Land use mix	Community livability
Water pollution	Electronic communication	Cultural preservation
Land use impacts	Vehicle travel	Non drivers
Habitat protection	Transport diversity	Affordability
Habitat fragmentation	Mode split	Disabilities
Resource efficiency	Congestion delays	Children’s travel

#### 4.3.1 Development of Indicators

The research focuses on the development of the framework of a sustainable benchmarking system that will be used to rank the sustainability of the state transportation agencies using selective indicators and their respective adjustors. The literature search highlights the need for the proposed system. Most of the systems are concerned with the sustainability of projects, design, and materials.

First, the study identifies the indicators that should be included and second, the study emphasis the sustainable indicators suitable for the transportation sector. The research includes the following activities: (1) literature reviews on sustainable engineering and transportation practices and indicators; (2) examining the sustainable transportation practices of various

Departments of Transportation; (3) develop the indicator framework and identify future work to complete the indicator; (4) Proposed ranking of the states of their sustainable performances.

Consolidations of indicators are done from existing sustainable transportation rating system and from the social, economic and environmental factors. The table highlights level of importance and sources of each indicator. Data availability is an important consideration and the research team has to determine if the data is available and if the data comes from reliable sources. The indicators are grouped into quantitative and qualitative categories. These qualitative data are considered for the rating system to ensure that the rating system is more extensive and accurate.

#### **4.3.2 Level of Importance of Sustainable 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 on their importance to the research. For example, budget is an important 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 less data and can be neglected. Hence, it is of low importance. Bicycle path program is one important sustainable initiative that is implemented almost in every state but the data availability of bicycle program is qualitative rather than quantitative, hence it is considered of medium importance. Some of the indicators are treated separately and new indicators are developed to better reflect the needs.

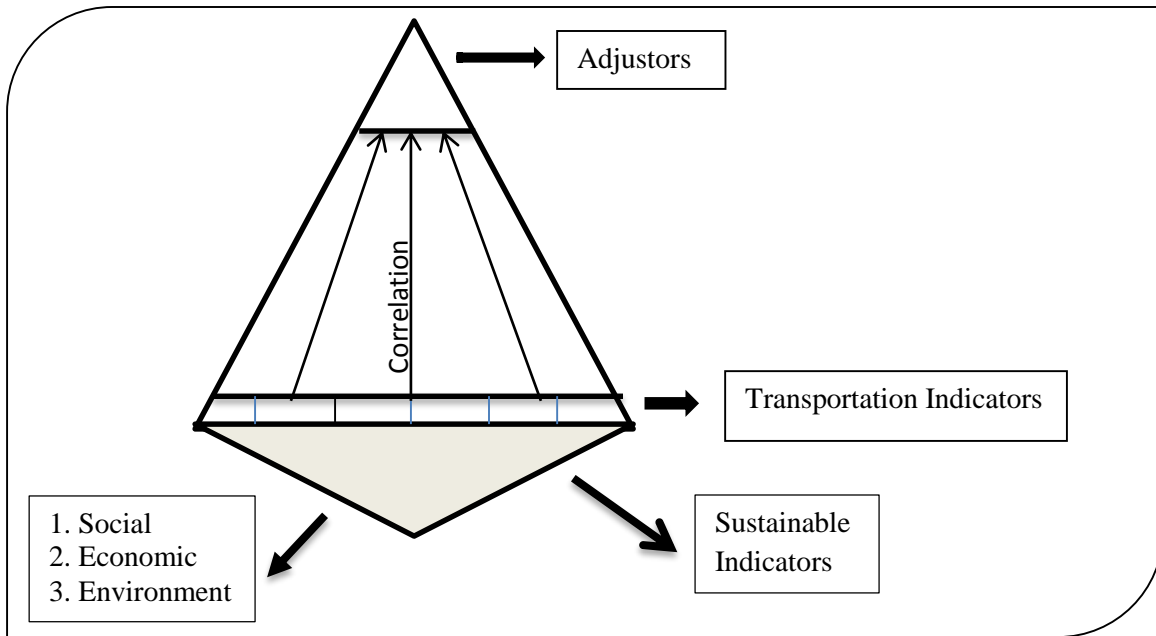


Figure 4.1 Relationship between indicators and adjustors

Two important adjustors population and Gross Domestic Product (GDP) are used in this research to make an adjustment to the analyzed data. The adjustments are made to reflect the state's efforts in sustainability due to a state's population and income. Population and Gross Domestic Product are widely used in order to determine state's credibility and efficiency in sustainability. Population and GDP are important real time factors, which changes with time and place at a regular interval. There are several other real time factors but the research team focused on adjustments through population and GDP in order to integrate sustainability and economic growth. Population is an important adjustor of this research. The indicators are adjusted through population and GDP. Energy consumption and carbon emissions are the indicators that have been adjusted by both population and GDP to identify which can provide better results in terms of sustainable transportation efficiency.



Table 4.2 Budgets on transportation (Sunshine review, 2010)

<b>Budget</b>		
<b>Sustainable indicators</b>	<b>Data sources</b>	<b>Importance</b>
Total state budget	Sunshine Review	High
Total budget on transportation	Sunshine Review	High
Budget on public transportation	Sunshine Review	High
Budget on sustainable programs	Sunshine Review	High
Budget on sustainable research	Sunshine Review	High

Table 4.3 Ridership on public transit (APTA, 2011)

<b>Public transportation</b>		
<b>Sustainable indicators</b>	<b>Data sources</b>	<b>Importance</b>
Ridership of public transport	American Public transit association (APTA)	High
Ridership on high speed rail	American Public transit association (APTA)	High
Ridership on commuter rail	American Public transit association (APTA)	High
Ridership on buses	American Public transit association (APTA)	High
Ridership on carpool/vanpool	American Public transit association (APTA)	High
Ridership on trolley buses	American Public transit association (APTA)	High
Ridership on street cars	American Public transit association (APTA)	Medium
Ridership on bicycle	American Public transit association (APTA)	Medium
Ridership on demand response	American Public transit association (APTA)	Low

Table 4.4 Emissions and fuel consumption indicators (EIA, 2010)

<b>Emissions and fuel consumption</b>		
<b>Sustainable indicators</b>	<b>Data sources</b>	<b>Importance</b>
Carbon emissions by public transportation	Energy Information Administration (EIA)	High
Carbon emissions by state buildings	Energy Information Administration (EIA)	High
Gasoline consumption	Energy Information Administration (EIA)	High
Ethanol consumption	Energy Information Administration (EIA)	High
Bio fuel productions	Energy Information Administration (EIA)	High

Table 4.5 Energy use and efficiency indicators (FHWA, 2010)

<b>Energy use and efficiency</b>		
<b>Sustainable indicators</b>	<b>Data sources</b>	<b>Importance</b>
Transportation energy	Energy Information Administration (EIA)	High
Operational energy	Environmental Protection Agency (EPA)	High
Embodied energy	Environmental Protection Agency (EPA)	High
State vehicles on alternative fuels	Energy Information Administration (EIA)	High
State vehicles on electricity	Federal Highway Administration (FHWA)	High
Number of alternative fuel stations	Energy Information Administration (EIA)	High
Number of electric charging stations	Energy Information Administration (EIA)	High
Renewable energy in public transit	Energy Information Administration (EIA)	High
Public buses running on electricity	Energy Information Administration (EIA)	Medium

Table 4.6 State agencies' commitments and goals

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

Table 4.7 Other important indicators

<b>Proposed other important indicators</b>		
<b>Sustainable indicators</b>	<b>Data sources</b>	<b>Importance</b>
Land used on highways	Web sources	High
Recycling and reuse of materials	Survey	Medium
Recycling rate by state agencies	Survey	Low
State Water Quality	Web sources	Low
Water use by state transportation agency	Web sources/Survey	Medium
Total number of OSHA violations	Web sources/Survey	High

State overall air quality	Web sources/Survey	Low
Vehicle toxicity emission	Web sources	High
Construction pollutants	Web sources/Survey	Medium
Vehicle emissions inspection	EIA/Survey	High
Particulate emissions	EIA/Survey	High
Productivity loss due to injury	Survey	High
Productivity loss due to death	Survey	High
Project delay	Survey	High

### 4.3.3 Selection of Indicators

The system that is developed for this research allows States DOT to use the indicators to compare themselves with the other DOTs, understand their position and learn how other DOTs apply their sustainable approaches. Several important indicators were dropped from the framework due to (1) the lack of available and reliable data, (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 standard of living, quality of life and health and crime, how community felt about various transportation projects. For example, the overall funding allocated for sustainability related initiative 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. The data availability of embodied and operational energy of state buildings is also not available and has to be omitted. Carbon emissions from the state buildings requires time to collect, hence the indicator is neglected at this time. Instead of tracking health statistics (where establishing a link between transportation and health can be very difficult), the research team targets pollutant emissions. It is difficult 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.

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 good rating system mentioned in Litman(2011)that fits the research at its best at this point of time. 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 on each other. Table 4.8 lists the various sub-indicators that come under the BRECE indicators.

Table 4.8 Selection of Indicators (BRECE)

<b>Sustainable indicators</b>	<b>Importance</b>
Total state budget	High
Total budget on transportation	High
Budget on public transportation	High
Budget on sustainable programs	High
Budget on sustainable research	High
Ridership of public transport	High
Ridership on high speed rail	High
Ridership on commuter rail	High
Ridership on buses	High
Ridership on carpool/vanpool	High
Ridership on trolley buses	High
Ridership on street cars	Medium
Ridership on bicycle	Medium
Ridership on demand response	Low
Carbon emissions by public transportation	High
Transportation energy	High
Gasoline consumption	High
Ethanol consumption	High
Bio fuel productions	High
Number of electric charging stations	High

## **Chapter 5- Data Analysis**

This chapter explains the data collection process, organization and analysis. The data are reorganized into different sustainable indicators and are adjusted by population size and GDP of the state.

### **5.1 Data Collection**

A significant part of this research is dedicated towards the data collection for the development of the analysis framework that will be used to benchmark the sustainability of states and their transportation agencies. The information are collected from established and reliable sources, such as databases and documents published by various US public agencies, like the United States Department of transportation (USDOT), Energy Information Administration (EIA), Environmental Protection Agency (EPA), American Public Transportation Association (APTA) and American Public Works Administration (APWA). The documents and articles published by state DOTs are used to gather information on sustainability from the transportation sector.

A spreadsheet with fifty states and indicators are populated with the data collected. The spreadsheet is then reorganized for better analysis and are grouped under five important sub-categorized indicators. These indicators are named as BRECE that mentions Budget, Ridership, Emission, Consumption and Energy efficiency. BRECE indicators comprises of sub indicators that is selected based on the reliability of information, data availability and importance of the indicator for the preliminary analysis on sustainable transportation. Apart from the quantitative data, the research team focused on using qualitative information available online from reliable sources. These qualitative data includes the documents, proposed plans and initiatives and reports on environmental prevention strategies by DOTs.

## **5.2 Survey form**

Survey is an important tool that is used to collect unknown information from a group of population in order to verify the usability of data. A survey form was developed to gather information from the DOTs. The link to the survey form (Survey monkey) was sent to the respective person in the DOT. It consists of nineteen questions and focuses on information that are not found on any website sources. The questions of the survey targets both qualitative and quantitative data and includes questions related to DOTs' energy efficiency schemes and consumption data. The research team focused at completing this data collection with 4-5 weeks. Each week 10-15 states were targeted with the mix of bigger, medium and smaller states (in terms of population). This survey form is used to collect data for the benchmarking matrix and sustainability indicators. Eighteen states responded to the survey form (some replied comprehensively while others sporadically). Emails and phone calls were made regularly by the research team to further collect and verify the validity of the provided information. The status of responses were monitored and a survey spreadsheet was created to update the information. The information collected from the survey form were verified of its accuracy, and were rejected from the data set if found irrelevant or questionable. The data from the survey is not completely available from all the states, hence the information are rechecked, and the qualitative information are preserved for future scope of this research. A sample of the survey form is available in the appendix.

## **5.3 Data Analysis**

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 population and GDP. The objective is to scale down the amount of energy and time spent on the research of sustainability issues in

transportation for future researchers in this field. The organization of this knowledge will follow similar approaches adopted by the National Institute of Standards and Technology (NIST), American Society of Civil Engineers (ASCE), Institute for Sustainable Infrastructure (ISI), and Federal Highway Administration (FHWA). The output has to allow states to compete and learn from one another in order to improve the sustainability performance of transportation. This knowledge is then organized into a readable and usable format available for transportation professionals and pioneers to access on the website. The research team focuses on preliminary analysis with the essential indicators i.e. (BRECE). The flow chart below shows the research focus and further directions.

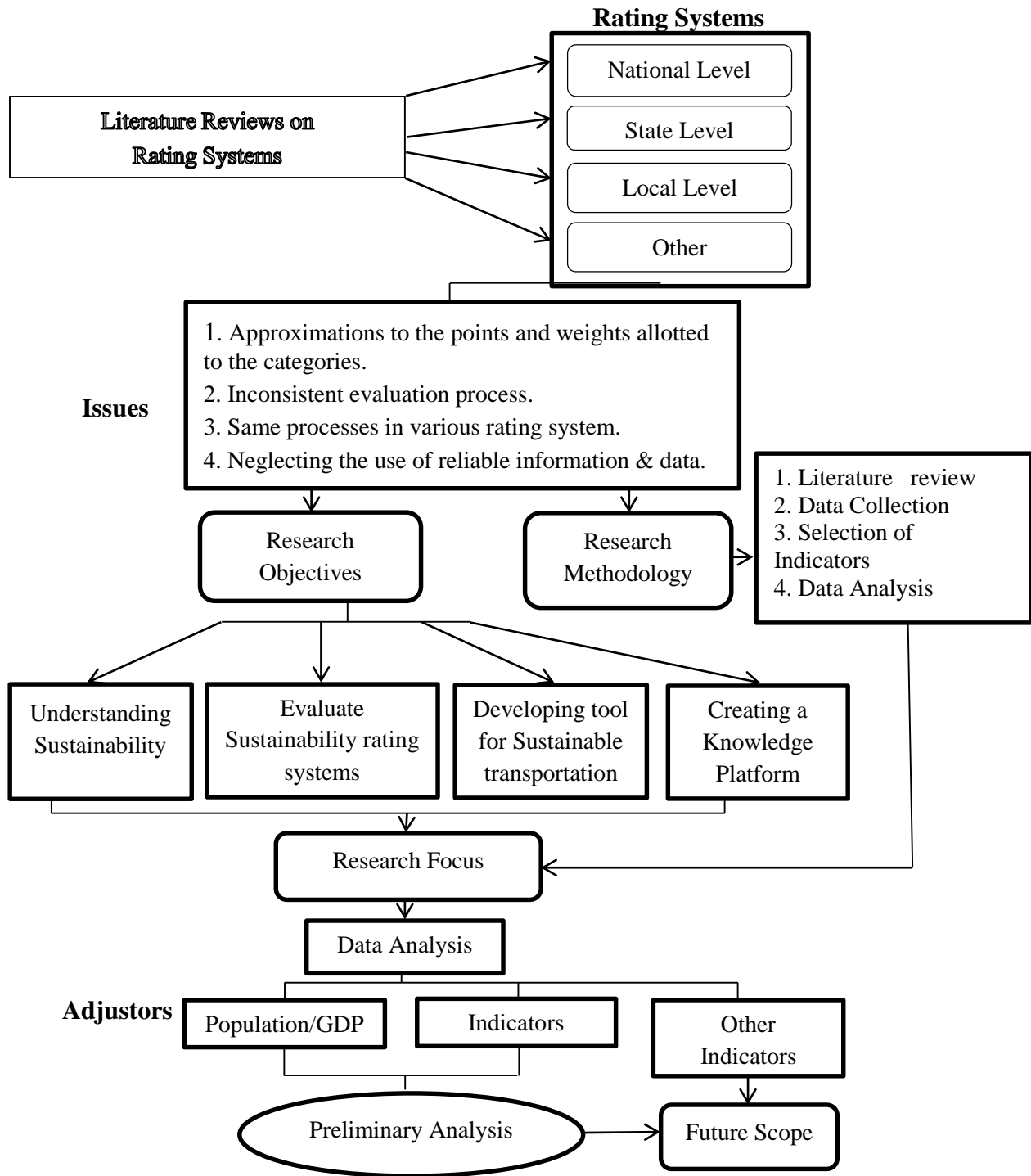


Figure 5.1 Flow chart representing Research Focus and outcomes



## 5.4 Population as an adjustor

Two adjustors, population and GDP, are used to adjust the indicators. Population influences the sustainability in transportation. It is used as key adjustors 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 greater population density. Large states have larger 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 total number of vehicles registered, total transportation budget, population density of state and largest cities and ethanol and gasoline consumption. The correlation between the sustainable transportation and population density with respect to place and time is obtained through Karl Pearson's correlation equation. Three different analyses are done with the population as an adjustor.

Table 5.1 Indicators adjusted by population

<b>Indicators adjusted through Population</b>	<b>Importance</b>
Budget	High
Automobiles	High
Population density	High
Ridership	High
Energy consumption	High
Carbon emissions	High

### 5.4.1 Budget and Population Density

The allocation of the federal budget in the United States is the outcome of a complex process involving numerous institutional players (Larcinese, 2004). Each state has their budget allocated by the Federal government based on taxes and other revenues collected by the state governments.

Table 5.2 Percentage of transportation budget to the total state budget, Source: (Sunshine review, 2010)

State	State Budget in \$bn	Transportation Budget in \$bn	% of Total Budget	Population Density/sq.mi
Wisconsin	14.2	6.5	45.7	105
Nevada	6.2	2.0	32.2	24.6
Illinois	63.8	17.5	27.4	231.1
Iowa	5.6	1.4	25.0	54.5
Oklahoma	6.7	1.7	25.0	54.7
Washington	32.1	7.8	24.3	101.2
Nebraska	3.4	0.8	23.5	23.8
Georgia	17.8	4.2	23.0	168
Utah	4.8	1.0	21.9	33.6
Mississippi	4.4	0.9	20.4	53.2
North Carolina	22.8	4.0	17.5	196.1
Oregon	14.5	2.4	16.5	39.9
South Dakota	4.0	0.6	14.2	10.1
Louisiana	24.6	3.5	14.0	104.1
Vermont	4.7	0.7	13.8	57.9

Table 5.2 shows the top 15 states that devote the largest percentage of their total state budget to transportation budget in 2010. The adjustment through population and population density over budget is necessary to reflect sustainability commitments and achievements of the transportation agencies due to their population size and overall budget. The adjusted figure better reflects the actual dollar spent on a resident in the state and according to the overall budget. Analysis found both population and population density to have an effect on transportation budgets, thus adjusting the indicators according to the budget and population would allow state to compare with one another.

Wisconsin spent the most on transportation, 45 percent of its total budget, followed by Nevada at 32 percent. These states do not have high population density when compared with other states like Illinois and North Carolina. Does this mean that with high percentage of

transportation budget and low population density, the state can be more sustainable? It is difficult to conclude since population density reflects the intensity of investment and the increasing potential ridership through public transportation. However, there are greater opportunities for states like Nevada, Iowa and Oklahoma to invest and promote sustainability programs that can improve their sustainability performance. Bigger states like California and Texas spend more on transportation than District of Columbia but larger expenses doesn't mean California and Texas are more sustainable than D.C and Missouri. Bigger states require more investment in infrastructure and the government allocates more money for the construction, maintenance, and operation of transportation system. Thus by percentage, the transportation budget can be lower than in smaller and medium-sized states.

#### 5.4.2. Budget and Population

As with population density, the population size of a state is an essential factor when determining the efficiency of transportation sustainability. The figure 5.2 below shows the top ten states based on total transportation budget and budget per capita.

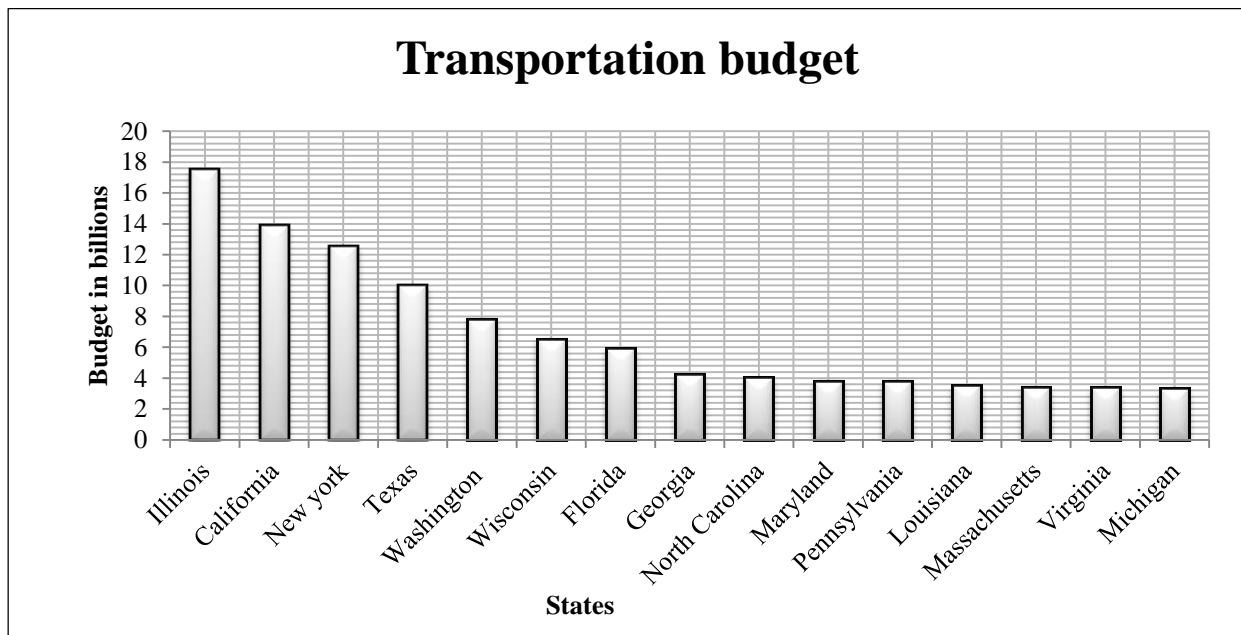


Figure 5.2 Transportation budget of states; Source: (Sunshine review, 2010)

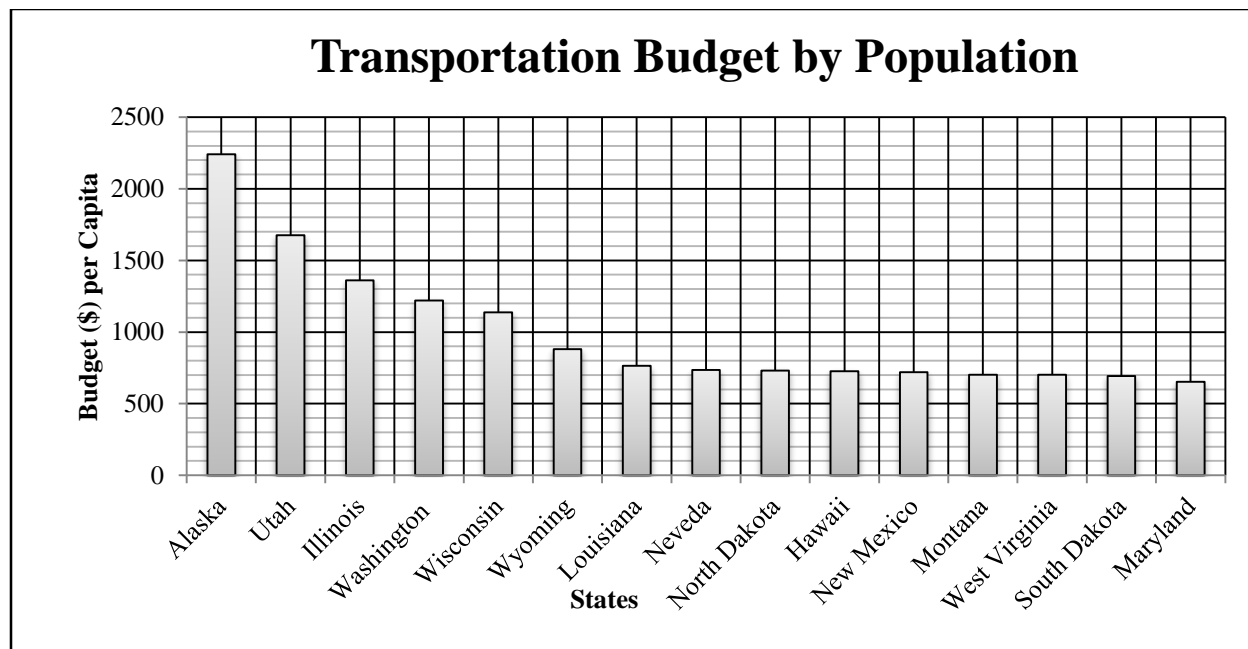


Figure 5.3 Transportation budget / Capita in US (2010); Source: (Sunshine Review, 2010)

**Analysis:** In figures 5.2 and 5.3, it can be seen that the budget per state differs widely before and after adjustment through population. It is not enough just to look at the amount of money that a state spends in total; the expenditures per capita must also be considered to give a clear picture of how a state’s investment in its transportation infrastructure benefits each individual citizen. This adjustment is required to elevate the accuracy of the results and improve the reliability of the research approach. Illinois and California topped the table for total budget allotted. Adjusted for expenditures per capita, Alaska and Wyoming topped the list. Does this mean Alaska spends and cares more about their transportation facilities? The reason swirls around factors such as transportation distances of construction materials, climatic conditions, and the population density of the state.

The adjustment makes more sense, as states with lower population densities require more funding to develop their highways as there are fewer public transportation facilities than in more densely populated states. The climate of the state also plays a major role in investment in

transportation infrastructure. Alaska has an average annual rainfall higher than the mean rainfall of the United States as a whole. Hence, the construction, operation and maintenance costs will tend to be greater since transportation development takes place at a slower pace due to adverse climate conditions. This can in turn increase the transportation budget of the state.

**Inference:** The state budget does not reflect actual achievements and commitments in sustainability and does not accurately reflect the importance of the sustainable transportation program within the state. Some programs can be more expensive but are not cost effective, while other programs can integrate with other less cost effective programs to yield better results. Some states may need more infrastructure to support new initiatives and more funding on the maintenance and operation of infrastructures.

#### **5.4.3 Automobile ownership and population**

Population has a major impact on the country's economy and development. The states are categorized into major and minor mainly based on the population size, population density, and the accessibility of goods and materials. With the growth in population, the demand for land also increases where the issues of construction, mobility, and accessibility arise. These issues have an impact on the environment through increased use of automobiles, which in turn leads to an increase in air pollution.

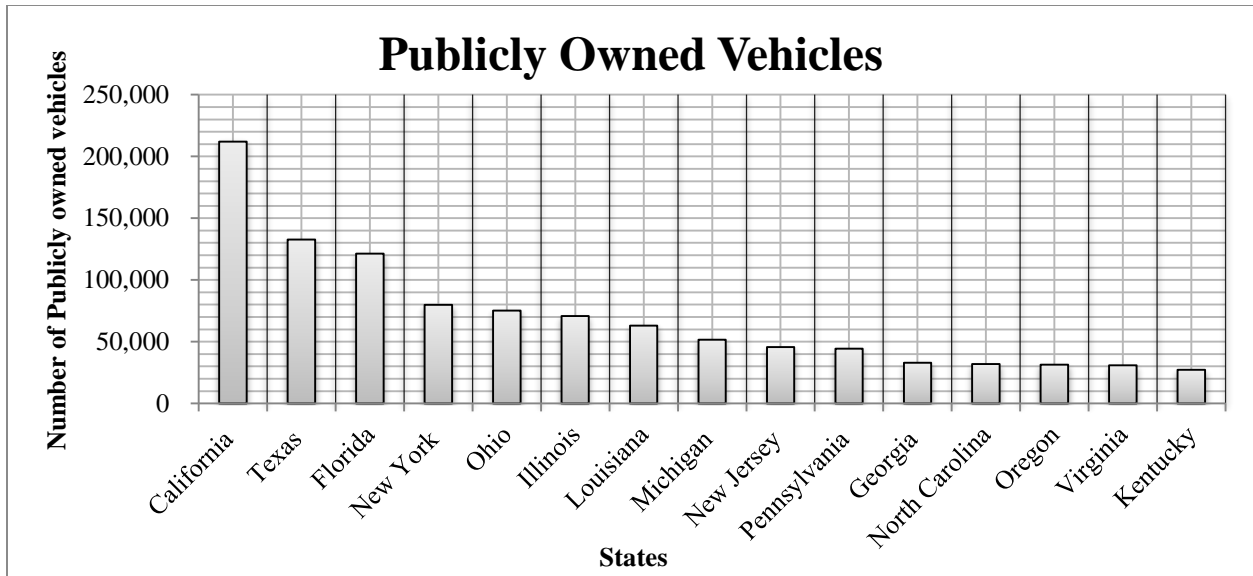


Figure 5.4 States with high number of publicly owned vehicles (FHWA, 2010)

Figure 5.4 shows the states with the highest number of publicly owned vehicles. The states with the largest populations, California, Texas, Florida, and New York are on the top of the list. The research team focusses on correlating this data with population to determine the level of consumption of fuels and the opportunities of sustainable efficiency in each state. The figure 5.5 below shows the number of registered vehicles per 100 persons in the state.

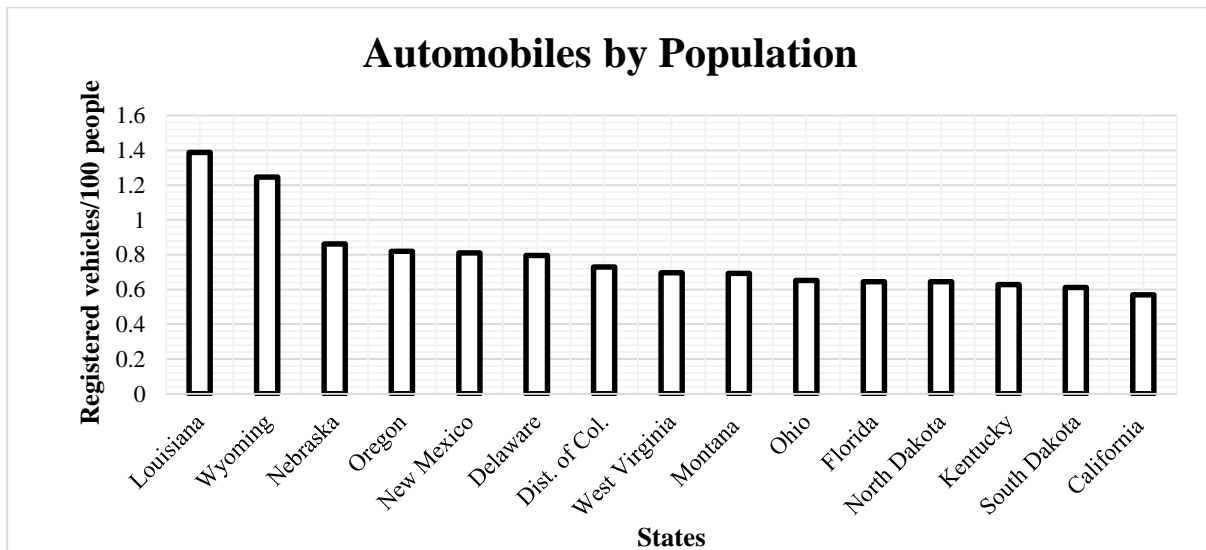


Figure 5.5 Public owned vehicles per 100 people, Source: (FHWA, 2010)

The number of registered vehicles ranges from 1-1.5 automobiles per 100 people in each state. This adjustment produces results that leave more densely populated states like Texas and Florida out of the top ten, and brings in less densely populated states like Wyoming and Delaware in the list.

**Analysis:** The gasoline consumption in Louisiana is 280.4 trillion Btu (EIA, 2010). In addition, from the figure, it is clear that Louisiana has high number of registered vehicles per 100 people. This information can tell us that the gasoline consumption in transportation is directly proportional to the number of publicly owned vehicles within the state. Similarly smaller state like Delaware and Wyoming tops the table. Does this lead us to infer that vehicle ownership per capita is a predictor of the sustainability of transportation? This is difficult to discern as people can own vehicles but they may not use them. Other factors also influence vehicle per capita such as total and average fuel consumed by the vehicles, distances driven, sizes of vehicles (energy efficiency), and the types of fuels used by the vehicles. In addition, the densely populated states like Missouri and Maryland have fewer registered vehicles per 100 people when compared with less densely populated states like Wyoming, Delaware, and West Virginia where, privately owned vehicles are the only reliable transport.

#### **5.4.4 Automobiles and Population Density**

Total population and population density are the other drivers of sustainability. High population density is needed to make public transportation available in states with large population. However, the chances of sustainable transportation efficiency increase only in states where the largest cities have higher population density than mean density of the city. In cities with population density less than mean density of the city, state governments require larger budgets per capita to make ridership and other sustainable programs more successful. Table 5.3

below tabulates the information of the top states based on number of registered automobiles in the state, and the population density of their largest cities.

Table 5.3 Population of the state Source: (Sunshine review, 2010)

State	Population	Population density per square mile	Largest city in the state	Density of largest city	# of Publicly owned vehicles
California	37253956	239	Los Angeles	8092	211980
Texas	25145561	96	Houston	3501	132604
New York	19378102	411	New York city	27012	79817
Florida	18801310	350	Jacksonville	1100	121257
Illinois	12830632	231	Chicago	11842	70736
Pennsylvania	12702379	283	Philadelphia	11379	44266
Ohio	11536504	282	Columbus	3624	75215
Michigan	9883640	174	Detroit	5144	51707
Georgia	9687653	168	Atlanta	3154	32862
North Carolina	9535483	196	Charlotte	2457	32027
New Jersey	8791894	1195	Newark	11458	45647
Virginia	8001024	202	Virginia Beach	1759	30752
Washington	6724540	101	Seattle	7251	29051
Massachusetts	6547629	839	Boston	12793	22447
Indiana	6483802	181	Indiana Polis	2270	29743

According to Karl Pearson’s population coefficient theory, the sustainable transportation efficiency ( $ST$ ) of the state can be related to the population density ( $R$ ) of the largest city in that state. The correlation between  $R$  and  $ST$  are positive with respect to change in place and time ( $X$ ).

$$C(R, ST) = \text{Correlation } (X(R), X(ST))$$

In general, sustainable efficiency in transportation is directly proportional to the population density of the largest city. The correlation is determined using Karl Pearson’s population coefficient equation (Wolfram, 2002).



The formula is rendered as

**$H_1: P > R \geq X, ST = \text{High possibility}$**

**$H_2: P > R < X, ST = \text{Very low possibility}$**

**Analysis:** California has the highest population and highest population density in its largest city. As per the correlation, since population density is directly proportional to sustainable transportation efficiency, it has greater chances of achieving sustainability through ridership and other public transit access programs. However, the number of publicly owned vehicles in California is greater than in other states that in turn means more emissions are generated by the state. It can be concluded that more public transportation facilities in the state can increase sustainability in transportation.

Illinois and Pennsylvania are the two states that have nominally lower publicly owned automobiles and higher population density. Thus, these states have greater chances of ranking on the top of the table since they increase the public transit operations.

#### **5.4.5 Ridership and Population**

Ridership of various forms of public transportation is an important indicator of how they are used, and how states can enhance their use. It is thus an important transportation sustainability indicator. Ridership is defined as the total number of passenger trips in a day utilized through various modes of public transportation (Bureau of Transportation Statistics, 2008). The use of public transportation could potentially reduce emissions and enhance energy efficiency. It is an important indicator of the state and plays a vital role in evaluating a state's public transportation and public policies on public transport. Nationally, only 2.1 % of all trips taken were on public transit whereas 85.8% were in private shuttles, 9.9 % by foot and cycle, and 2.2% by other means. Ridership data are collected for various modes of public transport such as

busses, high speed and commuter rails, car and vanpool programs, light rails, and other local transportation modes (APTA, 2011).

Table 5.4 Ridership values of the top states; Source: (APTA, 2011)

<b>State</b>	<b>Trips/Day</b>
New York	11583700
California	3559800
Illinois	2098800
Pennsylvania	1436800
District of Columbia	1326300
Massachusetts	1233700
Texas	794400
Florida	689300
Washington	679100
Maryland	529,600
Georgia	453100
Oregon	330800
New Jersey	294600
Colorado	292700
Arizona	271700

The summary of state ridership is shown in table 5.4. The states with the highest ridership are New York and California. It is true that these states invested heavily in transportation infrastructure and could potentially invest more on their transportation system due to their high population density. However, these states also rank high on the number of publicly owned vehicles, which means that many residents still rely on self-transportation and not on public transportation. Texas, large population contributes to the better trips/day on public transportation use. However, it is ten time larger than Maryland in automobile ownership. Hence, the adjustment through population is needed to have better analysis and outputs.

Ridership is now adjusted for population and the results are calculated. California and Texas is on the top of the list and states like Ohio and Virginia ranks among top ten states on ridership. These results require further analysis in order to understand the rankings.

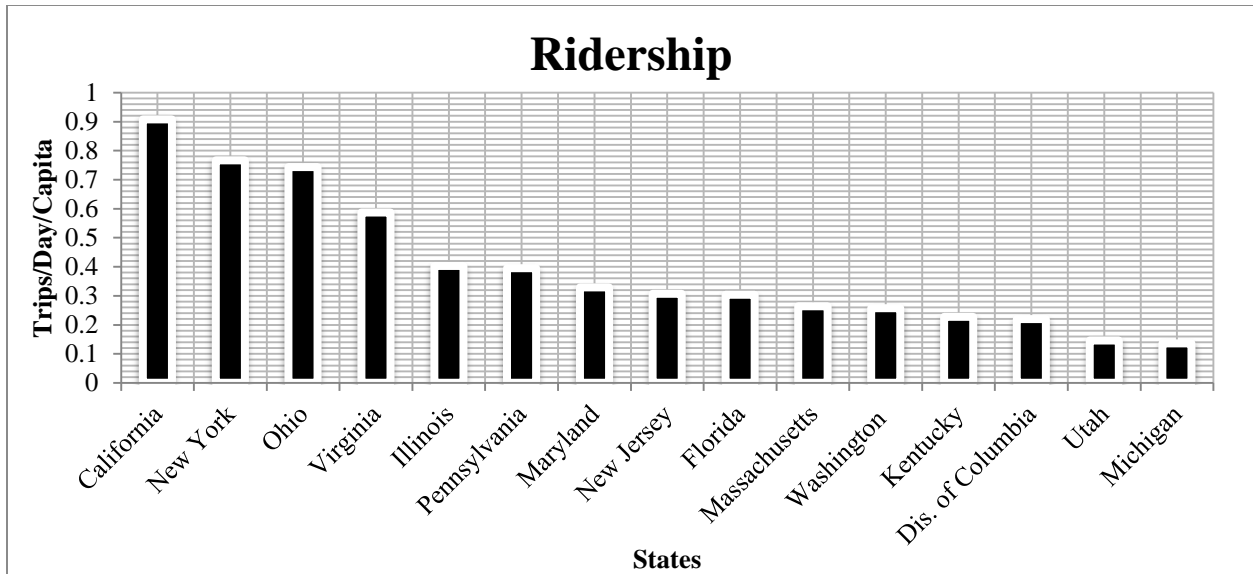


Figure 5.6 Ridership values(Trips./Day/Capita) for the top states (APTA, 2011)

**Analysis:** Figure 5.6 indicates the level of use of public transport in the top 11 states. California tops the list and Ohio stands third. The population of Ohio is almost less than half of California and its ridership is 0.75 trips per day. Also, the automobile ownership data shows Ohio has three times lesser number of registered vehicles than California. This shows the ridership utilization is more in Ohio than California. Hence with population analysis Ohio looks better than California. Virginia is one other state where the ridership is 0.6 and less-densely populated than mean density which means its ridership can be far better than California and New York.

**Inference:** Higher population does not mean greater ridership. It depends on various other factors such as land size, carbon emissions, energy consumption, and energy production in the state. Numerous initiatives to promote public transportation can be the major reason for increase in ridership. Further studies are needed to determine the importance of these indicator.

#### 5.4.6 Carbon Emissions and Population:

Greenhouse gas emissions (GHG) is an important sustainability indicator. Emissions are produced generated by many sources related to the operation and maintenance of transportation

infrastructure; construction and maintenance vehicles, the operation of transportation-related facilities like traffic operation control rooms and DOT buildings among others. State transportation agencies are significant emitters of greenhouse gases and consumers of energy within their state. The carbon footprints of transportation agencies should be included in the indicator since they generate and use huge amounts of energy and emit significant amounts of carbon.

A study on KDOT footprint is a good example as to how this is done. The Kansas Department of Transportation (KDOT) owns and operates over 950 buildings and 13,000 motorized vehicles, builds and maintains thousands of miles of highways, thousands of bridges, and countless numbers of lamp posts and railings. KDOT is the largest energy consumer and greenhouse gases emitter in the state of Kansas as a result. A recent study showed that KDOT generated 15,000 tons of greenhouse gases from its buildings and 1,800 tons of greenhouse gases from its vehicles accurately from 2008 to 2011. KDOT footprints consist of the buildings and vehicle fleets that it operates, while the footprints of Kansas highways, airports, and public transportation support facilities (such as lightings and rest areas along highways) are not included in the study.

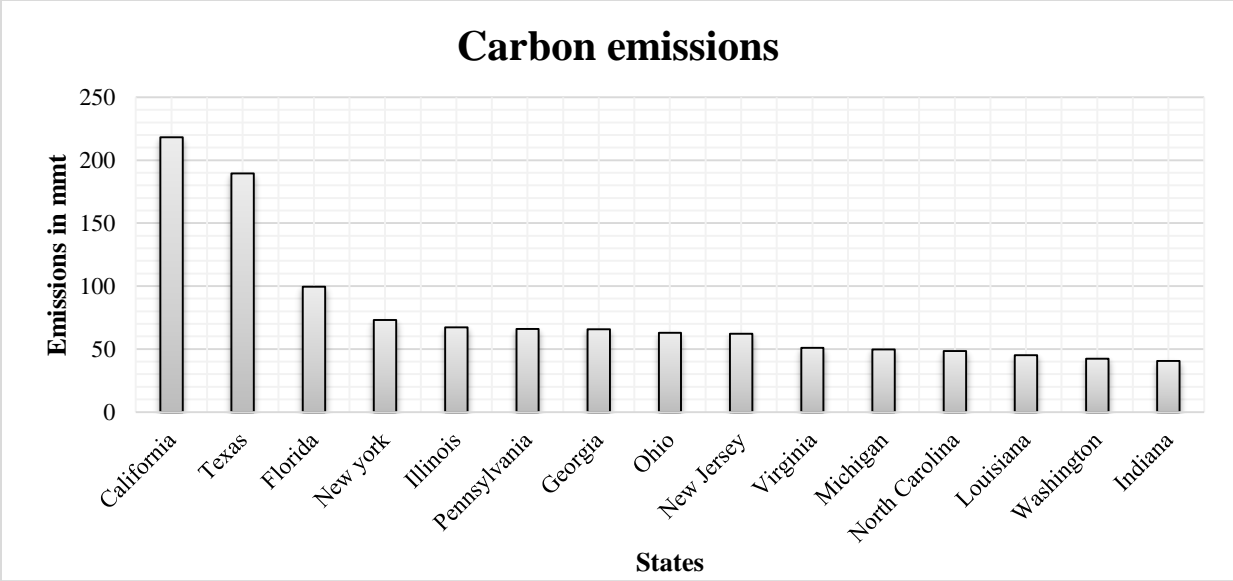


Figure 5.7 Details on carbon emission through transportation (million metric tons) (EIA, 2010)

Since carbon emission is an important indicator for the research, the emission data from the transportation sector of each state is collected from state DOT websites and from the Energy Information Administration (EIA). The figure 5.7 shows that California, Texas and Florida are the top three states contributing to transportation carbon emissions. Population, registered vehicles, and low utilization of public transportation facilities generated the impacts.

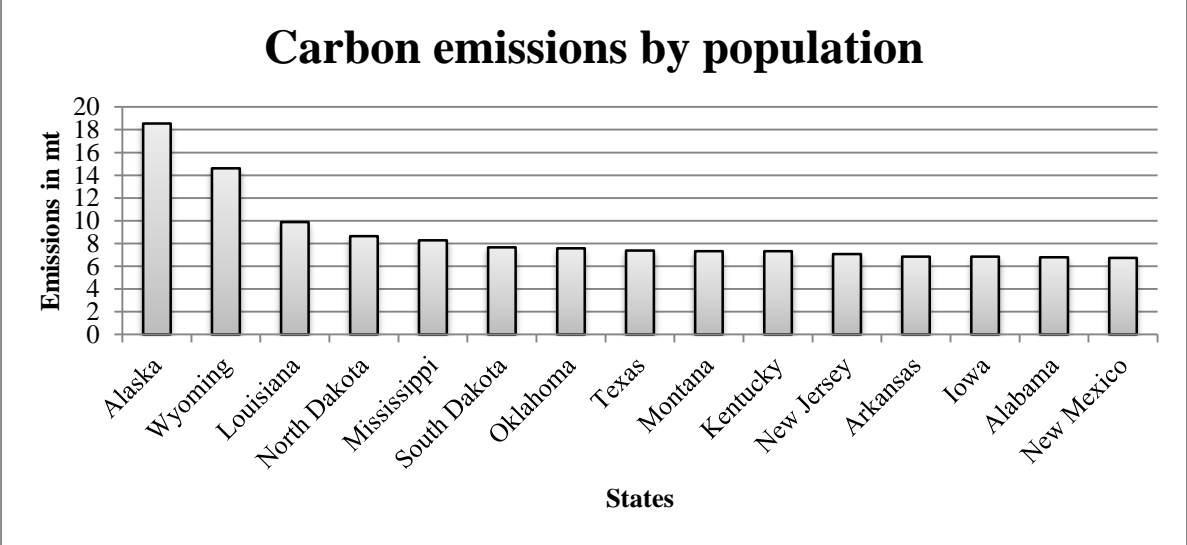


Figure 5.8 Ranking on emissions per capita (metric tons) (EIA, 2010)

Figure 5.8 shows the list of top states after adjusting by the population. Alaska stands top among the states followed by Wyoming and Louisiana. Bigger states like Texas fall lower on the table after this adjustment.

**Analysis:** Larger states like California and Florida are outranked when carbon emission is adjusted by their population, smaller states like Wyoming and Alaska topped the carbon emissions per capita ranking. Does this mean the more densely populated states have low emission per capita than the lesser densely populated states? The analysis identifies the impacts of population as an adjustor of the carbon emissions due to transportation. Alaska has a smaller population and thus larger transportation budget per capita. Transportation development moves at a slower pace because of climate conditions resulting in greater reliance on private transportation than public transportation, which may be the reason for the greater carbon emissions.

#### **5.4.7 Energy Consumption and Population**

The next sustainability indicator is the energy use by the transportation sector. The transportation sector consumes 30 percent of all energy consumed and generates over 30 percent of all greenhouse gases (GHG) emitted in the United States (EPA, 2012). Consumer products are transported rapidly through planes and other rapid transportation modes that consume more energy and emit pollution. Transportation accounts for approximately 25 percent of world energy demand and for more than 62 percent of all the oil used each year (World Energy Council, 2007).

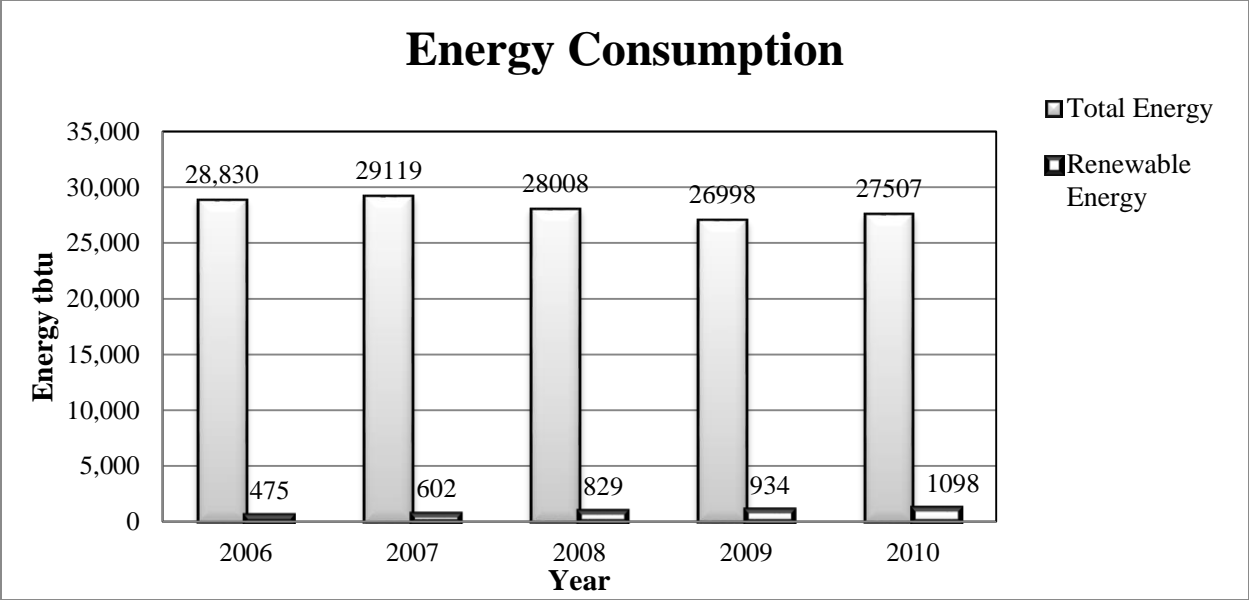


Figure 5.9 Details on energy consumption by Transportation sector (EIA, 2010)

Figure 5.9 illustrates that there was marginal change in energy consumption from the year 2006 to 2010 by the transportation sector. The total amount of energy consumed in 2007 was greater than it was in 2010, and the lowest of the 5 years was the year 2009. The figure also shows renewable energy production in the country. However, the margin is low compared to the overall energy consumption. Renewable energy use increased steadily over the year. This shows that the production and consumption of renewable energy have increased over years but much more is still required.

The EIA estimated that transportation consumed 29 percent, and transportation-related construction and infrastructure consume another 10 percent of all energy used in the United States (EIA, 2010). While rail transport is the most energy-efficient mode of land transportation (Rodridge, 2013), private automobiles have the capability to transport huge numbers of passengers due to low-density residential population. Maritime transportation accounts for 90

percent of cross-border world trade, which includes all imports and exports, and it accounts for 7 percent of all the energy consumed by transportation activities (Rodridge, 2013).

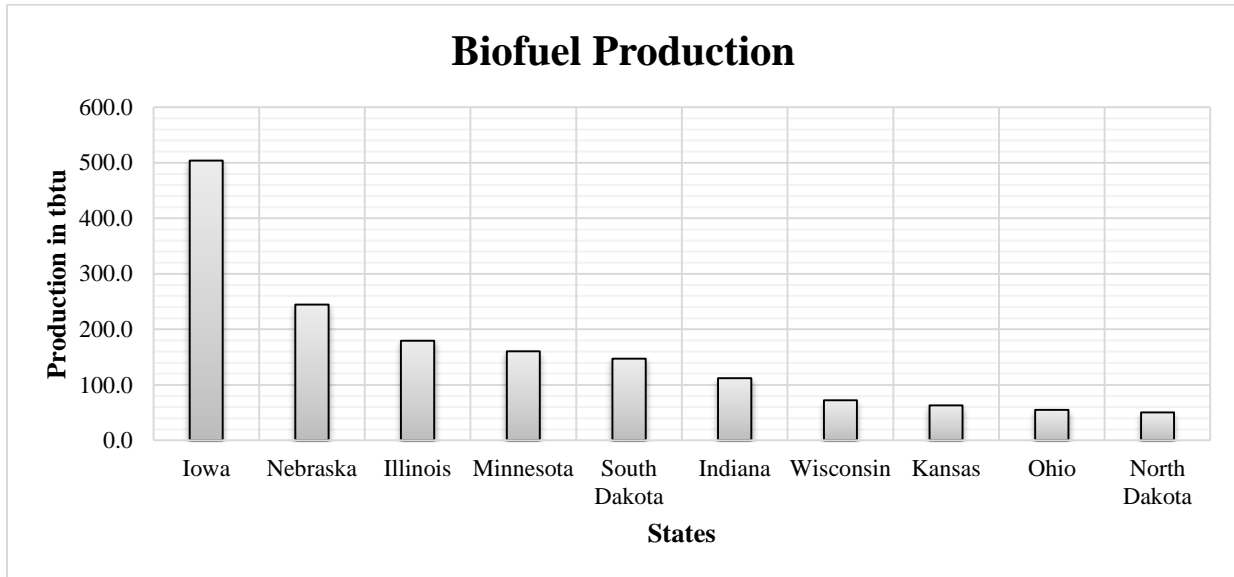


Figure 5.10 Biofuel production (Trillion Btu); Source: (EIA, 2010)

Figure 5.10 shows the biofuel production in various states. Biofuel production is considered for analysis to determine the amount of biofuel energy is used in the transportation industry and how it affects sustainability. Biofuel includes both biodiesel and fuel ethanol. The figure 5.11 shows Iowa tops the list on biofuel production followed by Nebraska and Illinois. Small states like Kansas and North Dakota produce a significant amount of biofuel.

**Analysis:** The production of biofuel in a state may suggest that the use of fossil fuels can be reduced. Biofuel has the potential to replace fossil fuel to run transports in the country. Most biofuel comes from ethanol produced from corn. Iowa, Nebraska and Illinois are three of the top corn producing states traditionally. Thus, their ethanol production level comes to no surprise. The sustainability of these states can be measured in two ways, first, its biofuel production and second, the use of biofuel by the local transports.



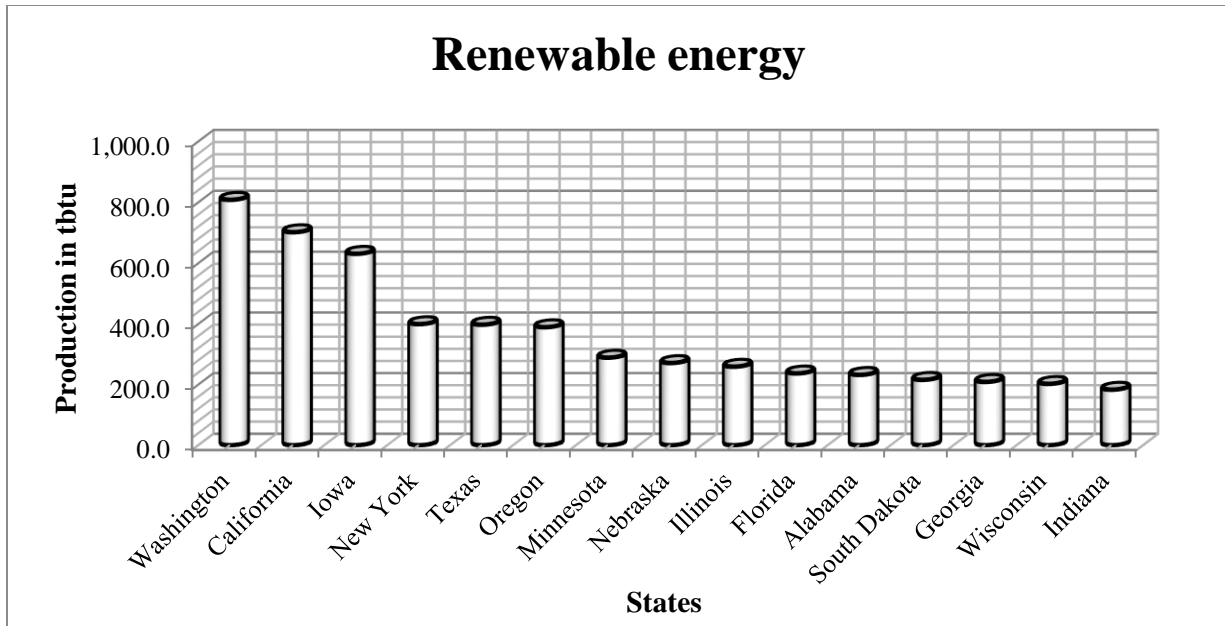


Figure 5.11 Renewable energy production, Source: (EIA, 2010)

Figure 5.11 shows renewable energy produced in each state and their biofuel production. As shown in figure 5.10, Iowa and Nebraska are top producers of biofuel. Figure 5.11 shows Washington produces more renewable energy than any other state whereas California is second. Iowa stands third and better than New York and Texas. Nebraska concentrates on biofuel production whereas New York and Texas, more densely-populated states have lower biofuel production.

**Inference:** The United States has the highest energy footprint per capita in the world. In the near future, renewable liquid fuels like biodiesel and ethanol are the only viable options to replace fossil fuel if vehicles continue to use liquid fuels rather than electricity. The scenario will be different if electric vehicles become more prominent. Thus, the use and production of ethanol and biodiesel are extremely important in the United States. The reduction of fossil fuel use also reduces pollution, carbon emissions and overall energy use. Motor gasoline is the highest consumed fuel in the United States (EIA, 2010), by both government and private sectors..

Though there are numerous efforts to promote the use of renewable energy and manufacture alternatively-fueled vehicles, these efforts and their effects take time to realize. Travel distances between work, home, and play became longer, increasing the dependence on fossil fuels in the United States since the long distance travel for day to day activities highly required private transportation. Many public transportation options are expensive to maintain due to the cost of operation and low ridership. Low density development makes public transit less viable in many regions.

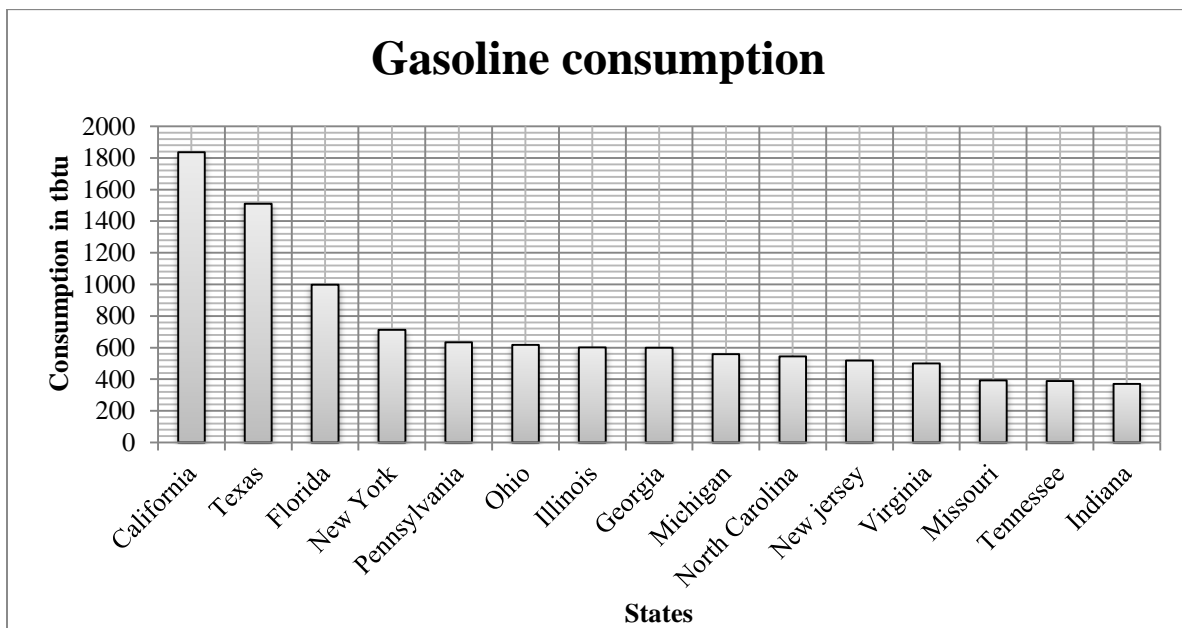


Figure 5.12 Details on Gasoline consumption by state, Source: (EIA, 2010)

Figure 5.12 shows the top fifteen gas-consuming states. Again, California, Texas and Florida top the list. These states are high consumers because of their population and other factors.

Consumption rates are correlated with population and the total road miles of the state are added to determine how this factor might influence consumption per capita.

Table 5.5 Details on Gasoline consumption/capita , Source: (EIA, 2010)

States	Gasoline(btu/capita)	Total road miles
Washington	530,747,772	83822
Utah	200,022,030	45123
Wyoming	70,578,959	28105
South Carolina	69,584,098	66023
Alabama	67,711,348	101574
Mississippi	67,483,361	75080
North Dakota	67,258,148	86842
New Hampshire	67,137,311	16084
Missouri	65,217,160	130359
Iowa	63,710,096	114382

Table 5.5 shows the ranking of the states by the gasoline consumption per capita and their total road miles in the state. Washington and Utah topped the table followed by Wyoming.

**Analysis:** Wyoming has very few road miles when compared with other states but its fuel consumption is relatively high. This makes the state less sustainable in terms of fuel consumption than the others. Similarly, Utah has less road (by miles) than South Carolina but it is the second largest consumer of gasoline per capita.

The population adjustment is used in ethanol consumption and the figure below represents the top states in the ethanol consumptions. Again, California and Texas top the table with other major states like Florida, New York, and Georgia found to be the top consumers of ethanol. Ethanol consumption is driven by the state government policy on fuel-fixing.

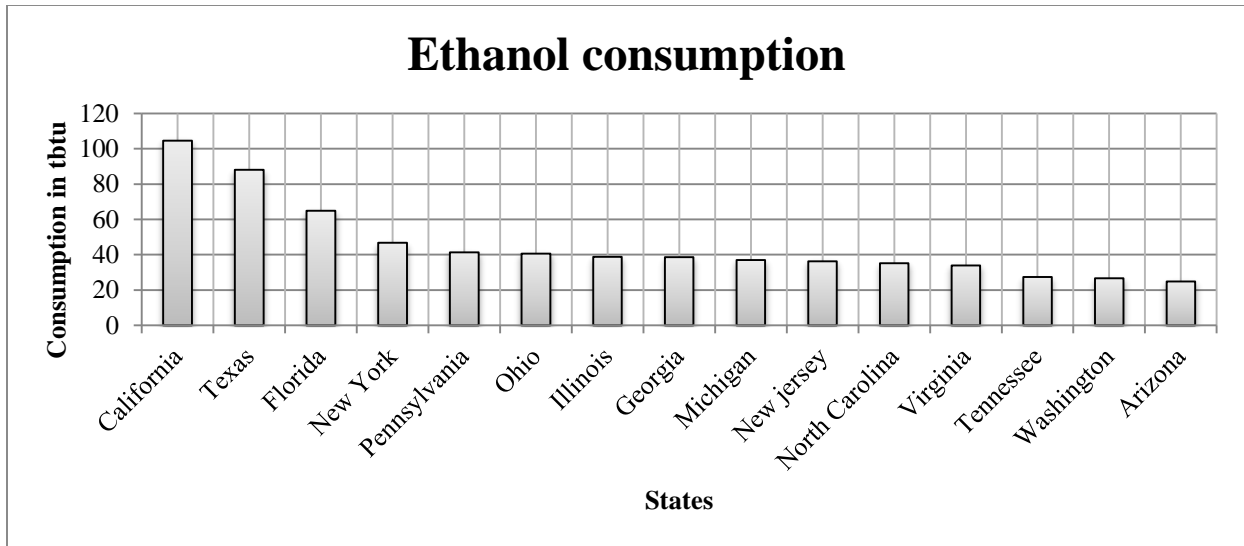


Figure 5.13 Details on ethanol consumption (EIA, 2010)

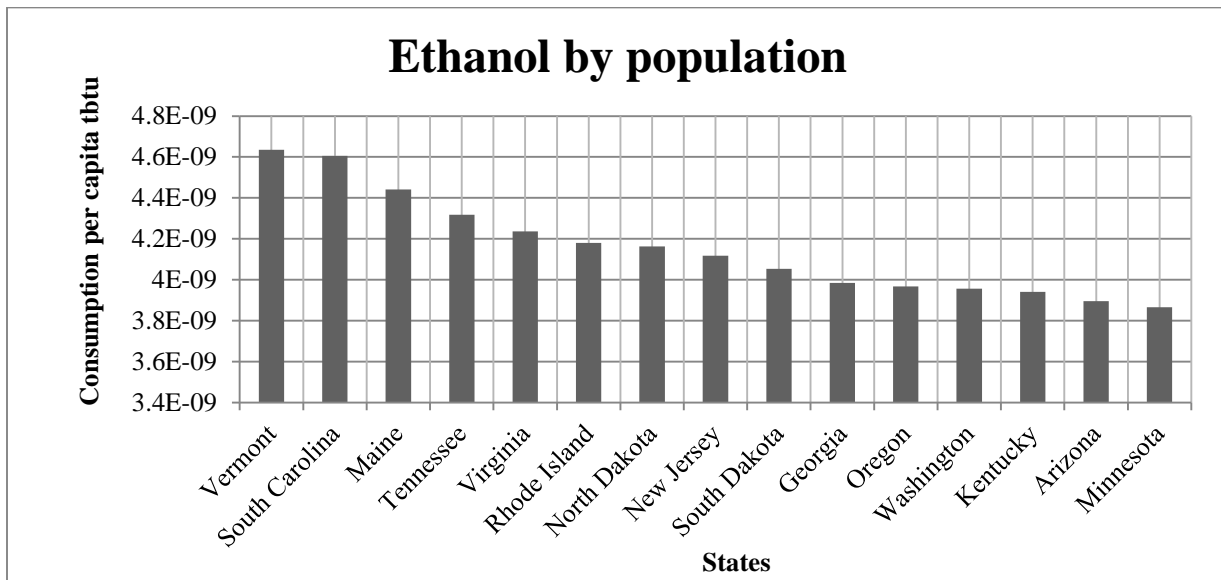


Figure 5.14 Ethanol consumption per capita; Source: (EIA, 2010)

Figure 5.14 shows the top 15 states ranked according to ethanol consumption per person in the state. Maine and Rhode Island is ranked 3<sup>rd</sup> and 6<sup>th</sup> place in the list whereas Vermont top the table. Georgia and New Jersey stands on top ten of the list after the adjustment too.

**Inference:** Adjustment through population results in a different picture. Increasing the use of renewable energy will reflect the importance of the sustainability of the transportation sector.

The carbon and toxicity footprints of ethanol and other renewable energy are far lower than petroleum's (EIA, 2010). In addition, diversifying energy sources will reduce the impact of demand and price fluctuation of fossil fuels on the economy, and reduce societal reliance on fossil fuels.

## **5.5 Gross Domestic Product (GDP) as an Adjustor**

Gross Domestic Product plays a vital role and is considered to be the major indicator of the economic health of a nation. Wealthier states tend to spend relatively more money on their investments than poorer states on GDP reflects the cost of living (Kimberly Amadeo, 2013). Total energy use has tripled and energy use per capita in the United States has grown by 1.5 times over the past sixty years (Behrens & Glover, 2012). The total energy use for transportation has grown by nearly 3.5 times, and energy consumption per capita for transportation has grown by 1.5 times (EIA, 2011). Passengers and their goods can be transported more energy efficiently and generate less pollution if they are transported on more energy efficient modes of transportation. While consumer awareness of energy-efficient transport is important, the ease of use of such transportation is the foundation of success.

### **5.5.1 Transportation Energy and GDP**

An approach to weigh GDP against energy use is utilized and the states are ranked based on their GDP to energy-consumption levels.

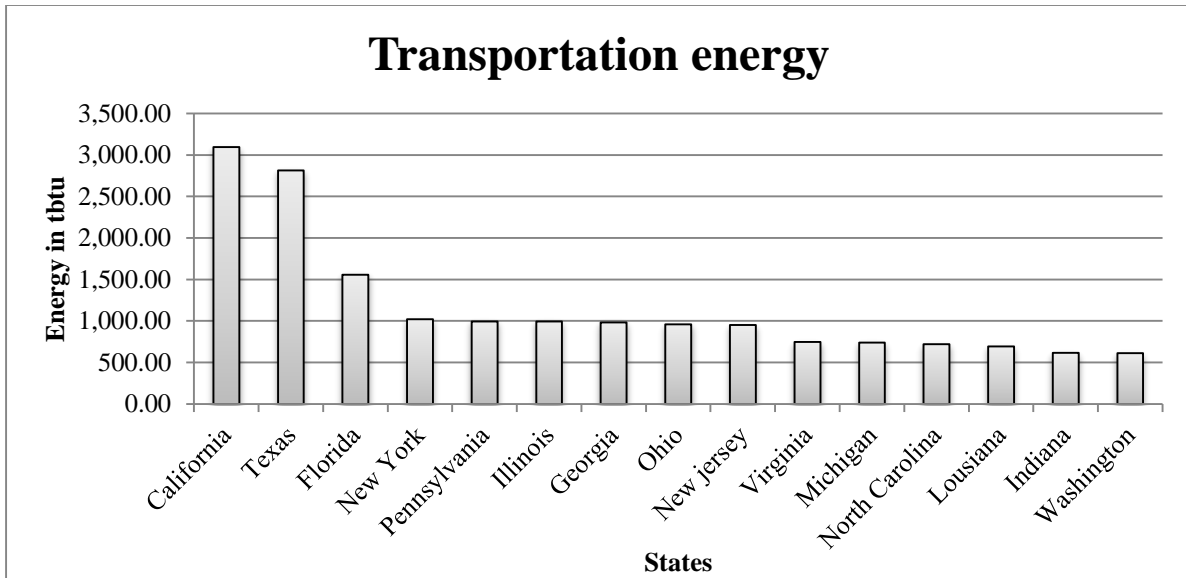


Figure 5.15 Total transportation energy details by state (EIA, 2010)

It is noted that California consumes greater transportation energy while Virginia the last. The figure shows that most of the bigger states consumed significant amount of energy for its transportation system. The GDP of these states are also considerably high. When adjusted by their GDP, Minnesota and Alaska rank at the top. Such deviations are helpful to make an analysis further to attain more accuracy in ranking.

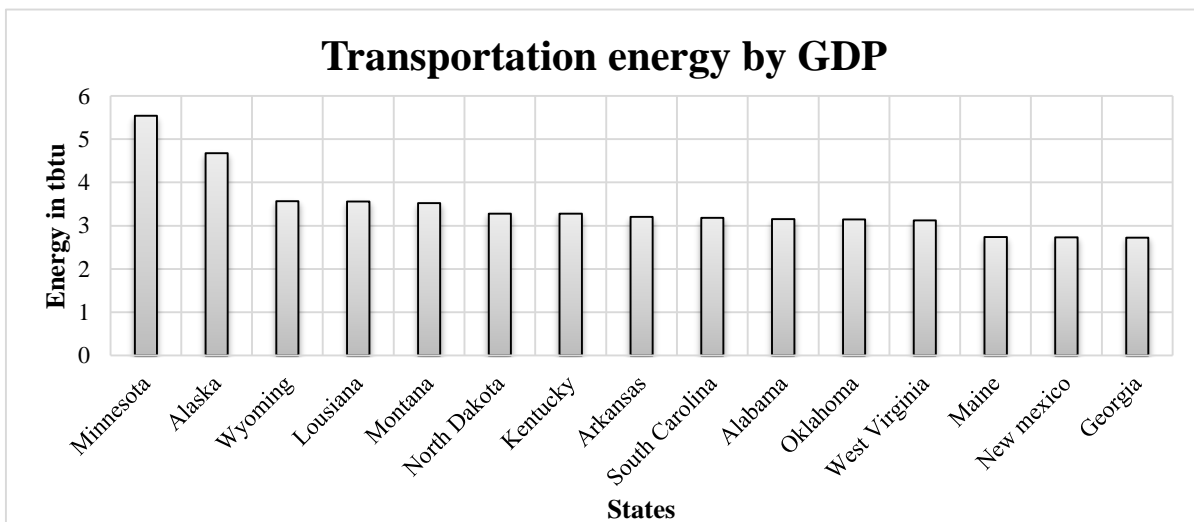


Figure 5.16 Ranking on transportation energy (EIA, 2010)

### 5.5.2 Automobile Ownership and GDP

Increasing the number of vehicles using renewable fuels on the road is another critical factor that improves the sustainability of a state transportation system. The use of renewable fuels reduce the stress on the demand of non-renewable fuels and reduce the emission rate. The following tables show the number of vehicles that could use renewable fuels in the following states.

Table 5.6 Total Number of vehicles using alternative fuels (Top 20 states); Source FHWA

Rank	State	Total number of vehicles	Biofuel Production(tbtu)
1	California	735,284	9.8
2	Washington	639,576	-
3	New York	388,388	-
4	Oregon	336,829	5.8
5	Alabama	240,654	-
6	Georgia	191,274	14.6
7	Florida	183,266	-
8	Maine	167,387	-
9	Tennessee	142,903	26
10	Louisiana	138,011	0.2
11	North Carolina	123,438	-
12	Wisconsin	122,495	72.2
13	Pennsylvania	114,591	14.6
14	Virginia	107,086	-
15	Texas	105,594	36.3
16	Idaho	103,737	7.8
17	Michigan	101,772	37.2
18	Minnesota	95,564	160.6
19	Arizona	93,777	8.0
20	Arkansas	84,158	-

**Analysis:** While California, Washington, and New York came topped on the total number of vehicles list, they are not even ranked on the top 20 list when state population and GDP are used to adjust their figures. Oklahoma, New Mexico, Iowa, and Utah topped the list in Table 5.8. The District of Columbia ranked fourth in Table 5.7 but it does not appear in the top 20 in Table 5.8.

The analysis shows that population size and GDP affect the outcomes. The challenge for the research team is to decide if GDP or population size is a better adjustment and treatment of the data.

Table 5.6 shows the data correlation between total number of alternative vehicles and biofuel production in that state. Densely populated California, which tops the alternative fuel vehicles list, has very little biofuel (ethanol) production. This can infer that the state depends on other hybrid vehicles. Similarly, it has to be noted that smaller states like Idaho also produce biofuel. The demography of the state, soil characteristics, and availability of the resources also reflect the production of alternative fuels.

Table 5.7 Total Number of Vehicles using Alternative Fuels per 1000 People (FHWA)

<b>Rank</b>	<b>State</b>	<b>Total number of vehicles(per 1000 people)</b>
1	Oklahoma	5.23
2	Nebraska	3.77
3	Iowa	3.67
4	District of Columbia	3.37
5	New Mexico	3.18
6	Utah	2.70
7	Wyoming	2.64
8	Colorado	2.61
9	South Dakota	2.42
10	Nevada	2.32
11	Wisconsin	2.31
12	Oregon	2.25
13	North Dakota	2.23
14	Indiana	2.18
15	Montana	2.16
16	Idaho	2.14
17	Michigan	2.07
18	California	2.02
19	Texas	1.99
20	Illinois	1.95



Table 5.8 Total Number of Vehicles using Alternative Fuels per \$100 million of GDP

<b>Rank</b>	<b>State</b>	<b>Total number of vehicles/\$100 million GDP</b>
1	Oklahoma	17.31
2	New Mexico	10.05
3	Nebraska	9.77
4	Iowa	9.53
5	Utah	8.10
6	Mississippi	7.36
7	Montana	7.31
8	Idaho	7.04
9	Oregon	6.39
10	South Dakota	6.37
11	Colorado	6.08
12	Wisconsin	6.05
13	Indiana	6.02
14	North Dakota	6.00
15	Kentucky	5.98
16	Arizona	5.66
17	Nevada	5.64
18	Michigan	5.62
19	West Virginia	5.57
20	Wyoming	5.55

The usage of flex-fuel vehicles in US is almost ten times greater than the use of electric vehicles (EIA, 2010). This shows that people tend to go for flex fuel vehicles and not hybrid electric vehicles. The reason lies with the fuel consumption. The flex fuel vehicles can be operated using ethanol 85 blend and gasoline. From the table 5.7, when adjusted through population, Oklahoma, Iowa and Nebraska are the top three states. Nebraska and Iowa are the top producers of corn, which is the primary feedstock for ethanol production. This may be a reason for these states to top the table.

### 5.5.3 Gasoline and GDP

When GDP is used as an adjutor with gasoline consumption of the state, the results vary widely with one respect to population as an adjutor. Figure 5.17 shows the top states of gasoline consumers with respect to thousand Btu of gasoline per dollar GDP. Minnesota and South Carolina top the table with smaller states like Maine also finding a place in the top list. Figure

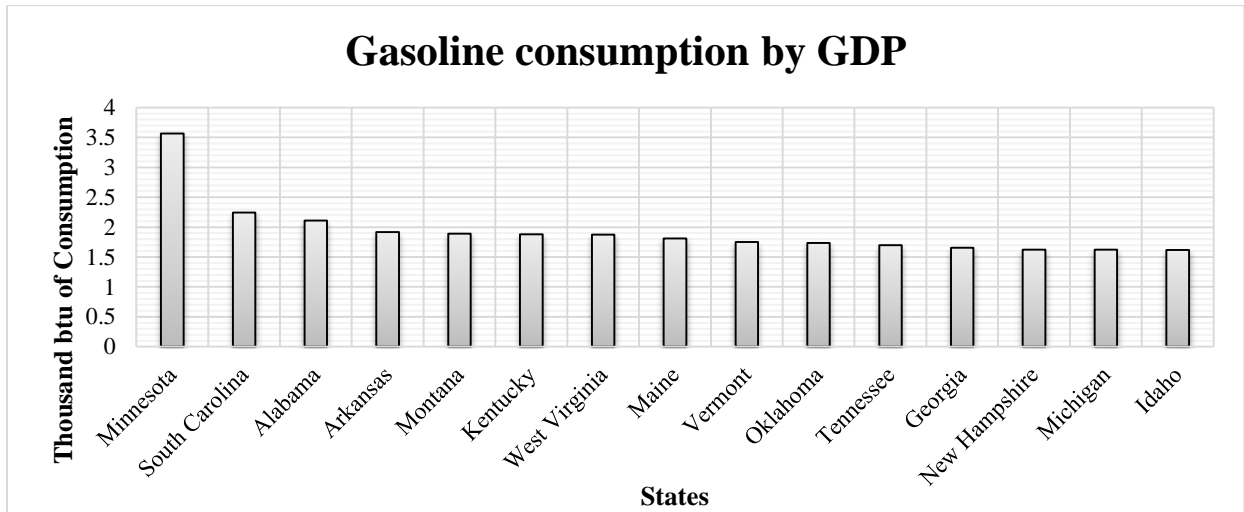


Figure 5.17 Gasoline per dollar GDP; Source: (EIA, 2010)

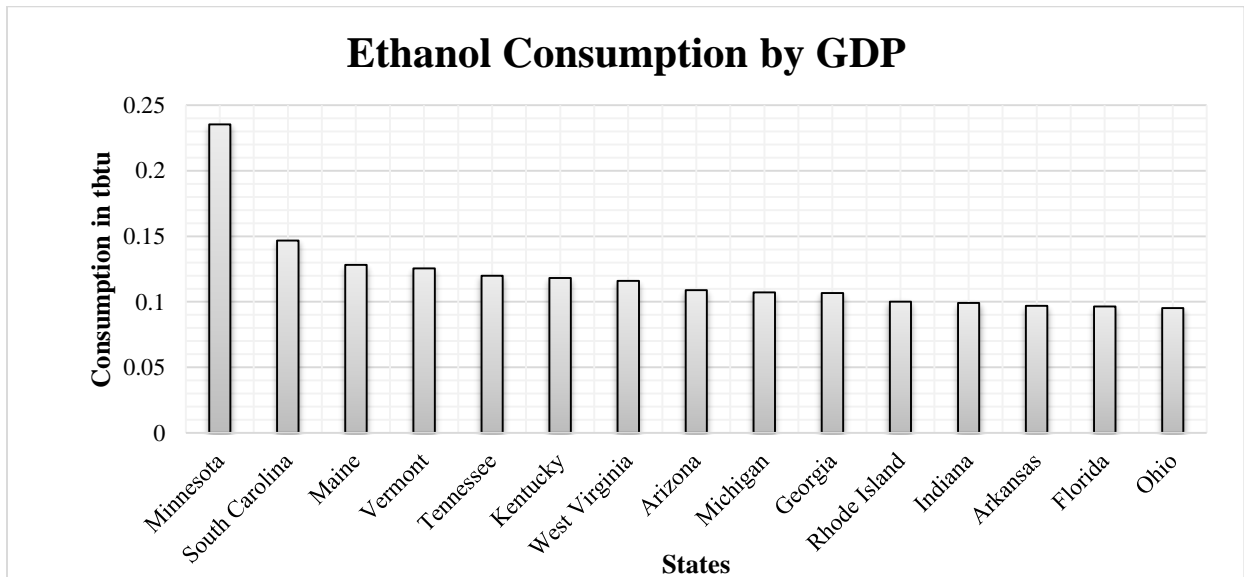


Figure 5.18 Ethanol consumption per dollar GDP; Source: (EIA, 2010)

**Analysis:** The results show that, when it comes to GDP, less-dense states with greater GDP can be a predictor of high consumption. Even moderate states can rise above in consumption with GDP as an adjustor.

#### 5.5.4 Carbon emissions and GDP

The GDP of the state is one of the important adjustors. GDP of a state may have a positive correlation with the energy use of the state. However, there are renewable energy production and other initiatives, energy use increases with increase in production, which in turn increases emissions. Thus, the GDP of the state is directly related to the carbon emissions. So does this mean California, the state with the largest GDP, has higher emissions than other states?

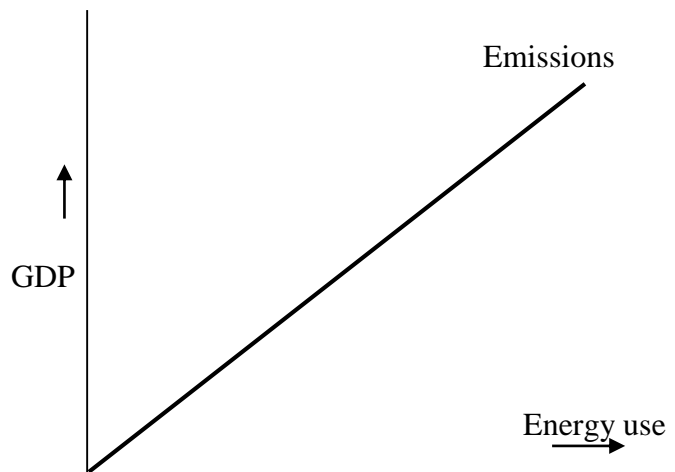


Figure 5.19 Positive correlation between GDP and Energy use

It is difficult to determine, as the carbon emissions included here are the emissions from transportation. Thus, GDP plays with real data and returns results that are more reliable on sustainability ranking when used as an adjustor. When population is used as an adjustor, Minnesota and Alaska stands ahead the table whereas major states like California and Texas drop

down.

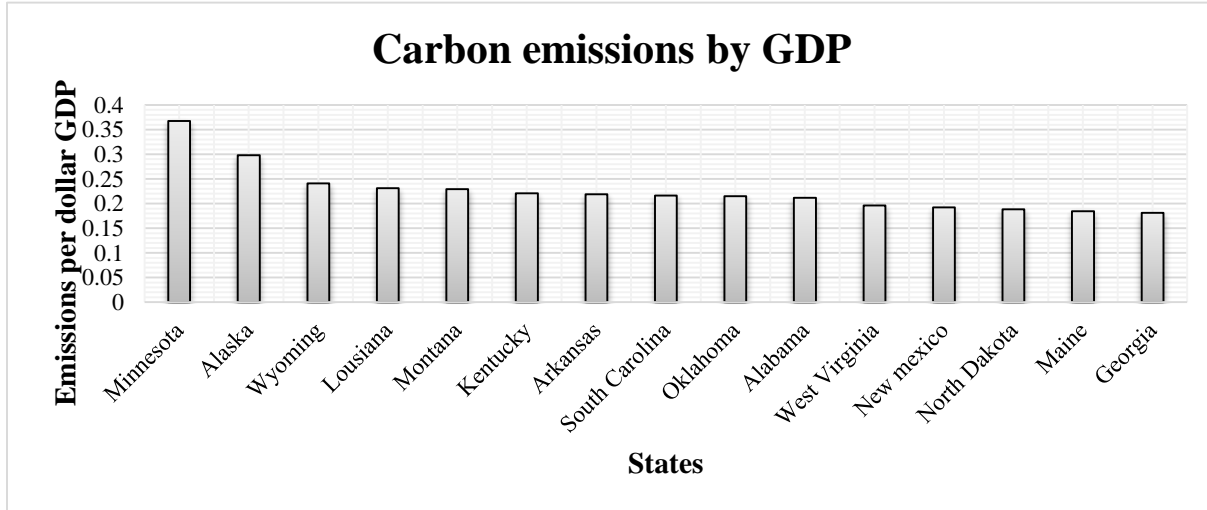


Figure 5.20 Carbon emissions per dollar GDP; Source: (EIA, 2010)

From the analysis, with adjustment through GDP on emissions and consumption, Minnesota stands first in all three analyses. This can infer that Minnesota has a larger impact on sustainability through GDP. The carbon emission of Minnesota is relatively high to its GDP (from the data collected). This can be a reason for Minnesota to be on the top of the list. Also, Minnesota is industrialized state which has the headquarters of major public companies (Target Hormel Foods and BestBuy). This can also be a reason for greater consumption and emission rates. It is also one of the largest producers of sweet corn and hence the consumption of fuel can be utilized in food production and other product manufacturing (Department of Employment, 2006)

## Chapter 6-Results and Discussions

The results of various analysis is tabulated as follows

Table 6.1 Results and Outcomes

<b>Ranking methodology</b>	<b>Top 3 States</b>			<b>Bottom 3 States</b>			<b>Indicators used</b>
<b>Budget</b>	IL	CA	NY	DC	RD	WY	1.Population 2.Transportatioon budget 3.State budget
Budget/Capita	AK	UT	IL	MI	NJ	AZ	
Population	CA	TX	NY	WY	DC	WA	1.Population 2.Total vehicles 3.Gasoline consumption 4.Ethanol consumption 5.Road miles
Publicly owned vehicles	CA	TX	FL	AK	VT	ND	
Automobiles per Capita	VT	NE	DC	UT	CT	IO	
Total road miles	TX	CA	KS	DC	HI	DE	
Miles/capita	ND	SD	MT	DC	HI	NJ	
<b>Ridership</b>	NY	CA	IL	WV	ME	NH	
Ridership per capita	CA	NY	OH	OK	KS	ME	
<b>Renewable energy</b>	WA	CA	IO	DC	RD	DE	1.Renewable energy use 2.Biofuel production 3.Population 4.Ethanol consumption 5.Gasoline consumption
Biofuel production	IO	NE	IL	WV	WA	VA	
Gasoline consumption/Capita	WA	UT	WY	VT	DC	NY	
Ethanol consumption/capita	VT	SC	ME	DC	UT	ID	
<b>Transportation energy</b>	CA	TX	FL	DC	VT	RD	1.GDP 2.Population 3.Total vehicles 4.Transportation 5.Gasoline consumption 6.Ethanol consumption
Transportation energy/GDP	MN	AK	WY	DC	NY	CT	
Ethanol consumption/GDP	MN	SC	ME	DC	CO	UT	
Gasoline consumption/GDP	MN	SC	AL	DC	NY	AK	
<b>Carbon emissions</b>	CA	TX	FL	DC	VT	RI	1.Carbon emissions 2.Population 3.GDP
Carbon emission per capita	AK	WY	LA	DC	NY	RI	
Carbon emissions/GDP	MN	AK	WY	DC	NY	CT	

## 6.1 Discussions

Sustainability plays an important role in the transportation infrastructure. It aims at formulating policies and techniques in order to achieve optimization of resource utilization so that it will not for the mere future. The research outcomes are tabulated and have greater scope for future directions since not all the indicators are adopted due to time constraint and lack of reliable resources.

Population is an interrelated adjustor and indicator to achieve sustainability. It is the root cause for several outcomes in the economy and environment. The transportation sustainability has its impact through population adjustor. The transportation budget, fuel consumption, carbon emissions and ridership widely depends on the population and population density of the state. The state DOTs and other transportation agencies need a quantification analysis with population adjustment to analyze their sustainable performances with respect to population and population density.

The research team tried a different approach of analysis with GDP as an important adjustor. The GDP per capita generally determines the economic growth of a country. The research team worked on a different dimension adjusting emissions, registered automobiles and energy consumption through GDP and the results are tabulated. The GDP and the wealth of people are inversely proportional. When a citizen decides to use public transit and reduce self-transportation, the GDP goes down because of low flow of money. Data analysis using GDP creates a unique result with various sustainable indicators. In addition, the carbon emissions and GDP are correlated with the increase in energy use.

The research focused on developing a preliminary analysis with essential adjustors and indicators. This analysis provides ranking on the states based on the adjustments through

population and GDP. The objectives of this research are to understand sustainability, evaluate sustainable rating systems and create a preliminary framework for improving the sustainable performances of state transportation agencies. Also, the research aims at creating a knowledge platform which will be done with the inclusion of other indicators and adjustors in future. Thus, the objectives are relisted to know about the research focus and level of completion.

- ☑ Understand what drive sustainability in transportation;
- ☑ Identify and evaluate the sustainable performances and indicators of transportation;
- ☑ Develop the sustainability for the transportation sector to elevate their performance; and

By this research, one can understand the essentiality of transportation sustainability and their adverse need in the transportation sector. In addition, the sustainable transportation cannot be just a word for this corporate racing world and tools and techniques must be adopted in order to achieve sustainability in a better way for which the suitable sustainable indicators must be chosen. Sustainability in transportation is one challenging adoption, which has its focus both in research level for numerous data analysis and relies on the implemental qualities to quantify the practices. This is a healthy movement all over the planet especially in US where roadways are considered the main stream of economic development.

*Limitations:* This research can possess few limitations. Some of them are

1. *Human errors:* The research is based on the data collection and information from the reliable sources. Though the information are from trusted sources, there are chances of human errors on data presentation on the websites.
2. *Preliminary framework:* The research proposes a preliminary alternative approach to evaluate the state sustainable transportation system. There is no defined model or a

statistical equation that can be used to incorporate the sustainable solution. The preliminary analysis framework aimed to define a quantifiable approach with real time factors to develop a model for the mere future.

## **6.2 Scope of the project**

Sustainable development of a state mainly depends on how they conserve the energy, land and other natural resources. The social and economic status of 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.

The further scope of this project relies on the reliable data available from trusted sources. In addition, land use and highway construction can be added to the indicators as they can reveal about the energy use and other important sustainable characteristics. The future directions of this research can be:

- *Further evaluation of indicators:* The research team can focus on adopting several other indicators with more accurate results and on creating a new survey form including more questionnaires, which will elevate the measurement of sustainability
- *Implementation on projects:* The rating system can be implemented on few states and their results can be populated in an online knowledge-sharing platform that would serve many people to know about their state sustainable performances in transportation, thus creating awareness to the citizens. This can also help in rectifying the loopholes of the rating system through feedback from the users.



- *Towards a system based vision:* The next step of this research is to understand more interrelationships of policies and sustainable transportation system and to create a database technology where the user can populate the data values to understand the sustainable efficiency of their state. This can be further developed as a web based system and can be implemented on states, counties and cities for deeper analysis of sustainable performances.

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**Appendices  
Appendix A  
Survey Form**

**1. What state are you representing?**

\_\_\_\_\_

**2. Please specify the budgets on transportation allocated for the current financial year (\$)**

Total budget on transportation \_\_\_\_\_

Budget on sustainable practices \_\_\_\_\_

Budget on public transportation \_\_\_\_\_

Budget allotted on state universities  
for sustainable program research \_\_\_\_\_

Others \_\_\_\_\_

**3. Does you agency have a specific person or a team for practicing sustainable practices?**

Team

A specific person

None

Specific person's name and contact details (if known)

\_\_\_\_\_

**4. List the various sustainable programs through state transportation agency**

**5. Does you agency... (Please answer with Yes, No or NA in the field)**

- Emphasize public involvement on sustainable programs? \_\_\_\_\_
- Share knowledge on sustainable programs with other state agencies/DOTs? \_\_\_\_\_
- Follow any standards and regulations on vehicle toxicity emissions? \_\_\_\_\_
- Adopt storm water management standards? \_\_\_\_\_
- Take measures to reduce pollutants and particulates? \_\_\_\_\_
- Provide annual reports on sustainable programs for public? \_\_\_\_\_
- Please provide the link/document for the above (if available)  
\_\_\_\_\_

**6. Specify the ridership of various transportation systems in your state (Passenger/People per day)**

- High speed rail \_\_\_\_\_
- Light street cars \_\_\_\_\_
- Commuter rail \_\_\_\_\_
- Bus \_\_\_\_\_
- Para transit \_\_\_\_\_
- Bicycle \_\_\_\_\_

**7. How much energy is used in your state transportation agency for the followings?**

- Embodied energy (Joules- Insert 0 if you use KWh) \_\_\_\_\_
- Embodied energy (KWh- Insert 0 if you use Joules) \_\_\_\_\_
- Operational energy (Kilowatt- hours KWh) \_\_\_\_\_
- Transportation energy (Gallons of Gasoline) \_\_\_\_\_
- Transportation energy (Gallons of Diesel) \_\_\_\_\_
- Transportation energy (Gallons of Biodiesel) \_\_\_\_\_
- Transportation energy (Gallons of Ethanol) \_\_\_\_\_

**8. Indicate the practices involved in diesel/gasoline reduction in transportation**

Reduce vehicle miles travelled

Increase fuel efficiency

Use alternative fuels

None

Other (please specify)

\_\_\_\_\_

**9. Indicate the percentage of**

State vehicles running on alternative fuel (biodiesel or Ethanol) \_\_\_\_\_

State vehicles running on electricity \_\_\_\_\_

Parking area for alternative fuel vehicles at airports \_\_\_\_\_

Renewable energy used in state agency buildings \_\_\_\_\_

Renewable energy utilized in public transportation \_\_\_\_\_

Public buses using electricity \_\_\_\_\_

**10. Specify the numbers of electric charging and alternative fuel filling stations located in the state**

Electric charging stations \_\_\_\_\_

Alternative fuel filling stations \_\_\_\_\_

**11. What is the rate of recycling and reuse by your agency? (%)**

Highway constructions \_\_\_\_\_

Non-constructions (e.g. Buildings) \_\_\_\_\_

**12. How committed is your agency in adopting green highway concepts**

High

Medium

Low

**13. Please write down the**

Carbon emissions through transportation (lbs) \_\_\_\_\_

Carbon emissions through state buildings (lbs) \_\_\_\_\_

**14. Which of these energy efficiency programs/technologies have been adopted by your agency in the buildings?**

- Photo sensors
- Thermostat
- Window ventilation system
- Auto-sleep mode in computers
- Alternative fuel consumption
- Low voltage lighting

Others (please specify)

---

**15. Which of the following water use reduction program/technology have been adopted by your agency?**

- Educational programs
- Water – efficient landscaping
- Water-efficient irrigation
- Treatment plant and recycle systems
- Faucets and shower heads
- Boiler/steam system
- Single-pass cooling equipment
- Cooling tower management
- Commercial kitchen equipment
- Grey water
- Distribution system audits, leak detection/repair
- None

Others (please specify)

---

**16. Specify the number of days on productivity loss due to injury or death in your agency**

---

**17. If your agency implements the Guiding principles for federal leadership in high performance and sustainable buildings (GP) for new/existing/leased buildings, what**

**percentage of buildings over the size of 5000 gross square feet meet high performance building standards.**

- None
- Less than 5%
- 5-10%
- 10-25%
- Over 25%

**18. Does your agency... (Please answer with Yes, No or NA)**

- Manage an environmental management system (EMS)? \_\_\_\_\_
- Provide EMS training for its employees? \_\_\_\_\_
- Receive any financial/training assistance form federal transit administration to develop any sustainable program? \_\_\_\_\_
- Own any renewable energy production plant(s) (e.g. wind turbines, solar panels)? \_\_\_\_\_
- Provide sustainability training for engineers/technicians? \_\_\_\_\_

**19. Please list any unique features of your sustainable programs that you want us to know (including links/ documents)**

\_\_\_\_\_