Comparative Bio-Economic Impact on Rural Transit Highways from Commuter Transit Types

A Dissertation
Presented in Partial Fulfillment of the Requirements for the
Degree of Doctor of Philosophy
with a
Major in Biological Engineering
College of Graduate Studies
Department of Biological Engineering
University of Idaho
by
Jeffrey K. Heath

Major Professor: Lee Ostrom, Ph.D.
Committee Members: Ching-An Peng, Ph.D.; Cheryl Willhelmsen, Ph.D.;
Michael McKellar, Ph.D.
Department Chair: Ching-An Peng, Ph.D.

May 2018

Authorization to Submit Dissertation

This dissertation of Jeffrey K. Heath, submitted for the degree Doctor of Philosophy with Major in Biological Engineering and titled "Comparative Bio-Economic Impact on Rural Transit Highways from Commuter Transit Types," has been reviewed in final form. Permission, as indicated by the signatures and dates below, is now granted to submit final copies to the College of Graduate Studies for approval.

Major Professor: ______________________________ Date: ____________________
Lee Ostrom, PhD

Committee Members: ______________________________ Date: ____________________
Ching-An Peng, PhD

______________________________ Date: ____________________
Cheryl Wilhelmsen, PhD

______________________________ Date: ____________________
Michael McKellar, PhD

Department Chair: ______________________________ Date: ____________________
Ching-An Peng, PhD

Abstract

The purpose of this study is to examine the bio-economic components affecting the several transit systems sponsored by the Department of Energy at their three remote sites in Idaho, Nevada, and New Mexico. Significant economic data was developed prior to and in conjunction with this research. Therefore, the primary focus of this research is on the non-economic factors and their effect on the overall bio-economic view of the transit system identified. Due to a prevailing assumption that one transit type was superior to others, the resultant Null Hypothesis was created to test the validity of this claim and to function as the framework for this research; as stated herein: there is not a quantifiable difference in bio-economic impact between busing versus carpooling with regard to enhanced safety, reduced environmental impact, or positive economics per user unit. As summarized in a final ranking of transportation types and ranked within the several key hypothesis effecting factors, this research overwhelmingly proved the Null Hypothesis false. The mass transit systems (buses) in place at the Idaho and Nevada sites remain superior to other transit forms in common use by commuters within the rural transit highway system studied. Limited but representative busing capability at the New Mexico site, ranks second overall in transit superiority. This research did not note any difference between the Government-provided service, like that found in Idaho and New Mexico, versus a commercially-provided service, like that found in Nevada. This research compiles the body of knowledge and demonstrated rigor needed to develop a framework to support further transit research to test if there is another more superior system to be used, perhaps rail.

Acknowledgements

With gratitude for my Dissertation Chair, Major Professor Lee Ostrom, PhD, and my committee Members Ching-An Peng, PhD; Cheryl Wilhelmsen, PhD; Michael McKellar, PhD.

…and…

Warmest appreciation for my support system; Carlo Melbihess, Juan Alvarez, Scott Wold, and Edward Anderson for providing me with data, perspective, mentorship, and for sponsoring this work; Chris Kent for the many counselling sessions and for keeping my head in the game; Albert DiNicola for being a believer in my potential, and for the many years of encouragement to take this leap; my brother Bradley Heath and my dear spouse Brendi Heath for their editorial review of this work; and Alice Allen for the years of assistance progressing me through this program.

Dedication

To my wife for extensive support, my children to inspire them,

and my parents with gratitude for my life

Table of Contents

List of Figures

List of Tables

Definition of Key Terms

Biome: biologically or geographically segregated zone(s).

Rural Transit Highways: highways and associated arterials outside urban use, used for transit to and from work or home, with primary use as a transit corridor for commuters.

Remote Site: work location geographically separated by significant distance (i.e. 50 miles) from the place of primary residence of the affected workforce population.

Bio-economic: pertaining to biological impact normalized in economic terms.

Professional Driver: a driver of a commercial motor vehicle with specialized training and in possession of a commercial driver's license. For this study, these are the bus drivers.

Road Scout: a professional driver driving a specialized vehicle for the purpose of collective weather and road condition data, real time.

Acronyms and Abbreviations Used

ANL: Argonne National Laboratory

AVC: Animal-Vehicle Collision

B20: 20% by Volume Biodiesel Blend

B100: 100% by Volume Biodiesel Blend

BAC: Blood Alcohol Content

BBI-BMPC: Bechtel Bettis Inc, later retitled as Bechtel Marine Propulsion Corporation

BEA: Battelle Energy Alliance

BLS: Bureau of Labor Statistics

BMPC: Bechtel Marine Propulsion Corporation

BNC: Bechtel Nevada Corporation

CA: Contracts Administrator

CARB: California Air Resource Board

CDL: Commercial Drivers License

CFA: Chartered Financial Analyst

CMV: Commercial Motor Vehicle

CNG: Compressed National Gas

CO: Carbon Monoxide

CO_2: Carbon Dioxide

COS: Chief of Staff

DEQ: Department of Environmental Quality

DOD: Department of Defense, specifically the Army and Nuclear Navy

DOE: Department of Energy

DOS: Department of State or State Department

DOT: Department of Transportation

E85 or e85: 85% by Volume Ethanol-gasoline Blend

EIA: Environmental Impact Assessment

EO: Executive Order

EPA: Environmental Protection Agency

GHG: Greenhouse Gas

GREET: Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation, ANL Transportation Model

GSA: General Services Administration

F: Fahrenheit (degrees)

H0: Null Hypothesis

H_2: Hydrogen

HC: Hydrocarbon

HSIS: Highway Safety Information System

HWY: Highway

IBM: International Business Machines

ICP: Idaho Clean-up Project

ID: Idaho

INL: Idaho National Laboratory

IRI: International Roughness Index

IRS: Internal Revenue Service

kWh: Kilowatt Hour

LANL: Los Alamos National Laboratory

LANS: Los Alamos National Security

Lbs.: Pounds (US)

LCA: Life Cycle Assessment/Analysis

LNG: Liquid Natural Gas

MCI: Motor Coach International

MPG: Miles per Gallon

Mt: Million Tons

NAICS: North American Industry Classification System

NEB: Net Energy Balance

NNL: Naval Nuclear Laboratory

NRF: Naval Reactors Facility (located on the INL)

NOAA: National Oceanic and Atmospheric Administration

NV: Nevada

NNSS: National Nuclear Security Site

NM: New Mexico

NREL: National Renewable Energy Laboratory

N_2O or NO_X: Nitrous Oxide and Compounds

O_3: Ozone

PM: Particulate Matter

POV: Privately Owned Vehicle

SO_2 or SO_X: Sulfur Dioxide and Compounds

SOF: Soluble Organic Fraction

SSC: Site Services Contract

TCO: Total Cost of Operating

THC: Tetrahedral Hydrocarbons (i.e. CH_4 or C_2H_6)

TSS: Total Suspended Solids

TT: Tank Truck

MVMT: Million Vehicle Miles Traveled

US: United States

VOC: Volatile Organic Compound

CHAPTER 1: INTRODUCTION OF THE STUDY

Background

Each year the United States (US) Department of Energy (DOE) spends tens of millions on mass transportation to its remote sites [business sensitive source – see Appendix E]. This significant budgetary figure represents an attractive target for continued financial evaluation of the funds being spent. In each of the DOE and contractor cases being studied to date, all are from financial viewpoints, though anecdotal information about safety and environmental responsibility is used as risk related perspective designed to retain the service. The Department of Transportation (DOT) and DOE have studied transportation safety, the Department of Environmental Quality (DEQ) and DOE have evaluated the impact of using biologically based fuels as an environmental impact mitigation strategy, and the General Services Administration (GSA) have several analysis aimed at financial responsible use of Government owned property. The DOT began a study series aimed at providing information for policy makers regarding the use of mass-transit on rural commuter highways (HWY) in 1970, with periodic and summary updates, i.e. [1] [2]. While their studies are primarily safety focused, they are general in nature and imply that there are location specific environmental factors to consider. Scholars have explored each of these several topics. Each of these views (Government, Industry, and Academia) is important for a more complete impact. References supporting these claims are detailed within this study.

The significance of this study is that it addresses an empirical gap of verifiable information to make a best-value decision regarding the DOE use of buses for employee transport. Current data is inconsistent, in disparate formats, with much of it being private and mired in manipulated calculations. The specific scholarly research value for this study is that it provides for a legitimate body of evidence with many aspects and considerations affecting a significant policy and financial decision, resulting in a dynamic impact to human, animal, and plant life. This research will add to knowledge and current discourse through combining multiple models and providing a comprehensive recommendation for deployment to the aforementioned problem, within a nationally impacting context for the DOE. This research matters because of the significant taxpayer cost and resultant pool of flexible monies that could be used elsewhere if reduction or elimination of services occur. The new context presented herein will represent the currently disparate body of knowledge for policy and decision makers to justify best value, independent of any assumed benefits. The data herein will show which mode(s) optimizes the economic, safety, and environmental impact reduction goals for the service.

Problem Statement

The problem investigated surrounds the impact that two primary forms of vehicle traffic have on the users, the flora and fauna, and the Government; with primary focus on non-financial, biological factors of safety and environmental impact. The problem being addressed is to provide a comprehensive, scientifically founded recommendation for the development, retention, modification, or termination of the DOE's bus service, currently in operation. The current data set is incomplete and thereby not studied systematically, resulting in significant decisions made on partial and biased information. Because all the system decisions affect the DOE contractor and employee base at the three remote sites, decisions are made differently, as independent business decisions. System components are individually considered and as a result are easily misinterpreted and potentially misleading. They are applied poorly without policy and uniformity among common constituents. These decisions are currently made on factors of, past precedence, altruism, perceived financial benefit, and available budget. Policy decision and ongoing debate include initiatives to shrink cost, reduce environmental impact, improve service (finance and safety), and full or partial service termination [business sensitive source – see Appendix E].

Significant accounting and economic data exists for these transit systems, though non-financial factors are not universally understood. They have significant potential impact to this decision. This study seeks to develop the non-financial factors to support the comprehensive impact of changing this service. The study seeks to consolidate disparate data into a single decision set illustrating best value to the Government for selecting the future of the three mass transit potential systems in place at the three remote DOE locations in Idaho (ID), Nevada (NV), and New Mexico (NM).

Purpose of the study

The purpose of this study is to rank through a scholarly approach the best value to the Government, relative to their mass transit system in effect, and to collect the body of knowledge required to continue with future research. Special focus of this study is placed on the biological impact of using the existing system versus eliminating or modifying it in lieu of another or no system at all. Though this study does not specifically address alternate mass transit systems, speculation within the contractor base suggests that rail transit systems, though significantly expensive initially, would offer a longest term comprehensive best value to the Government. This topic is reserved for additional research outside this study, but supported by the results of this study.

Research Questions

These questions, when answered provide decision makers with viable data and the associated perspectives of the key stakeholders; employee users, environment, mission organizations and taxpayers. This integrated view will enable a more responsible and informative decision basis regarding the use of mass-transit (specifically busing) within the DOE system outlined.

Key research question(s):

Is there a quantifiable difference in bio-economic impact from the use of mass transit versus personal vehicles on commuter transit HWYs at the three DOE remote laboratory sites? If yes, should the DOE modify the several mass transit programs at their three remote laboratory sites? If no, should the DOE discontinue the service offering?

Examples of further questions used to develop the research parameters were:

1. Is there a significant safety discriminator due to transportation type for human, animal, or plant life?
2. Is there a significant environmental impact discriminator between the use of biodiesel on buses versus petroleum based fuel for passenger vehicles per unit of transported personnel?
3. As an employee, which is the best transportation system to use (‘best’ is defined as economic benefit optimized for safety)?
4. As the DOE and its managing contractors, which is the best transportation system to use (‘best’ is defined as lowest economic impact optimized for both human safety and environmental impact)?

These questions resulted in several analytic focus areas to provide a comprehensive response to the key research questions, within the boundaries of this study:

1. Statistically proven safe way for employees to travel to and from their respective work locations; resulting in reduced loss of life, including wildlife, and mitigation of statistically significant human factors for extended driving.
2. Statistically significant decrease in negative effect to animal and plant life within the defined transportation thoroughfares; environmentally conscious specific to use of biofuels and reduced pollution of vegetated HWY shoulders. Validated through the use of biofuels, including biodiesel 20% blend (B20) versus petroleum-based fuels. Biological enumeration using concepts from Life Cycle Assessment (LCA) and Environmental Impact Assessment (EIA), including current biological impact to vegetated HWY shoulders per comparative transportation unit will be used.
3. Quantifiable reduction in economic impact to tax payers and to the employees who use the respective services.

Null Hypothesis

Producing an integrated view of the DOE mass transit program over the rural transit HWY system will enable decision makers to make more complete decisions regarding any material modification of their existing system(s). The resultant Null (H0) Hypothesis is designed to test the bus system and assumed superiority:

> H0: there is not a quantifiable difference in bio-economic impact between busing versus carpooling with regard to enhanced safety, reduced environmental impact, or positive economics per user unit.

Research Boundaries and Exclusions

The economic boundary is the significant budget, affecting thousands of users, approximately 386 miles over seven rural transit HWYs, and hundreds of direct support employees, at the three remote DOE laboratories in ID, NV, and NM. The boundary of this research is targeted to the comparison of busing versus carpooled personal vehicles within the transit HWY system supporting the commute to each of the DOE's three remote laboratory sites current bus system potential. The research defined by a common biome found in three geographic areas with comparable transit potential within DOE and Rural HWYs; 386 total rural transit HWY miles

[4]. The rural transit HWY systems inclusive of the vegetated HWY shoulders includes, median strips as applicable and both two and four lane transit roads. Specifically:

- Idaho National Laboratory (INL), operated by Battelle Energy Alliance (BEA). INL miles: Interstate 15 (I15) (24.7 miles) and HWY20 (51.3 miles) and HWY26 (42.2 miles (Scoville)) and Rigby/Rexburg HWY33 (63.2 miles (Howe)). INL also provides service to two other DOE prime contractors on the INL, the Naval Nuclear Laboratory (NNL), operated by Bechtel Marine Propulsion Corporation (BMPC) and the Idaho Cleanup Project (ICP), operated by Fluor-Idaho LLC. These locations will also be included in the net service offering from INL.
- Los Alamos National Laboratory (LANL), operated by Los Alamos National Security (LANS). LANL miles: I25 (18 miles) and HWY 550/4 (77.1 miles) and HWY 285/502 (81.4 miles) approximately.
- Nevada National Security Site (NNSS), formerly Nevada Test Site, operated by Bechtel Nevada Corporation (BNC). NNSS miles: HWY 95 (70.7 miles (N. Las Vegas NV. to Mercury NV.))

Additional information on the referenced DOE sites and operating contractors is found in APPENDIX F.

Humans and large animals (e.g. deer) were considered as they are impacted. Other biological factors have been considered as related to fuel selection used in support of US energy independence goals. Specific research and analysis was performed to support the key and associated hypothesis-supporting questions will be performed.

Extensive research has been conducted by others suggesting impacts of varying biofuels, their sources and consequences for use and as such, this has been explored outside the B20 biofuels, liquid natural gas, biomass sources or petroleum fuel variants outside those identified including fuel additives or engine modification were not addressed. Given the defined biome, any transit outside the rural transit HWY system, was not considered, though they are mentioned for context only. Nuance data or events, such as road construction, force majeure, and emergency related scenarios were not considered. Weather-related impacts do exist, though they were found to be inconsequential to this study except to note weather as an amplifying force to mortality risk across all modes presented. Vehicle types and associated drivers outside the immediate commuting employee base of the three laboratories were not considered, though transportation statistics have been provided to illustrate their respective use of the system as a percentage, as indicated by DOT statistics of vehicles used. Context was provided to illustrate current non DOE loading on these HWYs during the affected operational hours and at the three affected locations. Human factors and health effects outside accident-related transportation were not directly studied, though some limited general wellbeing anecdotes have been noted for context related to greater health-related factors.

Limitations, Delimitations, and Research Assumptions

Primary limitations came from disparate data, limited accessibility to private industry, DOE, and associated contractor data, the limited population set, and my experience. Data used for this analysis came from four primary sources; publically available US Federal Department data, publically available internet searchable data, journal data specific to fuels data, mortality, and vegetated HWY shoulders, and private company data of the three noted laboratory contractors and consultant data for use and cost. Due to the sensitive nature of the detail required to perform the research, the research results will not be made public, but will be provided to DOE – ID as the target audience, INL - BEA as the sponsoring organization, and The University of Idaho as dictated by my Major Professor supporting this research. As a final delimitation, I was the sole researcher primarily due to more than twelve years working on the several factors of this problem, and due to access to business sensitive information; as detailed in Chapter 3, section: History, Context, and Research Methodology Backdrop.

Primary assumptions stem from my experience that the terms presented herein are common for the reviewing audience, inclusive of the basic science behind the respective concepts presented. Secondary assumptions are that generalized terms are more impacting than nuance or special circumstance data, as every nuance circumstance would be difficult to detail and does not readily represent the population within three standard deviations from mean data. Economic data is primarily from the DOE contractor base and considered equivalent to market economic data. Final assumptions are that the research reviewing committee will be able to evaluate this research with limited business sensitive data. I assumed that financial data would be available for direct comparison. In several cases it was not and as such inference was developed using ID and INL data as the basis for the other two localities.

Design Controls

Generally accepted research and analysis methods were used, including; research of publically available information, comparative & inferential statistical analysis, LCA and EIA, human factors safety analysis, and engineering economics. Three primary design controls have been in place to ensure the highest quality data is presented; (1) the use of actual socio-economic data was used for the analysis of business information, (2) US Federal data, peer reviewed journal data, and meeting minute summaries (Appendix E) were used for analytical reference, and (3) Factors for final decision making have been normalized in economic terms, in as many cases as appropriate.

In addition, development of a system-level model has been used to illustrate the magnitude of the issue and relative impacts. Data used from media sources is primarily to illustrate popular media or implied social concerns supporting the issues presented herein.

Key Analytic Tools

Results have been ranked on key factors as they related to multi-person carpooled personal vehicles and passenger transit buses. Single user personal vehicles and multi-passenger vanpools will be used to enhance sensitivity boundaries and will be ranked in the results. Comparative analysis has been produced to compare personal vehicles, carpooled personal vehicles (POV), commercial passenger buses, and van pools (for perspective only as they reasonably fit the definition of commuter vehicle by the Internal Revenue Service (IRS)) [3], and are currently provided within the transportation mode mix. Comparative impact analysis has been performed to determine relative impact to vegetation as a result of biofuels use, animal and human safety, and net economic impact, within the study-defined biome of the US Federal HWY system and associated vegetated HWY shoulders for the typical commute to and from the three remote DOE laboratory's in ID, NV, and NM. Results have been reflected in economic values where appropriate to support decision making through the use of comparative models. Bus and GSA Van systems have been represented as they existed at the end of the US Federal fiscal year 2016.

Summary

The significance of this study is that a comprehensive answer is developed and provided for policy and decision makers to employ. This is especially timely considering changes in executive orders (EO), social concern for corporate social (environmental) responsibility, and added strain on the defendable elements of US Federal budget. To date, bus transit studies are limited primarily to economic impact and none completely or directly address the specific concerns and limitations experienced by the three DOE laboratory contractors with mass transit potential on behalf of the Government. The evaluation criteria for a best value determination for the Government are identified for this study as the greatest human safety optimized for least environmental impact.

Each of the following four chapters and associated appendices seek to provide contemporary and comprehensive views of the affecting factors that could bias a decision maker. Chapter 2 presents a broad, stratified literature review of key components relative to mass transit within the identified biome. Six topical areas are developed; the legal components affecting transportation, the rural transit HWY biome, transportation types being compared, transportation affected mortality, the limited environmental impact factors from fuel type usage, and the economics affecting the user and the provider. Chapter 3 outlines the research design and mixed-methodology, with associated design controls. Chapter 4 is the data analysis section, with information presented in many cases as a statistical inference from publically available data and consolidated in economic terms as appropriate. Chapter 5, Findings, Conclusions, and Implications, focuses on the development of a recommendation that can be duplicated by an independent third party and in terms and associated context where decision makers can best understand a more comprehensive impact of development, retention, modification, or elimination of any or all parts of the existing three laboratory mass transit system.

Appendices are included to provide specific topical data for use by decision makers and associated analytical staff. The appendices are not needed to perform or repeat the research outlined herein, but they provide for perspective to non-subject matter experts. Appendix A presents two bus inventory and performance summary tables designed to provide perspective to the target audience of this research; specific references used to develop these tables are included in the same appendix, though the DOT maintains this data within their databases, just not consolidated as shown herein. Appendix B provides nine pictorial views of the referenced transportation thoroughfares, to illustrate terrain and environmental similarities; the purpose of this appendix is for a broad audience to gain familiarity quickly. Appendix C functions as an added reference to Table 4.3, for added perspective, though not used to develop this research, the data analysis, or associated conclusions. Appendix D is a summary of equations developed to perform data analysis. Appendix E is an example of how this research is contributing to decision making within the managing contractor companies, and contains the titles and focus areas of the collective business sensitive references by topic and date. Appendix F contains the web links for the referenced companies.

CHAPTER 2: REVIEW OF RELATED LITERATURE

Introduction

The problem being investigated surrounds the impact that two primary forms of vehicle traffic, using like transit corridors, has on the users, the flora and fauna, and the Government; primarily non-financial, biological factors of safety and environmental impact. The problem being addressed is to provide a comprehensive, scientifically founded recommendation for the development, retention, modification, or termination of the DOE's mass transit service, currently in operation. The literature review focused on illustrating the consolidation of the biome developing factors, of geography, vehicular human-animal interaction, safety, and environmental impact. Other limited factors are considered only as they support assumptions.

My interest in this research topic began with economic analysis to support the financial side of DOE decisions regarding the future of mass transportation services for a contractor using the INL service (circa 2006); see Chapter 3, section: History, Context, and Research Methodology Backdrop, for added detail. Due to the many secondary factors frequently referenced anecdotally, literature review specific to this topic began in 2011, with the review of the Energy Independence and Security Act of 2007, signed into Public Law 110-140 by President George W. Bush [5] [6]. This act focused on energy independence primarily through the subsidy of biomass products designed to be a national asset as a viable part of the national fuels portfolio. Much of my initial basis of research is from the operational, contractual, and financial ownership of the mass transit system affecting the three DOE contractors located on the INL. In 2015 I developed a business sensitive briefing for the DOE and associated INL contractors suggesting that the bus service deployed should be retained based on non-financial factors of business productivity, environmental sensitivity, and safety; though financial factors suggested the reduction of the service. This briefing demanded more than internal and corporate information. In an effort to find corroborating evidence of my suggestions, I found literature limited and disparate, addressing only part of any single factor. Secondarily, given the DOE and contractor personnel are primarily economics focused, the need for greater data connection and economic conversion was required.

The theoretical framework focuses on the combination of and resulting consolidation of decision material requires a comprehensive research approach. Primary research subcomponents, focus on human safety factors, human-animal interaction, environmental impact, and economic factors. Prior to completion of this research, there were several suggestions supporting the 'retention-termination' decision; examples included reduced negative biological impact from use of biofuels, mortality and injury assumptions based on a bus being larger and heavier than a typical personal vehicle, and assumed economic benefit to the user, based on a heavily subsidized service. These anecdotal factors, when used by decision makers were not backed up by direct scientific work in a weak though somewhat effective argument to sustain the large financial burden mass transit requires.

The research is not designed to specifically support any other type of mass transit system considered or deployed within the nation. The DOT primarily focus their research on statistically supported transportation types, human mortality affected by transportation type and use, and fuel economics. Though the DOT provides associated data, they do not have a transportation service study similar to the one investigated herein. DOE primarily focuses on fuel types and associated environmental and economic factors. For the purposes of this research, the primary role of the DOE contractors is to advance the state of the art in basic science, application, environmental management, and on maintenance and operation of the several DOE contractor supported sites. The intersection of peer reviewed material, DOT and DOE data, and DOE's need to be financially responsible in their stewardship, demands the consolidation of the data to be viewed through a common context. This non-financial formulaic view of a financial decision is developed through research consolidation, in this chapter.

The literature investigated provides the framework for data analysis. Though the specific factors interacting through the biome are not found in a unified format in any of the research literature, connection of the data and associated interactions are readily found. The primary research literature is within the public realm of the DOT, DOE, and Bureau of Labor Statistics (BLS). Secondary research literature used to provide clarity of the primary literature comes from journal articles and business sensitive DOE prime contractor information.

Research Strategy, Limitations, and Legitimacy

This research has a legitimate benefit to making and defending financial expenditure decisions. The economic boundaries of the significant budget, the service affecting thousands of users, the seven rural transit HWYs, and hundreds of direct support employees, at the three remote DOE laboratories in ID, NV, and NM. Further, given the assumed human-environment impact of terminating the service in lieu of personal vehicles and carpools, the research is appropriate to help educate decision makers regarding the factors that should be considered relative to this too often oversimplified decision. The consolidation of decision information requires a comprehensive research approach. The research strategy deployed includes; actual observation of transportation type and usage over the previous twelve-month period in the ID biome as a representative basis for the other two DOE contractors considered, using (1) DOT comparative statistical data from their periodic summary reports, (2) DOE financial expenditure for the service, (3) various environmental impact and fuel use data, and (4) other factors considered key component to making the decision. The public information referenced herein is validatable by the average citizen and financially, by the respective decision makers within the DOE.

Timelines for the research used vary from dates as early as 1960 to those ending at the US Federal fiscal year end 2016. While this wide span may be considered significantly broad, the data available is dispersed, with the referenced material from reliable sources considered relevant by the referencing US Federal agency, and thus legitimate by me. Ethical considerations include my opinions and the limitation of the research data to include non-public and difficult to generalize data. Both of these ethical concerns are mitigated through secondary sources where available and through business sensitive meetings and DOE contractor leadership.

This research is not designed to provide an in depth scientific analysis of any one transportation subcomponent. It is designed to provide decision makers with a consolidation of typical usage comparisons, such that they can make effective and comprehensive transportation decisions. The primary limitation of this research strategy is that the economic data came primarily from business sensitive data from DOE contractors and that not all aspects affecting transportation are explored. Only functions that play a material part in a decision are explored. There is likely nuance data and circumstances that could shift the decision basis, though only slightly. Three examples to illustrate this point are:

- This research is based on carpooling compared to busing. Limitations for analytical purposes are invoked, such that vehicle type and loading has been normalized, though off-nominal conditions exist.

- This research assumes a comparison of environmental impact factors, limited to a full size sedan using petroleum versus a mass transit bus using B20. While all of the buses in service are using biofuel, the variability of the biofuel source is unknown, as it is not tracked beyond the primary use fuel. Additionally, there are vehicles using a biofuel as a transportation fuel, though data from driver polls in the DOE contractor system, illustrate a more than 91% [business sensitive source – see Appendix E] petroleum use as the primary fuel type.
- Each of the three biomes explored are remote desert areas and as such have significantly limited and similar vegetation, effectible water sources, and flora and fauna to be affected by the use of a transportation system. As such, if the analysis were to include a highly populated, lower elevation, forested area, as experienced in Virginia and similar geomorphologies, all factors affecting transportation impact would skew upward.

Final limitations of research stem from various scholarly papers and US Federal Department reports that reference similar, but differing statistically significant categories with inconsistent yearly representation. Latitude was exercised in an attempt to normalize the frequently disparate data.

Effective Research

Given the broad nature of the research topic and the end goal of consolidation of decision data, research as selected to support the basis of investigation and analysis. Six research subcomponents are explored to develop this basis; the legal components affecting transportation, what is a HWY biome, transportation types being compared, transportation affected mortality, the limited environmental impact factors from fuel type usage, and the economics affecting the user and the provider. Effective research has been selected to evaluate only the biome-specific bio-economic factors within the aforementioned research subcomponents, though associated EOs and general HWY systems are included for perspective. Research is summarized for effective EO, National HWY System, Transportation Type, Mortality, and Fuels and Environmental Impact, inclusive of life-cycle emissions. These subcomponents represent the non-socio-economic entirety of the decision matrix for assessing this service, and as such are provided for perspective to the reader.

Executive Order Summary

EOs are used as the broadest context affecting components of this study. Further, given the recent administration based change in EOs, this information represents the changing environment the decision makers must navigate regarding transportation services. Implementation of EOs 13514 and 13653, the council on environmental quality, the DOT has been submitting climate adaptation plans and similar documents that focus on the good repair of environmental sustainability within the transportation sector. This section summarizes pertinent parts of the orders along with a general summary of the order. These orders, though not all transportation related, form the framework for decision maker sensitivity to environmental factors. EO 13693 has specific focus on fleet management expectations within the US Federal construct [6].

EO 13514 US Federal Leadership in Environmental, Energy, and Economic Performance which US President Barack Obama issued on October 5, 2009. Replaced by EO 13693, titled Planning for Federal Sustainability in the Next Decade, issued by President Barack Obama on March 19, 2015. The order mandated that at least 15 percent of existing Federal buildings and leases should meet Energy Efficiency Guiding Principles by 2015, and that annual progress be made toward 100 percent conformance of all Federal buildings, with a goal of 100% of all new Federal buildings achieving zero-net-energy by 2030. The US Government is the largest consumer of energy in America. It has roughly 500,000 buildings, and most of these buildings are energy-inefficient. Fifteen percent of 500,000 buildings is 75,000 buildings. The EO states that "the Federal Government must lead by example ... increase energy efficiency; measure, report, and reduce their greenhouse gas (GHG) emissions from direct and indirect activities, such as: design, construct, maintain, and operate high performance sustainable buildings in sustainable locations; strengthen the vitality and livability of the communities in which Federal facilities are located; and inform Federal employees about and involve them in the achievement of these goals" [7].

EO 13653 Preparing the US for the Impacts of Climate Change was issued by President Barack Obama on November 1, 2013. EO 13653 is the US Federal Government's response to the rising issue of climate change. It was issued in order to prepare the Nation for the impending impacts on the environment brought by climate change and to implement risk management strategies to lessen the harm done by these impacts on the Nation. EO 13653 mandates that the Federal Government, as well as stakeholders, must manage these risks with deliberate preparation, cooperation, and coordination in order to effectively improve climate preparedness and resilience. With preparedness and resilience come a safer economy, infrastructure, environment, and supply of natural resources - allowing the continuation of Department and Agency operations, services, and programs. Agencies are called on to promote open lines of sharing and communication throughout all levels of Government, make both informed and strategic decisions, quickly adapt and adjust future plans when needed, and to effectively prepare for the future by planning. The order was rescinded by President Donald Trump on March 28, 2017 [7].

EO 13693, Planning for US Federal Sustainability in the Next Decade, was signed by President Obama on 19 March 2015, states Federal Agencies shall, where life-cycle cost-effective, beginning in fiscal year 2016, unless otherwise specified, promote building energy conservation, efficiency, and management by reducing agency building energy intensity measured in British thermal units per gross square foot by 2.5 percent annually through the end of fiscal year 2025, relative to the baseline of the agency's building energy use in fiscal year 2015 and taking into account agency progress to date. US Federal Agencies shall, where life-cycle cost-effective, beginning in fiscal year 2016, unless otherwise specified, improve data center energy efficiency at agency facilities. Ensuring the agency chief information officer promotes data center energy optimization, efficiency, and performance, installing and monitoring advanced energy meters in all data centers by fiscal year 2018, and establishing a power usage effectiveness target of 1.2 to 1.4 for new data centers and less than 1.5 for existing data centers. US Federal Agencies shall, where life-cycle cost-effective, beginning in fiscal year 2016 and encompassing expectations beyond 2025, unless otherwise specified, ensure that at a minimum, increasing amount of building electric energy and thermal energy shall be clean energy, accounted for by renewable electric energy and alternative energy [3]. Though this order focuses on building performance, the same is expected of all other Government assets in use.

Specific EO 13693 fleet impacts; if an agency operates a fleet of at least 20 motor vehicles, they will improve agency fleet and vehicle efficiency and management by taking actions that reduce fleet-wide per-mile GHG emissions from agency fleet vehicles, relative to a baseline of emissions in fiscal year 2014, to achieve percentage reductions of less than 4 percent by the end of fiscal year 2017, not less than 15 percent by the end of fiscal year 2021, and not less than 30 percent by the end of fiscal year 2025. Section 16 of this EO revokes, among other related things, EO 13423 of January 24, 2007, EO 13514 of October 5, 2009, Section 1 of

Presidential Memorandum of February 21, 2012 (Driving Innovation and Creating Jobs in Rural America through Bio-based and Sustainable Product Procurement), and Presidential Memorandum of May 24, 2011 (Federal Fleet Performance). The goal of EO 13693 is to maintain Federal leadership in sustainability and GHG emission reductions [3]. This order directly impacts the use of buses and though the order was rescinded, the concepts here-in have been incorporated into use and best practice, if even partially.

The essence of these orders is that if you are a Federal agency you must use clean, renewable energy sources (i.e. biofuels or electricity), and do it within the prescribed and changing timeframe and policy context. The underlying concern for decision makers is the potential changes in socio-politics and within the identified goals of the Energy Secretary. As users of GHG emitting vehicles, these goals demand the DOE and its contractors make environmentally impacting decisions judiciously, thus presenting the current challenge by policy makers to make transportation decisions without fact, but erroring on the side of assumed environmental good.

National Highway System Summary

The literature review of this section encompasses the boundary of the rural transit HWY system and associated road condition. The national HWY system was formed November 11, 1926 and is currently found in all states at a total length of 4.1M miles (for all HWY types). From the 1998 total road mileage and travel function system, 9.9% or 389,147 miles are HWYs and supporting arterials, though travel on these HWYs accounts for 48.2% or 1,273,139 miles of all ground travel. HWYs represent one-third of the functional systems mileage with 74% of that on rural HWYs [8].

The budget for HWY repair has escalation correlating to inflation [9], while construction cost per mile has run in parallel to the consumer price index, roughly twice the rate of inflation [10]. Quality of roads and bridges generally improved, though specific road conditions in the affected states, ID, NV, and NM are rated as fewer than one-quarter deficient, the best rating in the nation; though the NNSS is located within a zone of concern with more than 10% of households without cars. Each of these three states are within the best served rural transportation areas [11]. Per million vehicle mile traveled (MVMT) transportation HWY expenditures are not keeping up with observed degradation of these systems. Pavement surface systems are measured with the International Roughness Index (IRI). The lower the IRI score, the better the road condition, with 170 and lower representing acceptable to very good quality. Approximately one-half of the HWYs are at 95 or less with just over 40% measured between 95 and 170 and 7.9% at >170 [9]. With the biome HWY system determined to be in the best condition, road based impacts will be assumed as immaterial to this study.

Transportation Type Summary

From the most recent comprehensive report of the state of the nation's HWYs, $5.8T is spent on freight transport on HWYs. Transportation accounts for 18.6% of household expenditure. The IRS defines a commuter HWY vehicle as transportation provided by an employer to an employee in connection with travel between their residence and place of employment. The vehicle must have seating for at least six adults, excluding the driver and that 80% of the annual vehicle mileage usage is for the transport of employees in connection with work and where at least one-half of the passenger space is used [3]. From 1978-1998, population grew by 21.7%, though commercial transportation (including busing) miles grew by 70%; with the next closest transport types; Rail at 320B and Air at 229B. [9]. 92.7% of rural households have access to at least one vehicle compared to their urban counterparts at 88.9% [10].

Average commutes increased by 36.2%, keeping the average commuter on the road 13.5% longer, with average speeds increasing by 20%. The average commuter, commutes 25 minutes each way to work. Annual vehicle miles for the three state region are between 11.5K and 13.2K, a minimal separation of 13%. The average person travels 11.6 miles and 20.6 minutes to work; [9] [11]. The average commute was more than 25 miles per day. Long commutes are directly correlated with less sleep, higher divorce rates, unhappiness, and chronic neck and back problems [13]. About 1.7M American commuters (~8%) have an extreme commute as defined by at least 50 miles each direction or 90 minutes [12]. Average commuting especially by those who do super commutes of more than 50 miles has flattened, though these commutes take a significant health toll on users [12]. The average commute within the defined biome approximates to 50 miles each way.

During the 1970 to 1998 period, bus registration increased by 16.7%, while personal vehicles reduced by 1.5%. As calculated (0.7/131.8=~.005), .005 is the ratio of bus registration to personal vehicle registration, a rate of one-bus to every 400 vehicles on the road.

Mortality

The US Federal HWY Traffic Safety Administration reveals fatal crash mortality has been reducing since 1975, at a 2010 rate of fatalities per passenger vehicle 0.99 per 100MVMT. Significantly more than those experienced by transit trucks and buses. Fatal crashes for these larger vehicles decreased by 34% between 2005 and 2009; largely attributed to the enhanced training and experience by Commercial Drivers Licensed personnel. Injury related crashes also decreased over this time period by 33%. From the same database, 2010 and 2013 information, reflects fatal crashes involving a commercial vehicle at 0.13 and 0.12 per 100MVMT miles traveled respectively. What this suggests is that commercial vehicles are many times safer for the users of commercial services than for those in passenger vehicles, though in almost all cases involving a commercial vehicle crash, death occurred [1]. Average deaths per HWY mile per year for the same years is: 0.27 (2000) and 0.21 (2010 and 2013) per 100MVMT [14]. Select figures from HWY Deaths nationally are recorded as; 41,945 (2000), 32,999 (2010), 32,719 (2013) [15]. 2015 saw the highest fatality rates in passenger vehicles and light trucks, since 1991. Fatality Composition 2006 and 2015, Figure 4 from Sandow, Westerlund, and Lindgren (2014) reflects 3% and 4% of fatalities (2006 and 2013) associated with commercial motor vehicles, versus 67% and 69% for passenger vehicles and light trucks. Of the 6,064,000 police reported crashes, 32,166 deaths occurred [16]. Figure 2.1 reveals fatalities decreased from more than 50,000 for 31T miles traveled or one every 620M miles. Reducing to 2.1 deaths per 2.6B miles traveled from 1978 to 1998, reducing again in 2015; fatalities experienced per 100MVMT is; ID 120 or 1.5, NV 361 or 2.09, and NM 424 or 1.91 [9].

Sandow, Westerlund, and Lindgren (2014) studied the association between long-distance commuting, and mortality. Using longitudinal individual data points from 1985 to 2008, focusing on 55-year-old females in 1994, they modeled mortality among long-distance commuters and matched controls from the population travelling short distances to work. The results indicate that women who have experienced long-distance commuting face a significantly higher mortality risk compared with women with short commutes to work [16]. The US National Safety Council (whose data collection and analysis methodology differs slightly from the National HWY Transportation Safety Administration) reports a rate (including deaths of pedestrians and cyclists killed in motor vehicle accidents) of 1.25 deaths per 100MVMT in 2016 (see Figure 2.1). In rural areas, deaths per vehicle occupants represent twice that of urban areas, with speed, increasing temperature and daylight increasing the probability. Approximately 55% of the total deaths are day time rural deaths; for large transportation units like buses, users experience 13.5% of deaths versus 78.4% in other vehicles [19].

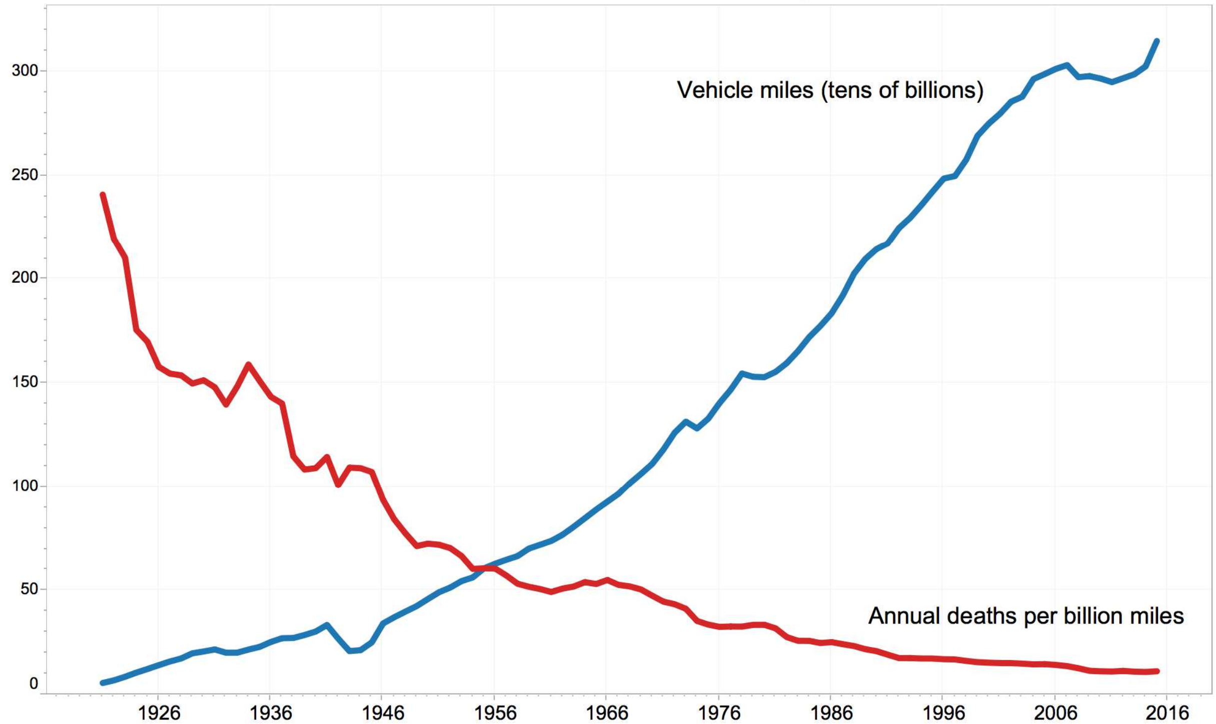

Figure 2.1: US Vehicle Miles Traveled and Proportionate Fatality Rate [17]

Khattak (2003) presents a literature review with the following pertinent data from six cited authors; financial estimates of crashes effecting vehicles and animals in 1996 was more than $1B, there were 1353 human fatalities between 1991 and 2010 from animals, and serious effect on local fauna due to rural HWY transit corridors, with one instance of more than 598 dead rabbits on a 50 mile stretch in south-central ID. Also noted was an increase of 69% in animal-vehicle crashes between 1985 and 1991 and vehicle-animal crashes as the primary crash category in rural HWYs on North Carolina. And finally, that larger animals involved in crashes with personal vehicles had a greater survival rate than in any other vehicle-Animal crash. I reviewed each of the six sources used by Khattak and have validated their conclusions are accurately represented in Khattak's work [18]. In 2000, 160 vehicles were involved in 145 vehicle-animal crashes, with 144 fatalities. This represents a decade long study where on average 1.21 vehicles and 1.06 human fatalities were a result of vehicle-animal crashes. Crash frequency data was collected for a four state region (ID, Nebraska, Wisconsin, and South Carolina), suggesting that remote western desert terrain was less than half of that experienced in highly forested areas, where animal populations are significantly higher. Apart from rates experienced in California, NM, and Texas, all western states experienced a reduced crash frequency than compared to their eastern counterparts, between one-half and one-fifth, though Khattak identifies ID as a state that is trending in the negative direction [18]. Within the defined biome, ID, NV, and NM share similar vegetation, ecology, road conditions and weather, and as such ID is a good meta-comparator for the three state region; ID data was used in lieu of complete data from the other two states.

Environmental Impact

The US used 140B gallons of gasoline in 2015 [20]. Each gallon emits 24.7 lbs. of net Carbon Dioxide (CO_2) to the atmosphere. This equates to ~3.458B lbs. of CO_2 per year, basically equivalent to CO_2 emissions from coal to produce electricity, 3.442T lbs. [21]. What this really means is best shown through an example: imagine a 10,000 gal tank truck (TT) of gasoline going down the HWY. Then imagine 1,500 TT's following it. Those 1,500 TT's represent the volume of CO_2 emitted from that single TT of gasoline. That is over 6 miles of TT's. If we replaced half the gasoline with biofuel, 845M tons per year of CO_2 emissions would be reduced. The key to increased environmental sensitivity is to stop use of petro-carbon and use renewable carbon already above ground to make motor fuel.

National emission trends show rapid reduction in Carbon Monoxide (CO) emissions at 88 million tons (Mt) in 1970 down to 51Mt in 1998. Transportation has shown this drastic reduction, while all other sources in the market have held flat at a reduction of just 2% to 39Mt. Volatile Organic Compounds (VOC's) have followed this trend, reducing from 13Mt to 5Mt with other sources decreasing from 17 to 13. Nitrous Oxide (N_2O) levels have increased from 7Mt to 8Mt and 14Mt to 17Mt, for the same transportation and other sources sectors. N_2O reductions began approximately 1990 with a more than 1Mt reduction between 1990 and 1998. Air quality trends have also improved from more than 25 exceedances of CO annually in 1975 to less than 1 by 1998. Ozone (O_3) has also decreased, though the reduction has been more sinusoidal in nature dropping from 12 exceedances to 2 annually [21] [22] [23] [24] [25]. CO_2 emissions are significantly higher than any electric or fuel cell vehicle as can be seen with Table 2.1. Table 2.1 is designed to be complimentary to Figure 2.2 and Tables 2.2 and 2.3; primarily used to identify emission levels in typical vehicles based on fuel source; primarily to identify the emissions of biofuels as lower than all sources, an assumption that can be carried forward regardless of transit modality.

Table 2.1. Select Vehicle Statistics and Associated Emissions [20]

Vehicle Manufacturer	Fuel Use	Net CO_2 emitted per unit	emission/mile
Chevy Equinox –	26 miles per gallon (mpg - combined)	24.7 per gal/petrol	0.95
Chevy Volt –	37 mpg (combined)	24.7 per gal/petrol 8.33 per gal/ethanol	0.667 0.32
Honda Civic CNG	37 mpg (combined)	23.25 per gal/petrol 6.74 per gal/ethanol	0.591 0.259
Toyota Mirai Fuel Cell	25 miles per lbs Hydrogen (H_2)	3.25 per lb Compressed Natural Gas (CNG)	0.488
Chevy Volt Hybrid–	100 miles per 35 kilowatt hour (kWh)	1.21 per kWh	0.424
Tesla S (85 kW) –	100 miles per 34 kWh	1.21 per kWh	0.411
Nissan Leaf -	100 miles per 30 kWh	1.21 per kWh	0.363

LCA is a technique used to assess the environmental impacts of all stages of a product's life, including raw material extraction, processing, manufacturing, distribution, use, and disposal or recycling. When comparing fuels, LCA may focus on particular portions of a fuel's life cycle, such as from extraction-to-use or well-to-wheels; to determine the merits or problems associated with each fuel. LCA completed by Argonne National Laboratory (ANL) found that GHG emissions for 100% biodiesel (B100) are 74% lower than those from petroleum diesel [21]. Recently, the California Air Resource Board (CARB) reported similar values for its LCA of biodiesel from various sources [22].

Comparative analysis literature review by Hill et al. (2006), on the effects of biodiesel on the emissions of carbonyl compounds gave discordant results, noting aromatic emissions from B20 and Diesel oil were virtually the same, though another study showed a decrease of light aromatic emissions by approximately 60% when the biofuel was from rape seed oil methyl esters. Hill, et al, cite four papers that support the development of their conclusions. Each of the four papers have been reviewed and are accurately reflected in their work [27]. Though their study is primarily focused on the life-cycle environmental benefit from several ethanol biofuels and biodiesel, Hill et al., state that using a net energy balance approach, both ethanol blends and biodiesel production result in Net Energy Balance (NEB) >1. Further, they state that biodiesel is environmentally superior to ethanol, which is environmentally superior to petroleum based fuels. They state that GHG emissions are reduced by 12% for ethanol compared to petroleum fuels and 41% by biodiesel. Further, that biodiesel releases less pollutant matter than mail stream biofuels such as Ethanol and Biodiesel [22] [23].

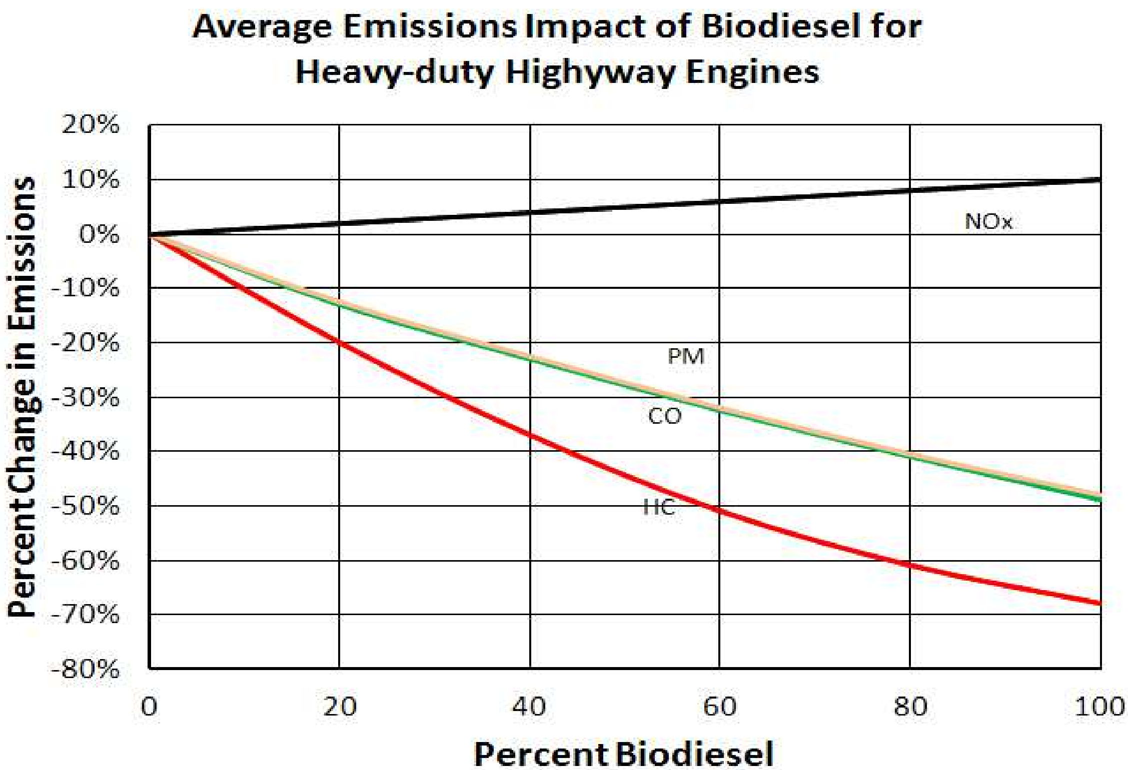

Figure 2.2: Biodiesel Grade (Blend %) Versus Diesel (HC-hydrocarbons, CO-Carbon Monoxide, PM-Particulate Matter, NO_X-Nitrous Oxide) [25]

For perspective, one primary economic concern is that the use of corn or grain based fuels is not sustainable; that if all of the US corn and soybean production would only meet 12% and 6% respective demand for ethanol and biodiesel. Sheehan et al. (1998) reference the National Renewable Energy Laboratory (NREL) publications SR-580-24089 [28] and two other key papers, low levels of biodiesel blend into diesel oil reduce emission s of VOC, CO, Particulate Matter (PM) 10, and Sulfurous Oxides (SO_X) during combustion and over life-cycle emissions relative to diesel. Finally, they state that ethanol from cellulosic biomass would result in added NEB and would be a more sustainable production alternative to fossil fuels, though total estimated maximum biofuel production is equivalent to about 32% of total gasoline consumption worldwide. They reference a study of 47 published LCA's with discordant results for estimated impact and capability, leaving some scientists in support and others opposed to biofuel and bio-fuel production from food-alternate sources. Both the NREL publication as well as the other two references cited have been reviewed and validated for accurate representation in the work of Sheehan et al. [28].

Contrary to other opinions presented, Turrio-Baldasarri et al. (2004) advance the work of two previous papers to suggest that the use of B20 does not significantly impact the environment negatively when compared to diesel oil used in the same urban bus engine. Their measurements suggest only a slight difference in VOCs, within 10% or less. They recognize significant discord in the research results of others and note an increase in formaldehyde, but not in other VOC's, and a sharp decrease in aromatic emissions (approx. 60%) with biodiesel from rape seed methyl esters, but a 135% increase when fueled with rape seed oil. Also noted is that the balance of emissions from either a biodiesel or a diesel oil were statistically the same. Conflicting results are assumed to be a result of the specific vegetable oil composition and preparation process used to produce the biodiesel. The only significant environmental factors referenced in this article are the 3% increase in consumption required to perform the same task for B20 versus diesel oil and that formaldehyde is significantly increased by the use of B20, 18%. While the preponderance of evidence suggests reduced environmental impact from the use of biofuels, I have reviewed the two key sources Turrio-Baldasarri et al. cite and have validated the sources are accurately reflected [20] [24].

Turrio-Baldasarri et al., compared the emissions of B20 and diesel oil and did not find any statistically different emission outputs at a 95% confidence level, though biofuel based emissions resulted in a slight reduction of aromatic and polyaromatic compounds. They also state that formaldehyde increased by 18% with the B20. Turrio-Baldasarri et al. cite three papers in their work that contribute to these conclusions, each have been reviewed and are accurately represented. They suggest biodiesel as virtually free from sulfur and other aromatic compounds, to be generated from natural and renewable energy sources and to be non-toxic and biodegradable. They performed an analysis of several studies to confirm use of biodiesel results in lower emission of PM and THC but an increase of SO_X and NO_X. If the whole life-cycle of fuel production is considered, then 20%-30% can yield similar decreases in global CO_2, while 70-90% is achievable with neat biodiesel [20]; Neat biodiesel is a B100 ideal. For perspective, USA is the top biodiesel producer [26]. Tables 2.2 and 2.3 reflect the pertinent consolidated data presented within this section of the literature review.

Table 2.2. Biodiesel Emission Comparison Against Conventional Diesel		
Emission	Pure Biodiesel (B100)[3]	Biodiesel blend (B20)[3]
Total Unburned Hydrocarbon (HC)	-67.0	-20.0, -21.0[2]
Carbon Monoxide (CO)	-48.0, -42.7	-12.0, -13.1,[4] -11.0[2]
Nitrous Oxide (NO_X)	-47.0, +13.2	-12.0, +2.4, +2.0[2]
Sulfates (SO_X)	-100.0	-20.0
Polycyclic Aromatic HC	-80.0	-20.0, -21.0[2]
Ozone Potential of Speciated HC	-50.0	-10.0
Particulate Matter (PM)	-55.3	-8.9[4], -10.1[1]
Volatile Organic Compounds (VOC)	63.2	-17.9

Average Change in Mass Emissions; diesel engines using biodiesel mixtures relative to the standard diesel fuel (%) [25]; 1[23], 2[26], 3[28], 4[30]

Tables 2.2 and 2.3 are composite tables designed to capture net emission impacts from several data sources when compared to the use of the typical CMV fuel, diesel. Table 2.2 outlines the use of biodiesel and biodiesel blend emissions as high and much higher performing than conventional diesel. Table 2.3 provides for a detailed variant of table 2.2 specific to the target fuel in this study as used by INL buses, B20. What table 2.3 also illustrates is the disparate results when compared to the B20 section of Table 2.2 for emission performance. What I discovered in the data research is that biofuels are typically cited as better performing fuels thou some research suggests that they are simply different, but perform the same.

Table 2.3. Emission of Regulated Pollutants					
	Diesel	N=3	B20	N=3	Statistically Different
	Mean	SD	Mean	SD	
Tetrahedral Hydrocarbons (THC), g/kWh	.6	.1	.5	.1	No
CO, g/kWh	2.1	.2	1.9	.2	No
NOx, g/kWh	5.3	.3	5.3	.4	No
PM, g/kWh	.26	.02	.27	.03	No
Fuel Consumption, g/kWh	237	1	224	1	Yes
SO_X%	49	1	52	12	No

Assumes vehicle using biodiesel 20% blend and was compared against the same vehicle running diesel over the same mileage [23] [27]

Improved emission performance in today's diesel vehicles are the result of sophisticated engine controls and exhaust after treatment devices. All engines have to meet the same tail pipe emissions standards, regardless of fuel type, as defined by the Environmental Protection

Agency (EPA). When used as a vehicle fuel, biodiesel offers some tailpipe and considerable GHG emissions benefits over conventional gasoline and diesel [23] [27].

All effected States have a DEQ at the state level. Each of them have sampled and cleanup up various HWY roadways. Each with similar results as discussed by From Barrett et al. (2004), standard roadway design results in buffer strips equivalent to those that are specifically engineered for water quality performance typically achieved by 16' buffer strip. The mechanisms of pollutant removal are sedimentation, absorption, infiltration into the soil, and biochemical activity on the grass and soil media. Total suspended solids (TSS) reduced from 112.9 mg/L at the edge of the roadway to between 32.8 and 38.7 mg/L at the edge of the swale [30]. Dermibas et al. (2009) analyzed vegetated HWY buffer strips and noted efficiencies of buffer strips for TSS removals ranging from 98% to -7% [31]. Concentration reduction consistently occur for TSS and total metals and frequently for dissolved shoulders. Water quality performance declines rapidly when the vegetative cover falls below 80%.

Summary

The literature review identified clear areas for further research and analysis, as explored in Chapter 4. The EO's identify the changing political landscape for service providers, with special focus on bus fleet noted in EO 13693. Within the context of the national HWY system, transportation types, and mortality, the review notionally identifies impacts to safety factors from animal-vehicle and vehicle-vehicle interaction. Though disparate results on fuel type correlation to GHG emissions were noted by Turrio-Baldesarri et al., the balance of the research identifies bio-fuels as environmentally superior [20]. Apart from maintaining compliance with EO's, they will not be explored further. Biologic factors of safety and environmental impact analysis was used to suggest whether the service should be optional or mandatory with regard to DOE-contractor agreements. Sufficient detail has been provided herein regarding fuel type and resultant GHG emissions, and as such assume the posed majority opinion as valid, though further analysis will be developed to illustrate a more accurate performance view of vehicle type and associated fuel selection.

CHAPTER 3: RESEARCH & DESIGN METHODOLOGY

Introduction

The DOE budget includes funding for transportation services at their remote laboratories in ID, NV, and NM. Each of these have potential to offer mass transit systems. Current offering is through various means, from direct funded service with Government owned equipment and direct employees to subcontracted personnel and equipment. Some detail regarding the financial situation of these services is discussed herein, but only as an extraneous discussion to compare with other transportation types. This chapter identifies the research methodology deployed herein. My history and experience with the subject matter and the discovered associated focus areas are outlined herein and included to establish my expertise and set the stage for the use of this mixed-methodology approach to analyze and prove of the aforementioned H0.

History and Context

In June 2006 I was hired by Bechtel (BBI-BMPC) as a Contracts Administrator (CA). Shortly after being hired, I was assigned the site-services contract (SSC), a $10M+ memorandum agreement between two Government contractors, BBI-BMPC and INL. Transportation was the majority expense of the SSC. As a CA, my role was to manage the agreement, perform basic analysis, and account for financial outlays. Being curious about the details of the contract and unable to adequately account for the financial transactions, I began performing more detailed analysis of the cost factors and to look at external sources of the same service, with a focus to reduce costs by any means. In early 2008, I was asked to justify the service at its current cost and to consider terminating the service in lieu of spending the funds on programmatic work. I was given basic guidelines to consider the benefits of the workforce arriving at the same time at work and the assumed safety benefits the bus service provided over POV's. I was able to perform limited economic analysis; though environmental or safety-related analysis was not completed, as I did not know how to do it at that time. The economics-based proposal was at the time sufficient to justify retention of the service based on a very limited analysis of two market comparators.

Spring 2008, due to unique capability to perform atypical business analysis, I was moved into a more senior role. Due to the knowledge I had developed with the SSC, I was required to retain many CA functions to support that contract. My next big analytical task was the joint BBI-INL route optimization analysis; no safety or environmental factors were considered. During the course of the next eight years, I changed jobs several more times within the BBI-BMPC in financial and operational management roles. Each move came with the requirement to retain the SSC and as such, each move reinforced my role as the programmatic expert of transportation services. In 2012 and 2013 significant added analysis was completed including a formal market analysis with alternate contractors, as well as the training of a new and highly credentialed financial analyst to assume the contracts management role for the SSC, now pushing $20M, transportation still the majority share. Feeling I had achieved a victory by passing on the contract, I moved on to other things, closing the transportation management chapter...or so I thought at the time.

The end of 2013 saw four significant changes relative to SSC transportation; (1) an employee driving a POV was killed on the commute from the remote site, (2) President Obama had signed new environmental legislation aimed at Federal agencies for the use of bio-based fuels and environmental impact reduction, (3) the Federal government challenged the subsidized transportation contract as taxable income as a perceived benefit to the users, and (4) the CFA I trained left the company. Due to these changes, I was moved back into the SSC to perform added analysis. The recent death presupposed that the person would not have been killed had they been on a bus versus a POV. This presupposition supported me making a logic leap that buses were inherently safe, though no real analysis had been completed. This same safety assumption was used to defend the existing subsidy for the users. Additional assumptions were made, as an assumed environmental benefit due to their transition of the INL to a newer fleet and the use of a biofuel blend.

In my final role with BBI-BMPC, I was the senior business administration manager at the remote site, which meant that the business (contracts, fleet and logistics, analytics, etc.) personnel reported to me. Unable to find a suitable replacement as a transportation subject matter expert, I retained formal ownership of the contract. Prior to my role in operations, I had completed coursework in environmental science and had recently finished a master’s degree in mechanical engineering. This combined business and technical knowledge supported my claim, though due to the demands of the balance of work, significant analytical detail other than financial was missing from my recommendations. In early 2016 in another joint-corporate market survey and economic analysis was launched to defend the growing transportation expenditure. Due to strongly rooted belief of the safety enhancement a bus provides compared to POV's, the economic analysis was aimed at which bus service should be used, including the comparative analysis of total costs of operating; lease-buy, overheads, allocation rates, and expertise to manage the service.

In 2016 I left Bechtel to work for INL, in the Facilities & Site Services directorate as their Chief of Staff (COS). Given the change of work type and company, I felt I had left the bus business for good, and had again closed that chapter. However, in early 2017 due to questions of growing cost escalation, the Government asked for added work justifying the expense for retaining the mass transit service in any form. Three contractors operating on the INL were using the services at a total cost to the government at just less than $30M per year. I agreed to lead a team of finance, contracts, and subject matter fleet experts to develop the 'answer' for retention or termination of the bus service. I worked with the team for several months, and though the team had solid knowledge in their specific fields, transferring knowledge between them proved to be difficult due to the need for well-developed business and engineering acumen, as well as having history, context, and nuance detail for defense in depth of how and why the service operated the way it did. By mid-2017, having established many of the core functions I was hired to do as the COS, and due to no reasonable alternative, I terminated the team effort to do the analysis myself. I was asked to perform the analysis as a subject matter expert within the DOE system and to author the recommendation as such. The analysis was to provide a comprehensive recommendation for the INL and the two other contractors on the INL that could be used as the technical and administrative basis for having the service in any form. Given the broad impact my recommendation would have on the three INL contractors and two potential other DOE locations, I felt I needed to do the research to develop as complete a recommendation as reasonably possible to defend whatever the decision should be, with scientific data and comprehensive thought. The capability to do this level of research and recommendation is a function of many years of experience and graduate work in both business and engineering.

The business need for a comprehensive decision framework works well with my academic interests. Prior to 2017, I had worked on several PhD environmental science research concepts through the University of Idaho, and was in search of a project that would advance the state-of-the-art in an area I was interested in, and that would complement my work. This search for legitimate research matter was coincidental and convenient for the newly accepted assignment for the INL. I initially proposed the comprehensive analysis work to meet the joint requirements for the INL and the University. Since I have started the work on this research proposal, the other two INL site contractors have become aware of this work and are looking for the results so that they can support their decision basis. Additionally, through several correspondences with LANL's fleet operations management, they have expressed interest in this work as they are in the consideration of expanding their existing fleet.

My goal for this research and data analysis work is twofold: (1) catalog the body of knowledge I have developed relative to the logic and methodology acquired in my twelve years of work in this area in a comprehensive package with a robust and defendable recommendation for retention, modification, expansion, or termination of the service and (2) to develop the basis document for the next owner of this service to have the needed context to re-solve the problems of the past and to support expanded analysis if the transportation construct were to change again, to say, high-speed rail or self-driving vehicles, etc. Given the robust economic analysis already performed, the focus of the research and recommendation is biological; to look at a more complete impact to human safety, the environment, and the taxpayer as a result of retention versus termination of the service. Based on the enclosed history and context, my selected research methodology is targeted at the several subcomponent focus areas discussed in Chapter 2, with analysis designed to connect key subcomponents to form a composite formula illustrating impact (see Chapter 4), and a transportation mode ranking table (see Chapter 5) for making the transportation decision.

Problem and Purposes

The primary problems within these mass transit systems are that the cost to operate and maintain the service has significantly increased over the previous decade and the user base has dwindled, amplifying the cost factors born by the laboratory contractors and ultimately the Government. The financial burden to provide these services is in the tens of millions annually [business sensitive source – see Appendix E], making it an attractive target to reallocate funds to mission critical work or to provide relief to the DOE and associated US Federal budget. Due to cost being the focal point of transportation, other important biological factors are overlooked or included anecdotally. The purpose of this research is to quantify pertinent bio-economics in a meaningful and usable, way though several other factors should be considered as important. For this research, those categories have been divided into several pertinent categories;

environmental stewardship and human safety, including the emergency response stature from the personnel safety aspects. The factors requiring a broad reaching and mixed methods approach are outlines as:

- The concept of safety typically is considered within the context of the people using the service are assumed to be safer.
- Environmental stewardship is viewed through the lens of fuel source, noise and light pollution, and the divided habitat that frequently traveled HWYs create. Noise and light pollution were not discussed due to the remote transit corridors within the defined biome. Fuel source is the comparison of personnel vehicles to mass transit systems using biofuels versus petroleum based fuels. The function of animal population effects as a result of divided habitat are discussed within the greater context of effects on local fauna.
- Human effects are divided into two categories, effect of mass transit versus personnel vehicle use relative to exhaustion and vehicle-animal or vehicle-vehicle accidents resulting in death.

Research Focus Areas

These research focuses, when addressed provide decision makers with viable data and perspectives of the key stakeholders; employee users, environment, and taxpayers. This integrated view will enable a more responsible and informative decision basis regarding the use of mass-transit (specifically buses) within the DOE system outlined. While the summary questions assume a consolidation of impacts, they have many aspects that must be viewed separately and within the context of their effect on each other. In summary, the key research focuses are:

1. Statistically proven safe way for employees to travel to and from their respective work locations; resulting in reduced loss of life, including wildlife, and mitigation of statistically significant human factors for extended driving.
2. Statistically significant decrease in negative effect to animal and plant life within the defined transportation thoroughfares; environmentally conscious specific to use of biofuels and reduced pollution of vegetated HWY shoulders. Validated through the use of biofuels, including B20 versus petroleum-based fuels. Biological enumeration using

concepts from LCA and EIA, including current biological impact to vegetated HWY shoulders per comparative transportation unit will be used.

3. Quantifiable reduction in economic impact to tax payers and to the employees who use the respective services.

Producing an integrated view of the DOE mass transit potential over the rural transit HWY system will enable decision makers to make more defendable decisions regarding use of the program, expansion or reduction. The H0 developed seeks to answer the fundamental question of transportation mode superiority. Results are ranked on key factors as they related to multi-person carpooled personal vehicles and passenger transit buses. Single user personal vehicles and multi-passenger car and van-pools are used to enhance sensitivity boundaries and will be ranked in the results. Each of these are examined and discussed in greater detail in Chapters 4 and 5.

Research Design and Boundaries

Research design for this study is simplified to models of both economic and non-economic factors as they apply to the comprehensive consideration and evaluation of the decision resulting from answering the key research questions. A mixed-methods approach was used to support appropriate data collection, analysis, and results, primarily due to data and analytic techniques are both qualitative and quantitative. According to Teddlie and Tashakkori (2003) [32] and Teddlie and Yu (2007) [33], mixed-method is the appropriate research and analytical framework due to several supporting factors:

- The study is purposive
- Both numerical and textual data are relevant
- The data is dispersed and unconnected suggesting the need for a thematic analysis
- The analysis is expected to produce multiple conclusion types, subjective (i.e. relative ranking) and objective (i.e. safety statistics)

The research functional boundaries are the mass transit systems (buses) in use supporting the DOE remote laboratory sites and their current bus use profile (for current use or potential) as detailed in Chapter 1. Due to the sensitive nature of revealing competitive strategies and financial information, this information will be paraphrased or generalized where possible; with the respective locations using a normalized 55 passenger bus. These transportation systems have been compared to POV and Van-pools. Bus loading has been estimated at 65% (36 persons as an average of recorded data) as a realistic measure of average daily loading currently being experienced in ID. Bus systems and associated potentials are represented as they existed at the end of the US Federal fiscal year 2016.

The biological boundary is focused on human mortality and safety, large animal (i.e., deer, elk, antelope; classified as large animals due to their impact in a collision and their relative impact to the supporting ecosystem). Small animals (i.e. rabbits and mice), birds, and raptors were not evaluated. Other ecosystem impacts as a result of transit HWY usage are discussed. This study did not delve into other research boundaries, such as mechanical systems corrosion and poor fuel economy associated with non-petroleum sources. Added discussion regarding the US National Energy Independence goals, is limited to the suggested benefit of the use of a nationally sourced biomass being viewed as superior to a foreign petroleum fuel source [5] [6]. Significant other biofuels research exists elsewhere, and as such, new fuel types or biomass sources are not discussed. The biofuel source assumed herein is B20.

Some factors not included, but pertinent to this research is the assumed productivity mass transit systems provide, and personal liability due to use of a mass transit system releasing the average user of any liability associated with any affect their daily transit may have. Due to the sensitive nature of some of the comparative data, where information has been found to be unavailable from either the NNSS or LANL, the INL is used as the assumed as normalized data; INL bus service was used as the representative sample set.

Extensive research has been performed already suggesting impacts of biofuels, their sources and consequences for use and as such, this was not explored further. Other biofuels, biomass sources or petroleum fuel variants outside those identified including fuel additives or engine modification were not addressed. Given the defined biome, any transit outside the rural transit HWY system, though information has been provided regarding miles of use on other common transportation routes were not considered, though they are mentioned for context only. Nuance data or events, such as road construction, force majeure, and emergency related scenarios; or weather-related impact, though weather related traffic slow-down and hazards exist were not considered. Drivers outside the immediate commuting employee base of the three laboratories were not considered, though transportation statistics have been provided to illustrate their respective use of the system, as indicated by DOT statistics of vehicles used. Context is provided to illustrate current non DOE loading on these HWYs during the affected work hours and at the three affected locations. Human factors and health effects outside accident-related transportation were not directly studied, though some general wellbeing anecdotes are noted for context related to greater health-related factors. Primary limitations come from disparate data, limited and targeted studies, the limited population set, and my experience, including my interpretation of the experiences of others associated with this study. Due to the sensitive nature of the detail required to perform the research, the research results will not be made public, but will be provided to DOE – ID as the target audience, INL - BEA as a prime user, and The University of Idaho as dictated by the major professor supporting this research.

Primary Research Methods and Data Collection

Leech and Onweuegbuzie (2007) [34], present a typology of mixed-methods research, wherein they reference several of the pioneers developing this emerging approach to research and analysis. The typology they identify that best fits the approach for this study stems from the work of Daley and Onweugbuzie (2004) [35]. Of the typologies they propose, the one that best fits is the 'fully mixed concurrent equal status design' (F1). The reason for identifying the noted typology, is to support a common framework of language as proposed by Tashakkori and Teddlie (1998) [36] and Teddlie and Tashakkori (2003) [37]. Over the ten-year span of 1998 to 2017, these five authors build upon each other's work to develop the foundation of mixed method research and analysis. My reliance on these mixed-methods founding authors assumes their research design and analysis was collectively robust and that their recommendations are sound. Their work allows for both qualitative-purposive and quantitative methods to be used to develop context rich recommendations, similar to the goal of this study.

Research methods for this privately held DOE contractor information are designed so that connections can be inferred to generalize publically available data impacting the geographic region and transportation type. Research sources include traditional methods and research areas. Research and analysis methods was conducted using Microsoft Excel and include formula development and testing to develop the scoring criteria for gradient of optimization (sensitivity analysis). The Data Analysis add-in from Microsoft Excel was included to perform regression and other statistical analysis for variable dependencies. Research outputs were used to develop an abbreviated EIA, Human Factors safety analysis, and various comparative analyses. The abbreviated EIA is tailored to the biome boundary and limited to key factors relative to the target audience of this study.

Supporting methodologies are designed to better assist in the analysis of the respective data to form quantifiable findings, such as the development of a system-level model to illustrate the magnitude of the issue and relative impacts. Additional research was performed on privately held DOE contractor information in the form of analysis of business information and engineering economic analysis. An actual-values research technique was deployed to validate the legitimacy of the DOT data as applied to the biome considered. Physical observation and road scout collected data were also used to develop an actuals-based view. Sensitivity Analysis was conducted to determine when and how the results change based on transportation unit loading. Qualitative and sometimes anecdotal information formed the basis for this investigation, with data elements developed to form a decision model and ranking system from both qualitative and quantitative data sources. Mixes of qualitative and quantitative data types and analyses within the same study were used, with research objectives being primarily purposive and analyses being primarily thematic, data from multiple source types, and the inference drawn from the data ranking and associated sensitivity analysis.

Reliability and Validity

Given the data being analyzed is both generalized US Federal-level data and DOE contractor actual data, the reliability of the results is expected to be accurate at a better than 90% confidence. This assertion is based on the reliability of the data considered, the contiguous nature of the HWY systems and transportation systems. The validity of the information being used is in two forms; limited comparative economic analysis has been performed multiple times within the contractor base and it bares further analysis in terms that can be generally understood and applied within unified decision making. Secondary forms of validity come in the form of an economic common denominator for the various nontraditional economic comparators, as available and appropriate. Several significant factors need to be considered regarding the validity of the data; I assumed generalized vehicles and performance, fuel types, and established normalization, such as the relatively similar geographic conditions for the respective biomes that the ID data was reflective of those experienced within the other geographies considered.

Given the relevant decision basis being enumerated in economic terms, as many as appropriate researched factors were translated into an economic equivalent for comparison. Several examples of this are illustrated, such as:

- As an employee, what is the best transportation system to use ('best' is defined as economic benefit optimized for safety)? How much safer are people and animals due to transportation type?
- As the DOE and its managing contractors, what is the best transportation system to use ('best' is defined as lowest economic impact optimized for both human safety and environmental impact)?

Experiments were not performed, though analysis was completed with results falling within the categories of journal comparison of biofuels against diesel oil with notional economies discussion, comparative analysis of busing to commuting relative to biome-specific mortality for human and animals, and an abbreviated EIA using an applied qualitative statistics approach. EIA and Economic Input-Output Assessment instruments were used to support LCA impact discussion of transportation modalities on vegetated HWY shoulders, based on vehicle type, fuel type, and occupant loading and traffic density.

Data Analysis Techniques and Methodology

Data analysis methodology is simply to research every reasonably associated subcomponent affecting safety, environmental impact, and economics. Techniques employed to do this were to perform a detailed literature review and to search data sources as mentioned herein. Further as illustrated in several of the tables in Chapter 2 and Chapter 4, data has been consolidated into the relevant components and calculated as needed to normalize and bridge any data gaps experienced. Developing a reduced economic impact position for tax payers and the employees who use the respective services required several different analyses and various questions to be addressed. Beneficial to reduced business Interruption, resulting in more consistent productive time, and thus increasing value of taxpayer monies. An examples is; comparative statistical impact to productivity for use of respective comparative transportation unit (consistency as enumerated in taxpayer value). As DOE contractor data was not found to be consistent in what is collected and distributed, the INL and ID data sets were used as if it was the normalized data from an exact population-matching sample data set. The resultant H0 remains as stated in this chapter.

Analysis has proven which transit type is superior for travel to and from respective work locations; resulting in reduced loss of life, including wildlife, and mitigation of environmental impact. An example of analytic results is; comparison of loss of life, wildlife per comparative transportation unit, or safety aspects for human life per comparative transportation unit. Determining the negative effect to animal and plant life within the immediate transportation thoroughfares included herein. Environmentally conscious specific to use of biofuels and reduced pollution of vegetated HWY shoulders, with examples of; use of biofuels, including biofuel mixes versus petroleum-based fuels, biological enumeration using LCA factors; or current biological impact to vegetated HWY shoulders per comparative transportation unit.

Summary

The population considered was the three remote DOE contractor-operated sites, specific to the associated miles of rural commuter HWY and associated vegetated shoulders. In areas where private contractor data was unavailable or withheld, ID and INL were used as the representative sample. These data were collected from both traditional formats as well as the use of private data, as available. The data collected was generalized. Data analysis was performed using economic factors as the primary result expression unit. It was expected that the analysis would reveal the H0 posed herein as valid. This research and the associated analysis and results will enable decision makers to make a more complete decisions based on real information and on factors that are important to societal and political arenas within the US. Simply stated, the evaluation of the use of a mass transit system based on an economic tradeoff of what the funding could be used for is an inadequate basis for a comprehensive, socially responsible decision.

CHAPTER 4: ANALYSIS OF THE DATA

Introduction

Based on initial indicators in the literature review, data was further mined from traditional sources, or developed as calculated values from these sources. This chapter contains data analysis, with information presented in many cases as a statistical inference from publically available data, consolidated in economic terms as appropriate. Data and associated analytics are key to this study as all elements of the hypothesis test rely on them. In areas were data was unavailable, inconsistent, or conflicting, the I have worked to de-conflict data, find added sources for validation, and to develop calculations to form data from respective sub components. This section serves as the primary connection from the previous three chapters to the final chapter.

Organization of Data Analysis

Data analysis has been conducted in three areas: descriptive data characteristics, qualitative and quantitative data, and analysis of the data. A mixed-methods approach was used to support appropriate data collection, analysis, and results; primarily due to data and analytic techniques being both qualitative and quantitative. With the focus of this study placed on biological impact, results are ranked by key factors as they related to single and multi-person carpooled personal vehicles and passenger transit buses. Single user personal vehicles and multi-passenger vanpools were used to enhance sensitivity boundaries and will be ranked in the results. The data analysis show which transportation mode optimizes economics, enhanced safety, and reduced environmental impact.

Descriptive data characteristics have been developed primarily from composite data initially analyzed primarily by US DOT and other agencies, and from composite tables I developed. Quantitative data is the primary data form, with both qualitative and quantitative forms following the analysis. Analysis of the data followed the initial format posed in Chapter 2 of this research, with detailed investigation into; the national HWY system, transportation type (modality), mortality, and environmental impact. These four analysis segments are further expanded and analyzed in several subsections; mortality (human impact), wildlife impact including data on

Animal Vehicle Collisions (AVC), an abbreviated EIA on the use of biofuels in use and vegetated HWY shoulders, commuting, road conditions, traffic density, and weather related impacts.

One significant challenge in organizing data for analysis is the codependence of varied data sets to generate results. Many of the data sets blend the key data divisions, such as AVC required for both wildlife impact, human mortality, and commuting impacts. A secondary difficulty with comparing the data across fuel types, States, mortality factors, and weather incidents is that the data is inconsistently reported per State, year and unit of comparison. Very few factors are the same in each of the DOT state date, such as 100MVMT. Much of the data is disparate with some common data factors, but in differing years or with common years but with different measures and reporting of what each state uses as pertinent data.

Hypothesis and Associated Research Questions

This hypothesis is tested using the principle question; is there a quantifiable difference in bio-economic impact from the use of mass transit versus personal vehicles on commuter transit HWYs at the three DOE remote laboratory sites? The goal of this question is to develop a quantifiable biological impact to human, animal, and plant life for the three remote sites and their associated transit HWYs, inclusive of the vegetated HWY shoulders. If the null hypothesis is found to be false, should the DOE modify the several mass transit programs at their remote laboratory sites? If found to be true, should the DOE discontinue the service offering? Secondary questions as summarized in Chapter 1 were used to develop pools of data for analysis, namely; is there a significant safety discriminator due to transportation type for human, animal, or plant life? And, is there a significant environmental impact discriminator between use of biodiesel on buses versus petroleum based fuel for passenger vehicles per transported occupant?

Primary analytic subcomponents focus on human safety factors, human-animal interaction, environmental impact, and economic factors. Research subcomponents seek to support the data consolidation and normalization within two economically optimized categories; significant safety discriminators due to transportation type for impacted biology, and significant environmental impact discriminators between use of biodiesel on buses versus petroleum based fuel for vehicles per transported occupant.

Presentation of Descriptive Characteristics for Data

Data used for this analysis comes from business sensitive as well as traditional sources, as stated. This research is based on carpooling compared to busing. Limitations for analytical purposes are invoked, such that vehicle type and loading has been normalized, though off-nominal conditions exist. For this research, those categories have been divided into several categories; environmental impact and personnel and animals affected. Environmental impact is viewed through the lens of fuel source, vegetated HWY shoulders and divided habitat that frequently traveled HWYs create. Fuel source is the comparison of personnel vehicles to mass transit systems using biofuels vice petroleum based fuels. The function of animal population effects as a result of divided habitat will be discussed within the greater context of effects on local fauna. Humans and large animals (e.g. deer and antelope) were considered as they are impacted. The biological boundary is focused on human mortality and safety, large animal (i.e., deer, elk, antelope; classified as large animals due to their impact in a collision and their relative impact to the supporting ecosystem). Specific analysis has been performed to support the key and associated, hypothesis supporting questions as stated in Chapter 3, Research Questions.

Analysis of Data

Analytic results ranked transit types for travel to and from respective work locations; resulting in reduced loss of life and mitigation of environmental impact; decreased the negative effect to animal and plant life within the immediate transportation thoroughfares. Added ranking was embedded to illustrate reduced economic impact to tax payers and to the employees who use the respective services. Of the data sets analyzed, results are summarized in three areas, enhanced safety, reduced environmental impact, and economic value. Due to limited access to contractor specific data at the NV and NM DOE sites, ID data will be used as if it were normalized data from a population-matching sample data set. The Data Analysis add-in from Microsoft Excel was used to perform analysis related to variable dependencies, with final results are in the form of a ranking of key factors as they related to multi-person carpooled personal vehicles and passenger transit buses.

Mixed-Methods: Qualitative and Quantitative Data

Primary results of the study focus on an optimized formula for what the busing actually costs in bio-economic terms, versus the benefits provided, and an associated recommendation regarding the development, modification, retention, or termination of the bus service for contractor and DOE policy and decision makers. Single and multi-user personal vehicles and multi-passenger vanpools were used to enhance sensitivity boundaries and were ranked in the results. Comparative analysis was produced to compare transit types as stated in Chapter 1, for impact to vegetation as a result of biofuels use, animal and human safety, and net economic impact. This mixed-methods analysis relied on several tools used for data analytics; the tools used are:

1. Sensitivity Analysis with Bus versus POV Occupant Loading
2. Traffic Density and Correlated Fatality/Mortality Analysis
3. Abbreviated LCA and EIA Discussion
4. Adjusted Density Formulation
5. Accident Causal Factors Analysis
6. Adjusted Fatal Accident Rate Formulation
7. AVC Analysis
8. Weather Impacts to Transit
9. Urban versus Rural Transit System Comparison

Note to the remaining Analysis of Data subsection: Appendix B: pictorial illustrations of roadway conditions should be used as reference of actual conditions experienced in the three state targeted transit corridors. Pictures 1 through 9 are taken from different vantage points along the respective three-state transit systems. These pictures show similar landscape, similar brush density, and straight and dry roads.

Transportation Type Detail

To develop ranked results, comparative analysis was produced to compare personal vehicles (one person use), carpooled personal vehicles and van pools (estimated 3 to 8 person use), and 55 passenger buses (36 passengers with professional driver), for impact to vegetation as a result of biofuels use, animal and human safety, and net economic impact. Results are expected to be reflected in economic values per item being measured to support decision making and easy to apply comparison models. Given the H0 assumption that the use of a mass transit system is superior to the use of personal vehicles in all factors deemed significant for comparison and impact, the use of statistical analysis is limited to the comparison of mass transit system actual data versus the average commuter personnel vehicle using observation data, as well as those previously mentioned. Bus loading is estimated to reflect generally experienced averages, though day of week, seasonal, and unrelated factors cause loading to flex between 60% and in limited cases, 100%. These buses experience an averaged 6 miles per gallon fuel consumption when using B20 [38]. Personal vehicles used are assumed as a reflection of the average vehicle type used in actual observation. Four separate observation samples were developed in early December 2017 and late January 2018. Using specific site populations, known bus loading, and POV's present at observation the calculated average POV commuter loading rate is 1.4 people per POV (Samples 1 through 4 identified rates of 1.32, 1.41, 1.46, and 1.42 respectively, with a 0.03 assumed variability based on fluctuating attendance of site personnel). These vehicles assume at a minimum a 1.4 person loading and at a maximum, a three-person loading, both with a non-professional driver. The vehicle assumed is a 5-7 year old mid-sized sedan with an average HWY related fuel economy of 22 MPG [38]. Given the vast majority, more than 90% of the personal vehicles used are not flex-fuel or biofuel capable, petroleum fuel is the assumed fuel source.

Mortality

The single biggest issue of this transportation study was found to center around the concept of mortality and traffic modality impact on human mortality or fatality. The Centers for Disease Control state that Road Traffic Accidents is the twenty-first of the top twenty-five causes of deaths annually in the US (Table 4.1) [39].

Table 4.1. US Mortality Rates (2002)						
Group	Cause	Percent of deaths		Deaths per 100,000		
		Group	Subgroup	All	Male	Female
–	All causes	100.0%	100.0%	916.1	954.7	877.1
A	Cardiovascular diseases	29.3%		268.8	259.3	278.4
B	Infectious and parasitic diseases	23.0%		211.3	221.7	200.4
A.1	Coronary artery disease		12.6%	115.8	121.4	110.1
C	Malignant neoplasms (cancers)	12.5%		114.4	126.9	101.7
A.2	Cerebrovascular disease (Stroke)		9.7%	88.5	85.4	95.6
B.1	Respiratory infections		7.0%	63.7	63.5	63.8
B.1.1	Lower respiratory tract infections		6.8%	62.4	62.2	62.6
D	Respiratory diseases	6.5%		59.5	61.1	57.9
E	Unintentional injuries	6.2%		57	73.7	40.2
B.2	HIV/AIDS		4.9%	44.6	46.2	43
D.1	Chronic obstructive pulmonary disease		4.8%	44.1	45.1	43.1
–	Perinatal conditions	4.3%	4.3%	39.6	43.7	35.4
F	Digestive diseases	3.5%		31.6	34.9	28.2
B.3	Diarrhea diseases		3.2%	28.9	30	27.8
G	Intentional injuries (Suicide, Violence, War, etc.)	2.8%		26	37	14.9
B.4	Tuberculosis		2.8%	25.2	32.9	17.3
B.5	Malaria		2.2%	20.4	19.4	21.5
C.1	Lung cancer		2.2%	20	28.4	11.4
E.1	Road traffic accidents		2.1%	19.1	40.8	10.4
B.6	Childhood diseases		2.0%	18.1	18	18.2
H	Neuropsychiatric disorders	2.0%		17.9	18.4	17.3
A.3	Hypertensive heart disease		1.6%	14.6	13.4	15.9
G.1	Suicide		1.5%	14	17.4	10.6

Adapted from Centers for Disease Control [39].

Table 4.2. US Motor Vehicle Safety Data								
					Rates per 100MVMT			
Year	Fatalities	Injured persons	Crashes	Vehicle-miles (millions)	Injured persons	Crashes	Year	Fatalities
1960	36,399	N	N	718,763	N	N	1960	5.06
1965	47,089	N	N	887,811	N	N	1965	5.3
1970	52,627	N	N	1,109,724	N	N	1970	4.74
1975	44,525	N	N	1,327,664	N	N	1975	3.35
1980	51,091	N	N	1,527,295	N	N	1980	3.35
1985	43,825	N	N	1,774,826	N	N	1985	2.47
1990	44,599	3,230,666	6,471,202	2,144,362	151	302	1990	2.08
1995	41,817	3,465,279	6,699,415	2,422,823	143	277	1995	1.73
2000	41,945	3,188,750	6,393,624	2,746,925	116	233	2000	1.53
2005	43,510	2,698,976	6,159,350	2,989,430	90	206	2005	1.46
2010	32,999	2,239,074	5,419,445	2,967,266	75	183	2010	1.11
2011	32,479	2,216,962	5,337,829	2,950,402	75	181	2011	1.1
2012	33,782	2,362,175	5,615,045	2,969,433	80	189	2012	1.14
2013	32,893	2,312,845	5,686,892	2,988,280	77	190	2013	1.1
2014	32,744	2,337,707	6,064,217	3,025,656	77	200	2014	1.08
2015	35,092	2,443,000	6,296,000	3,095,373	79	203	2015	1.13

Adapted from calculations by US DOT, Bureau of Transportation Statistics [2] [40] [41] [42] [43].

The US DOT reports that more than 35,000 fatalities (Table 4.2) occurred in 2015, a slight uptick from a fifty-year downward trend to safer roads. The fatality rate is measured over 100MVMT. Table 4.2 is a composite of five DOT tables combined to form a 55-year view of motor vehicle safety data for net fatalities and injuries and net miles driven as well as the comparative 100MVMT statistics. It is important to note that over this 55-year term, total Fatalities have decreased by 2%, while vehicle miles traveled have grown by more than 400%. The message here is that the transit corridors are safe and growing safer for all vehicle types. This becomes even more relevant as transportation types and associated statistics are overlaid as in Tables 4.4 and 4.5.

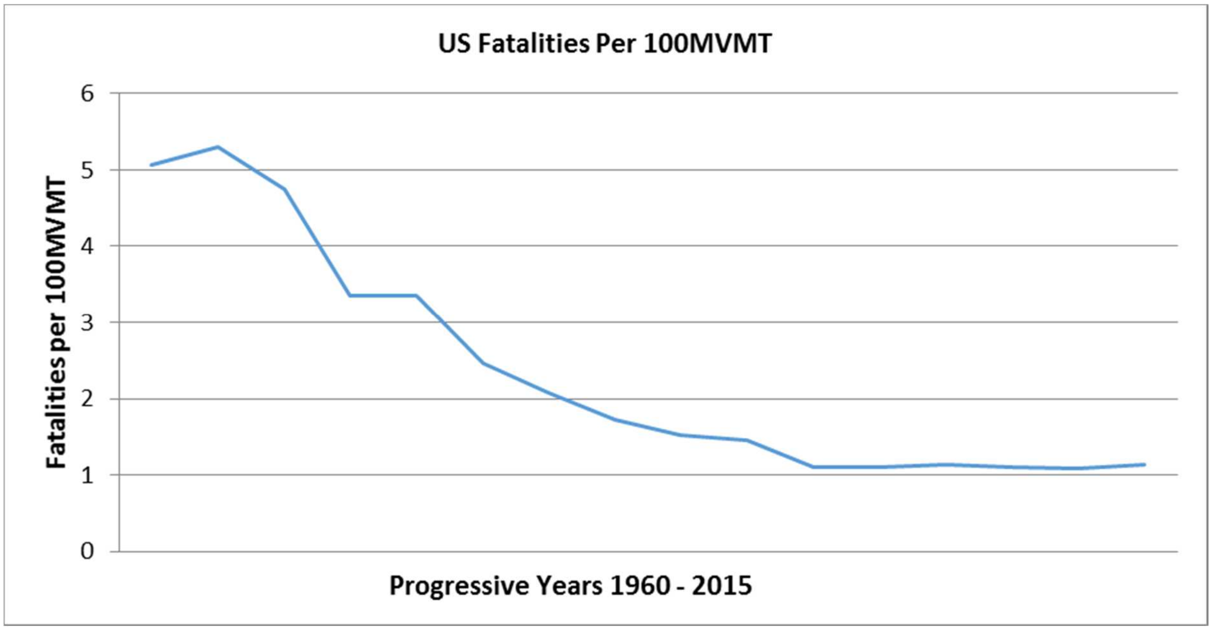

Figure 4.1: US Fatalities per 100MVMT [44].

Table 4.3. US Fatality rates per 100MVMT										
Year	Rural total	Interstate	Other arterial	Collector	Local	Urban total	Interstate	Other arterial	Collector	Local
1980	4.4	1.68	4.67	5.28	5.91	2.52	1.35	2.63	2.68	3.46
1985	3.35	1.39	3.51	3.97	4.84	1.85	0.94	2.17	1.89	1.93
1990	2.97	1.35	2.99	3.68	4.45	1.47	0.81	1.68	1.34	1.78
1995	2.57	1.2	2.7	3.13	3.76	1.2	0.63	1.34	1.14	1.62
2000	2.21	1.21	2.14	2.74	3.47	0.95	0.61	1.06	0.74	1.24
2005	2.36	1.27	2.35	2.95	3.45	0.95	0.58	1.04	0.84	1.31
2010	1.83	0.86	1.86	2.32	2.67	0.74	0.44	0.8	0.59	1.1
2011	1.81	0.81	1.89	2.27	2.67	0.74	0.45	0.79	0.64	1.09
2012	1.86	0.75	2.07	2.26	2.65	0.77	0.44	0.83	0.69	1.16
2013	1.87	0.85	2.07	2.15	2.73	0.74	0.42	0.81	0.59	1.15
2014	1.81	0.76	2.07	2.16	2.4	0.75	0.45	0.84	0.59	1.06
2015	1.84	0.81	2.37	2.07	1.85	0.71	0.45	0.85	0.58	0.71

Adapted from calculations by the US DOT, Bureau of Transportation Statistics [44].

The affected system for this research is the Rural-Other Arterial system. As illustrated in Table 4.3 the rural rates have become 2.4 times safer over the past thirty-five years and 5.6 times in urban areas. The rural rate, however represent the best view of rural circumstances, with multilane interstate systems. As of 2015, Fatality rates per 100MVMT was 2.6 times higher for rural road systems; with the affected systems at 3.3 times higher rates, when compared to the same mileage in urban areas.

The adaptation mentioned in Table 4.3 was performed in an effort to reduce a multi-sheet data table to pertinent transit system type data. The initial report divided the transportation routes into a more granular look to illustrate exact transportation route type. Given the referenced three state HWY system meets the rural-other arterial definition, which is the focus of the net highway system length. The driving purpose of tables 4.2 and 4.3 is to illustrate that the 386 miles of referenced HWY represents a very small percentage of the total freeway system and as such can experience significant statistical shifts in performance over the 100MVMT denominator. Translating Table 4.3 into vehicle type for comparison of the more than 35,000 collision fatalities in 2015, forty-nine came from the bus subset of commercial vehicles, Table 4.4. This approximates to just over 0.001% of all fatalities attributable to bus systems and almost one-third coming from POV's.

Table 4.4 is particularly pertinent when comparing the bus subset of commercial vehicles, CMV's, and POV's. In 2015, Buses represented 0.005% of the total CMV fatality category, which represents 29.9% of the total traffic fatalities. The real message in this table is that the probability of being in a fatal accident as the perpetrator or victim when using a bus approximates to 0.001 of the total accidents, a very low number. The secondary implication from this table and the data in Table 4.2 and 4.5 is that fatality related bus incidents are very rare. I had assumed this was due to buses being heavier and thus not leaving the road or due to CDL training and maintenance requirements. What I discovered, from the work of Kordani, Rahmani, Nasiri, and Boroomandrad (2018) is that despite the weather condition and resulted friction coefficient, bus breaking and stability was at most the best of the average sedan, and at worst, double that of an average sedan (snowy conditions) [48]. So if Sedans have higher safety performance, then why do they have such a greater share of total fatalities versus CMV's and Buses? What I have determined is that the training required to achieve and maintain a CDL coupled with the high consequence (loss of employment) of error and the added training an employer requires to convey high value goods and personnel, better prepare CMV and bus drivers for abhorrent conditions.

Table 4.4. US Fatalities by Vehicle Type for Occupant and Non-occupant					
Year	Total traffic fatalities	Net occupant fatalities (by vehicle type)	Passenger car total	Truck Commercial Motor Vehicle (CMV) total	Bus subset of CMV
1975	44,525	35,925	25,929	5,817	53
1980	51,091	41,927	27,449	8,748	46
1985	43,825	36,043	23,212	7,666	57
1990	44,599	37,134	24,092	9,306	32
1995	41,817	35,291	22,423	10,216	33
2000	41,945	36,348	20,699	12,280	22
2005	43,510	37,646	18,512	13,841	58
2010	32,999	27,889	12,491	10,312	44
2011	32,479	27,140	12,014	9,942	55
2012	33,782	28,003	12,361	10,115	39
2013	32,893	27,175	12,037	(R) 9,881	54
2014	32,744	26,901	11,947	9,759	44
2015	35,092	28,671	12,628	10,480	49

All categories except passenger car fatalities by vehicle type: 1975-08 [45] [46], passenger car fatalities by vehicle type [47].

Table 4.5. US Select HWY Traffic Fatalities and Rate Data: 2000 & 2016									
	Fatalities		Bus Subset (2000)		Fatality Rate per			Fatalities on Target HWYs	
State	2000	2016	Incident	Fatality	100K licensed drivers (2000)	100MVMT (2000)	100MVMT (2016)	2000	2016
Idaho	276	214	6	0	31.2	2	1.34	1	0
Nevada	323	262	707	0	23.6	1.8	1.06	2	1
New Mexico	430	310	49	0	34.7	1.9	1.24	0	1
Massachusetts (Low)	433				9.6	0.8			
Mississippi (High)	949				47.3	2.7			
US Total (1,000)	41.8	32.7	23.2	93.0	21.9	1.5	1.09		

Adapted from Table 2-1-1, 2-13, 2-14, and 2-15 of Transportation Profile; US DOT Bureau of Transportation Statistics (BTS): 2000 & 2016, HWY Traffic Fatalities and Fatality Rates [49] [50]

Table 4.5 is a composite table of select state data from the DOT traffic incident tables for the 2000 and 2016 year reports. The data selected was in an effort to reduce the unneeded detail from the six total tables referenced to the detail pertinent to this study. The primary purpose of the table is to show that net fatalities and total fatality rates have decreased between the years 2000 and 2016. Both reports use the same table titling, thus helping to pull data from the mentioned tables from each of the two reports. I selected the national high and low states based on the 2000 report 100MVMT statistics for perspective when looking at the three target states; the three target states have very similar 100MVMT performance and are mid-line between the national high and low. I used the more comprehensive 2000 year tables showing volume of licensed drivers, fatalities recorded using buses versus looking at all fatalities in all vehicle types. I also selected data from both 2000 and 2016 to illustrate fatalities experienced on the target 386 HWY miles.

From the DOT Transportation Profile composite for 2000 and 2016 (Table 4.5) illustrates there is statistically no difference between on or off duty behavior, and as such the recorded rate on a roadway should be considered the normalized rate, with the single exception of non-commute and recreational transportation. General results are used for on duty commutes. Table 4.5 clearly shows the three state regions trending to more safe, consistent with that experienced elsewhere in the US.

From targeted data in Figure 4.2, from the three state regions for months of impact for fatalities, of the 800 recorded fatalities, February, April, and November represent the lowest fatalities and the summer months represent half of the annual fatalities.

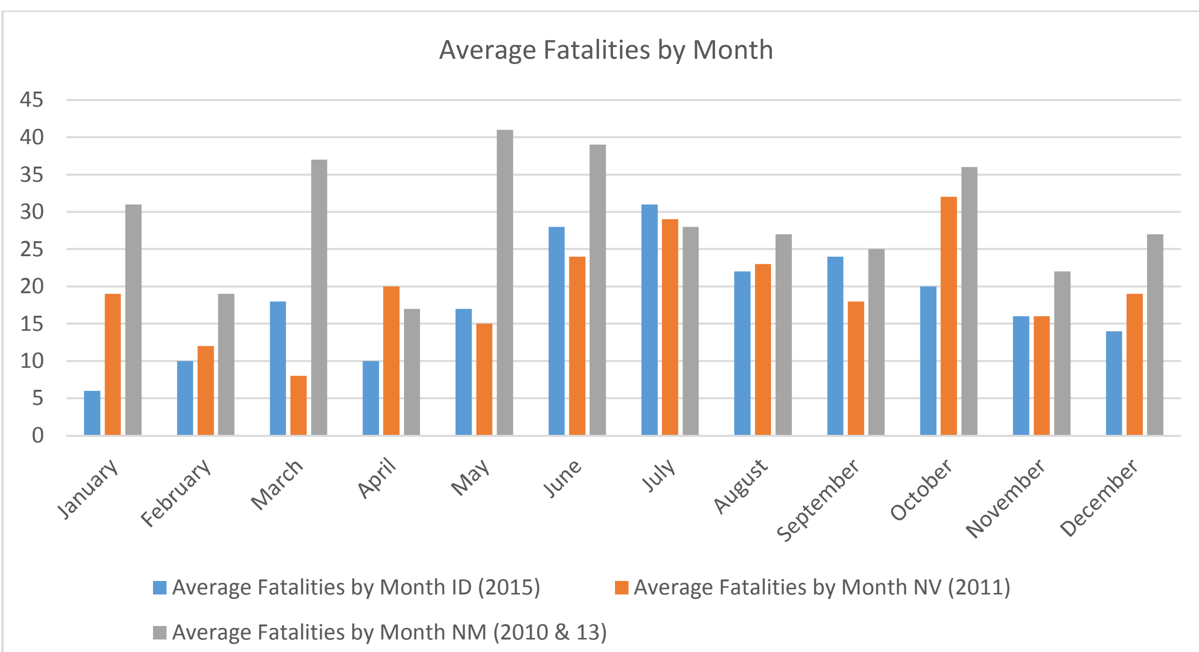

Figure 4.2: US Average Fatalities by Month; adapted from [49] [50].

Driver inattention, excessive speed, and intoxication are the three most commonly referenced factors associated with a traffic fatality; weather issues such as fog, snow, or icy conditions rank very low in the typical traffic fatality. Comparing data from Table 4.6, almost 30% of all fatalities result from high blood alcohol content. Time of day was not a factor in traffic fatalities, except for limited cases of AVC, where dusk, dawn, and various weather conditions have been shown to increase risk of AVC.

Table 4.6. US Fatalities in Motor Vehicle Crashes Involving High Blood Alcohol Concentration

State	2012 Total fatalities	2012 fatalities involving high BAC	2012 Percent	2013 Total fatalities	2013 Fatalities involving high BAC	2013 Percent
Idaho	184	54	29.3	214	58	27
Nevada	258	82	31.8	262	79	30
New Mexico	365	97	26.6	310	93	30
US, total	33,561	10,322	30.8	32,719	10,076	31

High BAC ≥ 0.08 grams per deciliter [51].

Table 4.7. US Estimated Economic Costs for Human Injuries and Fatalities

Maximum Human Severity	Average Cost of All Injuries/ Fatalities	Distribution % of All Collisions	Distribution % of Human Incident Accidents	Contribution Cost to Average Human Incident Accident
Possible Injury	$ 24,418	2.34%	50.87%	$ 12,421
Evident Injury	$ 46,266	1.75%	38.04%	$ 17,601
Incapacitating Injury	$ 231,332	0.47%	10.22%	$ 23,636
Fatality	$ 3,341,468	0.04%	0.87%	$ 29,056
Totals		4.60%	100.00%	$ 82,715

Table 4.7 reveals the average cost of a fatality at more than $3.3 million, with the average of all injuries and fatalities costs for injury or fatality causing accidents at approximately $83,000 [52]. Using data from Pynn and Pynn (2004) [53] coupled with the research of Conover et al. (1995) [58] to calculate the average per incident cost at $6,126 for large animals, with white-tailed deer, big horn sheep, moose, bear, elk, livestock representing largest populations causing human fatality. 91.5% of animals die in or shortly thereafter in an AVC. Human injury from AVC is estimated at 4.6%, .04% for fatalities, primarily from deer 12% and moose 6%.

AVCs now represent approximately 5 percent (or 1 in 20) of all reported motor vehicle collisions.

The largest ID and NV 2015 single-vehicle crash factor was overturn at 69.9% and 43.4% respectively. I did not consider Motorcycles, Pedestrians, or Peda-cycles as the data was sparse, inconsistently measured, and represented a very small sample of each of the respective three state fatality rates. NV has almost 40% of fatalities from people out of their state. In 2015, NM had almost 25%. 28% of NM fatalities are in the commute counties for LANL [54] [55]. NV has a disproportionately large youth driver population. New Mexican's hit three times as many animals as Nevadan's and twice as many as Idahoan's, though the numbers remain very low when compared to the more wooded states in the Eastern US.

After reviewing traffic crash data from the respective state DOT's, there is no one year where all three states have published data. I reviewed data from 2007-2016 for NV, 2009-2015 for NM, and 2011-2015 for ID. I have correlated data from overlap years to come to the conclusion developed herein. Difficult to compare disparate data from the three respective states, due to the states collecting differing data and with general reporting performed in differing years. Meta-analysis was performed where data was available for same years; when compared, the results varied by 1-3%, considered as mute. It is therefore my opinion that the 2015 ID data, 2016 NV data, and 2015 NM data can be compared as if in the same year. 2015 NV DOT data was used as available from their 2016 report.

Given the data analysis performed herein, the following key factors were used to develop a relative Fatality rate for use on a particular stretch of road and vehicle types.

- Non-intoxication-based traffic fatalities represent such a large category of traffic fatalities, the balance are those outside intoxication or 70%.
- Using INL data, 95% of total road traffic on the impacted rural transit HWYs supports Government work.
- Using known data from INL that no fatalities occurred within the bus fleet and from ICP that no fatalities occurred within the balance of the GSA Van fleet all the fatality producing accidents are from POV's. Those vehicle miles are estimated at 25 to 30 MVMT (averaged here at 27.5 MVMT) or about 21% of the 135 MVMT in the state of ID annually.
- 92% of vehicles on the affected transit HWYs are POVs

Fatality rates are typically calculated as: Fatality frequency in period per 100MVMT exposure in same period = fatalities per 100MVMT rate. Translating this would follow as:

Relative Fatality Rate (Rm) equation (4.1)

$$Rm = \frac{f * F}{v' * T}$$

Where:

- f = Non-intoxication fatality ratio
- F = Fatality frequency in period
- v' = Impacted vehicle modalities ratio
- T = 100MVMT exposure in same period

The relative fatality rate for ID on the impacted roadways is:

(0.70 X 214)/(0.92 X 135.3) = 149.8/124.5 = 1.2 fatalities per 100MVMT

What this means is that of the 100MVMT rate of 1.2, the 0.275 per 100MVMT experienced at the INL, a traffic fatality will statistically occur every 36 months. Though 1.2 is lower than the state average of 1.3, impairment issues experienced elsewhere can account for the reduction. In ID, approximately 59% of DOE supporting commuting employees use the INL bus system. If the balance of employees were to also ride the bus, 55 more buses would be needed and approximately 1150 POV's would be removed from the road. Another way of looking at this, today there are more than 100 miles of flowing traffic if posted speeds and safe following distances are adhered to, this would be reduced to 14.5 miles - A 6.8X reduction in compaction. Translating that back to the fatality rate, the current rate of 1.2 would be reduced to 0.18 or one statistical fatality every 20 years 5 months.

Another view of the bus versus POV equation is that the state of ID experienced 22,347 (2013) traffic crashes. Approximately 5% of those involve a human injury, estimated at $83K per incident on average. INL purpose miles represent 21% of the State's vehicle miles traveled. Which means an approximate 720 injury per fatality accidents will occur on the INL supporting transit HWYs, and 80% of those in support of INL business. This translates to $47.8 million will be spent on these traffic accidents. Four injury accidents occurred from the combined GSA buses and van fleets, yet they convey 59% of the personnel. This is an exposure of about $330K, less than 1% of the balance of the net exposure. Even if the entire population used the buses as the commute source, the statistically plausible economic costs approximate to less than $600K, approximately 1% of the current exposure.

Table 4.8 reflects the recorded 2016 mortality rates for the respective three states and shows the results of the relative fatality ranking per transportation type.

Table 4.8. State Fatality Rates and Associated Relative Rates by Vehicle Type (VT)

State Rate		Highway Specific Rate				
	All Vehicle Types[1]	Bus	Van	POV	Avg for State	SD for State
ID	1.34	0.30	1.20	1.30	0.93	0.43
NV	1.06	0.30	1.05	0.90	0.75	0.31
NM	1.24	N/A	1.16	1.24	1.20	0.04
Avg for VT	1.21	0.30	1.14	1.15	0.96	
SD for VT	0.12	0.00	0.06	0.18		

1. Table 4.5, 2016 figures for State Rates

Eliminating the bus service in lieu of POV's moves the economic, fatality, and density issues sharply in a more damaging direction. Based on this information, it is my strong opinion that the bus service in place at INL today represents a high-value proposition for commuters and the DOE indirectly through enhanced productivity and lower media exposure and mortality related expense due to impacting factors. This result is further detailed in Chapter 5.

A final note on mortality is that using known fatality rates per 100MVMT, if buses were filled and used exclusively in the ID INL commute, statistics reveal it would be approximately 20 years 4 months between fatality causing accidents, correlating to 1,700 years between fatalities per user (less than 3 chances in a million). This theorizes a fatality to such a small probability in a person's working and associated commuting career to be deemed as a fatality being considered the improbable event; yet POV's if exclusively used at average density will experience a fatality every other year. With Fatalities averaging at more than $3.3M each, buses are economically superior to personal vehicles by almost 850 times more. So for every bus fatality, there will be approximately 850 POV fatalities at an estimated cost of $2.8B on un-expended monies from reduced fatalities alone.

Table 4.9. Modality - Comparative Sensitivity Data Table										
Transit Type (Modality)	Occupant Load	Units (Est)	Daily Miles (1,000)	Daily Cost (IRS & GSA, $1,000)	Avg Gal used (1,000)	Traffic Density Ratio	Net Miles [1]	People per mile	Mortality (5 yr rate per 100MVMT)[2, 3]	Months between Fatality (Avg-Est)
POV's Avg	1.4	1,680	163	$ 89	7.4	1	70	68	2.542	24
POV High-Density	3.0	1,200	116	$ 63	5.3	1	50	96	1.816	33
POV/Van Low-Density	1.0	4,800	465	$ 254	21.2	1	201	24	7.263	8
Bus Avg	36.0	133	17	$ 124	0.8	0.5	11	420	0.004	13,500
Bus Max	54.0	89	11	$ 83	0.5	0.5	8	629	0.003	20,250
Van High-Density	7.0	686	67	$ 36	3.0	1	29	167	1.038	58
Van Avg	5.0	960	93	$ 51	4.2	1	40	119	1.453	41
Modality Average	15.5	1,364	133	$ 100	6.1	1	58	218	2.017	4,845

1. Net miles of road consumed one way by the modality count at posted speeds and recommended safe following distances [54].
2. Adapted from actuals and national data for POV or Van from 1.3 to 1.2 per 100MVMT [56].
3. Buses rates adapted from National rates for transit buses (2000) of 0.3 per 100MVMT [56].

Wildlife Impacts

AVCs are a serious safety risk for animals. In most cases, an animal that has been hit by a vehicle dies immediately or shortly after a collision. Conover et al. (1995) identified 21 federally-listed threatened and endangered species in the US for which road mortality from AVC is among the major threats to the survival of the species [58]. Of those studied none are commonly struck animals in the three state biome. Deer, Elk, Moose, Bear, livestock, other smaller animal (i.e. coyote, birds, rabbits) and the common impacting animal, though Deer represent between 54.4% and 81.2% of AVC nationally.

Collisions with large animals pose a safety risk to humans as well as wildlife. Based on research from various states, roughly four to ten percent of reported AVCs involving large animals result in injuries to drivers and their passengers. While this may not appear to be a large percentage, this translates into approximately 26,000 injuries per year that are attributable to these accidents. Only a very small proportion of crashes with large animals result in human fatalities. Nonetheless, an estimated 200 people die from AVCs in the US every year. From 2001 to 2005, an average of 38,493 fatal crashes occurred. Hence AVCs represent roughly 0.5 percent of fatal crashes [47]. There are an estimated one to two million collisions between cars and large animals every year in the US [52]. This presents a real danger to human safety as well as wildlife survival. State and local transportation agencies are looking for ways to meet the needs of the traveling public, maintain human safety, and conserve wildlife. AVCs have significant impacts on drivers and wildlife, often killing the animal.

According to data from national crash databases, 89% of all AVCs (2001–2005) were on two-lane roads. This might lead some people to conclude that AVCs are only a problem in remote, rural locations, though two-lane roads and AVCs are prevalent in areas where many people live and commute to work. Such two-lane HWYs are critical travel corridors, and, in the US, drivers use two-lane roadways for the majority of the total HWY miles they travel. These are the same descriptions used for HWY travel between the three DOE remote sites and their surrounding communities.

The US National Crash Database estimate the total number of reported collisions at 300,000 per year; however, most researchers believe that AVCs are substantially under-reported for a number of reasons [52]. Crash databases typically exclude accidents that have less than $1,000 in property damage, not all drivers report collisions with animals, and not all law enforcement, natural resource, or transportation agencies have the resources to collect detailed information on AVCs. Furthermore, many animals that are injured wander away from the road before they die and are never found. Study data was developed using a combination of carcass count data, insurance industry information, police-reported crashes, and interviews with the public [52]. Almost all AVCs resulted in no human injury (95.4%); though collisions with moose and other large animals can have a higher likelihood of resulting in harm to the vehicle occupant.

The occurrence of AVCs, is associated with many factors; more than 98% of AVCs are single-vehicle crashes. 89% of AVCs occur on two-lane roads, frequently on low-volume roads. Compared to all motor vehicle collisions, AVCs occur more frequently on straight roads with dry road surfaces and more frequently in the early morning (5 a.m. to 9 a.m.) and evening (4 p.m. to 12 a.m.), when deer and other large game are more active and traffic volume is relatively high, and in spring and especially in fall, when animals move around more due to migration, mating, or hunting seasons. The vast majority (as high as 90 percent in some states) of reported AVCs involve deer (White-tailed deer-vehicle collisions are associated with diverse landscapes with abundant edge habitat (transitions from cover to more open habitat) and riparian habitat. One estimate of the total annual cost associated with AVCs, based on available data, is calculated to be $8.4B [52] [53]. Collisions with deer constitute the single largest collision category involving human and vehicle accident costs.

Table 4.10. US Animal Vehicle Collisions (Select HSIS[1] State Data)

State	AVC	All Collisions	AVC (%)
California	5,580	890,215	0.63%
Utah	12,449	240,381	5.18%
Washington	5,606	207,133	2.71%

Five-year Crash Totals [59].

1. The HWY Safety Information System (HSIS), is a dataset that includes all reported crashes from Washington, California, Illinois, Maine, Michigan, Minnesota, North Carolina, Ohio, and Utah.

The total National number of AVCs is increasing at a rate of approximately 6,800 more AVCs per year. Deer populations have also continued to increase in many areas within the US. AVCs are more common on rural, two-lane, low-flow, high-speed roadways, during early morning and late evening hours, within spring and fall months, and in locations with high wildlife populations, especially deer (mule deer and white-tailed deer combined). Additional contributing factors include areas with many transitions from cover to more open habitat, riparian habitat, shrub land (for white-tailed deer) and large drainages and known seasonal migration corridors (for mule deer) and near forested cover and drainages. As a final note, AVC's primarily occur on dry, straight roadways are primarily as single-vehicle collisions. Each of the three states in this study experience traffic flow dominance in the direction of the respective morning and evening commute routes. Availability of consistent and detailed AVC data within the national crash database is limited, and the data points and sets do not always distinguish between species or species groups and the data suffer from severe underreporting. Furthermore, reliable AVC data for small or medium size species or threatened or endangered species do not exist on a national level [56] [57] [70] [71].

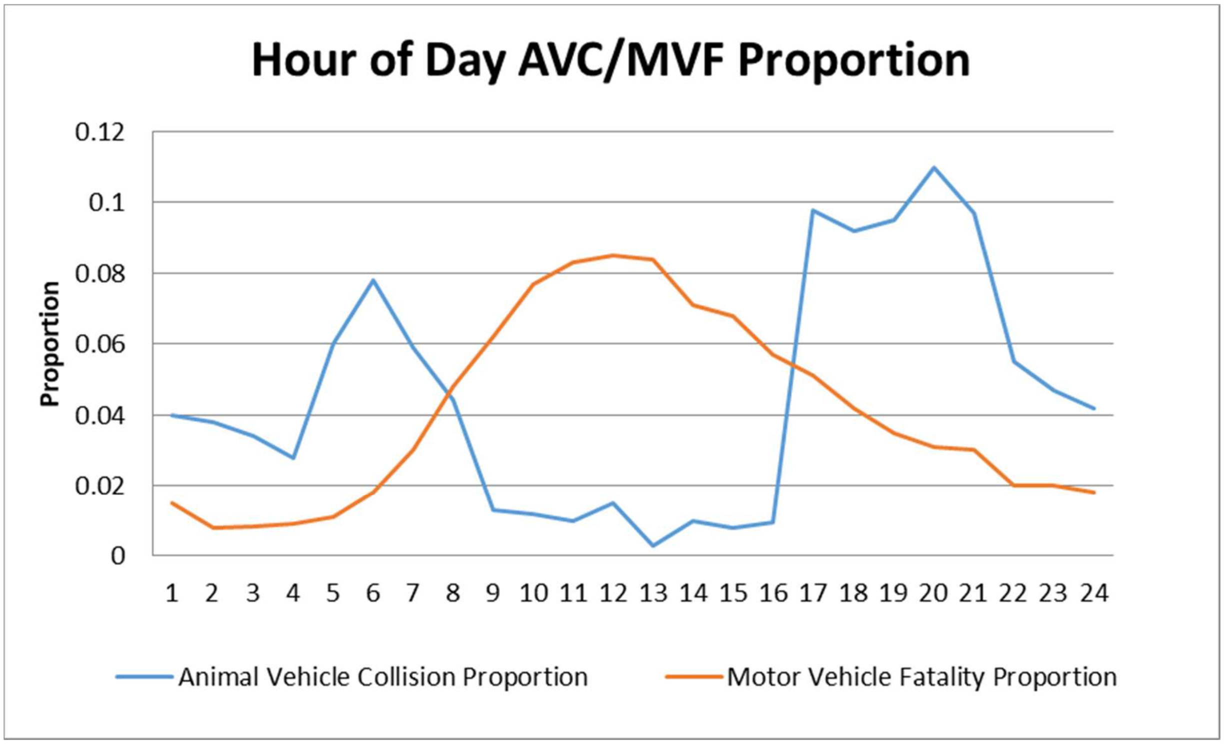

Figure 4.3. US Adapted Statistics from the National Crash Database, for HSIS States [59].

Abbreviated Environmental Impact Assessment

For this study, Environmental impact is comprised of GHG emissions and global warming potential, and habitat impact for wildlife. GHG emissions and global warming potential as shown in the research are reduced by the use of alternative fuels. The fuels used by the two bus transit companies are Liquefied Natural Gas (LNG) and B20. The rate of biofuel usage in POV's and commuter Vans is at best ethanol 85% blend (e85), and the bus systems are using B20 (INL) and LNG and B20 (NNSS). B20 and LNG have been shown to be less environmentally impacting than e85 and as such, bus systems using B20 and LNG are environmentally superior to conventional fuels; though B20 is environmentally superior to LNG and LNG blends [57]. Data from Tables 2.1, 2.2, and 2.3 clearly illustrate reductions in GHG emissions when biofuel is in use.

Based primarily on DOT wildlife collision data and ID State Fish and Game - state harvest numbers for big game (deer), Deer are one thousand times more likely to be killed by a hunter than a vehicle and more than one hundred times more likely to be killed by exposure and starvation than to be killed by a vehicle [60]. Both NV and NM experienced similar trends, though state harvest figures are inconsistent. As such habitat division by the introduction of the transit HWY system is deemed statistically insignificant at 0.1 and 0.01% respectively. Given the data being analyzed is both generalized US Federal-level data and DOE contractor actual data, the reliability of the results is expected to be better than 80% confidence. The 20% reduction in confidence level is an educated reduction due to limited data from the NV site and accounts for a 5% error estimated by the DOT for their assumed error rate.

Sheehan et al. (1998) demonstrated a 19% reduction in petroleum use based on the use of B20 (from soy oil). The also noted significant reductions in PM of 32%, CO of 35%, and Sulfur Dioxide (SO_2) of 8%. Emissions from tailpipe CO was demonstrated at 46% lower, with the use of B100 completely eliminating SO_2 emissions. A transition from B20 to B100 demonstrated a proportional benefit at 19% and 95% respectfully. B20 CO_2 emissions dropped 15.66% when compared to petroleum [28], see Tables 2.1, 2.2, and 2.3. Biodiesel yields 3.2 units of fuel product every energy cycle with 0.98 units of fuel product energy per every fossil fuel product equivalent versus the comparable petroleum at 0.83 units. The DOE's Clean Cities reports illustrate B20 is the least costly from an energy equivalent basis at $2.73 per gallon, Table 6 [61].

Table 4.11. US Fuel Alternatives Economics (2017)

Fuel Type	October National Average ($ per gallon)	October Energy Equivalent Basis (diesel*)
Gasoline (from Petroleum)	$ 2.49	$ 2.81
Diesel * (from Petroleum)	$ 2.76	$ 2.76
Ethanol (e85; 85% ethanol blend)	$ 2.10	$ 3.08
B20 (Bio-diesel 20% blend)	$ 2.68	$ 2.73

$* \ Diesel\ Fuel\ Equivalent\ Basis =$ *BTU per gallon of diesel versus BTU per gal of alternate fuel*

Adapted from DOE Clean Cities; Alternative Fuel Price Report [62]

Proc et al. (2006) sponsored by the NREL, performed a study on the 100,000 mile evaluation of transit buses operated on B20 for two years, nine 40' identical buses, five on B20, four on petroleum-based diesel, found no difference in the in transit fuel economy at 4.41 MPG. B20 caused higher maintenance $0.07 per mile versus $0.05 per mile; but with high variability of $0.02 per mile, deeming it statistically insignificant. Out of specification and difficult to identify B20, caused some fuel filter clogging. Economics were unchanged regardless of used cooking oil and vegetable and plant products [62].

Water quality performance based buffer strips are recommended for vegetative HWY shoulders at 16’ or more by Barrett et al. (2004). The mechanisms of pollutant removal are sedimentation, absorption, infiltration into the soil, and biochemical activity on the grass and soil media. Total suspended solids reduced between 66 and 71% due to buffer strips at 16’ [30]. Dermibas et al. (2009) analyzed vegetated HWY buffer strips and noted efficiencies of buffer strips for pollutant removal had wide ranging results ranging from 98% to -7%; though water quality performance declined rapidly when the vegetative cover falls below 80% [31]; as is the case in each of the three transit systems. These results are so dispersed, that they are determined by the author as unreliable for this study, though it should be noted that in each of the three respective states, vegetation occurs in low concentration and at distances frequently exceeding the 16’ from the road edge. Using the data from both Barrett et al. and Dermibas et al. suggests that the buffer strips in place in each of the three states targeted road systems are not developed for effective pollutant removal, and as such, regardless of vehicle type used, impact is similar. Biofuel usage would support a reduction in these contaminants, as would fewer vehicles on these roadways. Other ecosystem impacts as a result of transit HWY usage were planned to be discussed, though research focused on habitat division showed impacts as statistically insignificant for decision making, based on impacts in the three state region.

Commuting

Approximately 6000 people commute to any of the seven INL desert locations. Of those an approximate 48% come from Idaho Falls, Rexburg, Rigby, and surrounding communities, 49% from Pocatello, Blackfoot, and surrounding communities. Similar counts come from the various NV commute locations, primarily from North Las Vegas and from the several New Mexican locations, primarily from Los Alamos, Santa Fe, and the Albuquerque metropolitan area. The three state target area of approximately 386 rural transit HWY miles represents a small fraction of the overall systems in these states, see Appendix C for explanatory data elements.

The US Census Bureau in a 2011 commuter survey, revealed approximately 10% of average US workers carpool for their commute and of those with commutes greater than sixty miles, a modest 30% increase to approximately 13% for carpools. In striking contrast, the study revealed of all workers, approximately 5% used a public transport modality while those with longer commutes at an average of 23%; nearly five times more [63] [64]. The average commute is INL 97 miles daily, LANL and NNSS experience similar average commutes with NNSS slightly longer and LANL slightly shorter. What should be understood though is that average commute length data is significantly skewed downward based on several smaller communities located near the respective remote sites. The bulk of commuters experience average daily commutes exceeding 100 miles. Additionally, INL uses a combination of GSA Vans, GSA Buses, and POV's, LANL uses vans in limited cases, and NNSS uses primarily outsourced buses. There are between 1300 and 1500 vehicles commuting between the INL locations and the supporting communities. This approximates to 25 to 30 MVMT to the INL site annually. INL-based travel represents nearly 90% of weekday travel on the supporting HWYs. Personal Vehicles represent 92% of commute vehicles, buses at 4.2%, and vans at 3.8%. The average POV commuter vehicle in ID carries 1.4 people, while an average bus conveys 36 people, and the average van conveys 5 people. The INL represents less than one-fourth of the total employees commuting to the three DOE sites (NNSS, LANL, and INL). Supporting this detail is another US Census Survey data from 2000, 2011, 2013, and 2016 revealing the average commute time for US workers is 19 minutes, again with most driving alone and approximately 10% carpooling.

Table 4.12 is a composite table designed to combine four tables of similar data into a common table for comparison of relative values. The 2016 versus 2000 data illustrates that while the commuter ratio of the US is decreasing, is decreasing slower and in one case increasing in the target states. This is coupled with growth in commuter time on the road. Data in the 2013 section provides an additional view of commute ratios to compliment the 2000 and 2016 data, but adds new data on the average commute time to the target national laboratories and the comparative distance to others experienced in the same state. In each of the three states, commute times are more than double. The 2011 data reveals that longer drives are linked with added carpooling and with the use of public transport. Why would a longer drive be correlated with increased public transportation? Could it be that 23% of commuters trust the CDL-bearing professionals more than themselves for longer distance drives?

In urban areas, deaths per vehicle occupants represent twice that of urban areas, with speed, increasing temperature and daylight, all increasing that probability. Approximately 55% of fatalities are during daylight hours and in rural settings. For large transportation units like buses experience 13.5% of deaths in collisions involving a fatality versus 78.4% in other vehicles [65]; making these larger vehicles 5.8 times safer per modality, and many more times safer per occupant load. Sensitivity analysis reveals buses are between 26 and 224 times safer than POV's per occupant load, on average.

<table>
<tr><td colspan="10">Table 4.12. US Census Bureau Commuter Survey Data</td></tr>
<tr><td colspan="10">2011 Data[1]</td></tr>
<tr><td>Worker Commute</td><td colspan="3">POV's</td><td colspan="4">Carpool</td><td colspan="2">Public Transport</td></tr>
<tr><td>All workers who did not work at home:</td><td colspan="3">79.90%</td><td colspan="4">10.10%</td><td colspan="2">5.30%</td></tr>
<tr><td>All workers with 60 mile or longer commute:</td><td colspan="3">61.00%</td><td colspan="4">12.90%</td><td colspan="2">23.00%</td></tr>
<tr><td colspan="10">2000 & 2016 Data[2]</td></tr>
<tr><td></td><td colspan="3">Commuter Ratio</td><td colspan="4">Average Commute Minutes (min)</td><td colspan="2">Work travel %</td></tr>
<tr><td>State</td><td>2000</td><td colspan="2">2016</td><td colspan="2">2000</td><td colspan="2">2016</td><td colspan="2"></td></tr>
<tr><td>Nevada</td><td>10.10%</td><td colspan="2">10.50%</td><td colspan="2">22.3</td><td colspan="2">27.1</td><td colspan="2">13.1%</td></tr>
<tr><td>Idaho</td><td>11.70%</td><td colspan="2">9.60%</td><td colspan="2">19.7</td><td colspan="2">33.8</td><td colspan="2">13.2%</td></tr>
<tr><td>New Mexico</td><td>12.60%</td><td colspan="2">10.50%</td><td colspan="2">20</td><td colspan="2">37.60</td><td colspan="2">12.1%</td></tr>
<tr><td>US Total</td><td>11.20%</td><td colspan="2">9.40%</td><td colspan="2">24.3</td><td colspan="2">36.1</td><td colspan="2">13.0%</td></tr>
<tr><td colspan="10">2013 Data[3]</td></tr>
<tr><td>State</td><td>Number of Workers</td><td>Drove Alone %</td><td colspan="2">Carpool %</td><td colspan="2">US mean min to Work</td><td colspan="2">Mean min to DOE Sites</td><td>Mean min DOE to US Ratio</td></tr>
<tr><td>Idaho</td><td>696,905</td><td>77.8%</td><td colspan="2">9.6%</td><td colspan="2">19</td><td colspan="2">38</td><td>2.00</td></tr>
<tr><td>Nevada</td><td>1,246,513</td><td>78.4%</td><td colspan="2">10.5%</td><td colspan="2">22.8</td><td colspan="2">49</td><td>2.15</td></tr>
<tr><td>New Mexico</td><td>865,357</td><td>79.2%</td><td colspan="2">10.5%</td><td colspan="2">20.5</td><td colspan="2">42</td><td>2.05</td></tr>
<tr><td>US, total (,000)</td><td>142,962.1</td><td>76.4%</td><td colspan="2">9.4%</td><td colspan="2">24.7</td><td colspan="2"></td><td></td></tr>
</table>

Composite data for 2000, 2011, 2013, & 2016

1. 2011 Data: US Workers Commuter Survey; adapted from US Census Bureau, 1-year American Commuter Survey [63]
2. 2000 & 2016 Data: US Commuter Survey; Adapted from US Census Bureau, American Community Survey 1-Year Data [13] [63]
3. 2013 Data: Commuting to Work; Adapted from US Census Bureau, 2013 American Community Survey [64]

Traffic density is a significant contributor to the commuting experience. Density is essentially a function of vehicle size and associated safe following distance (total length) for some distance at some speed. This length, speed, and time function is explored further in this paragraph and the associated data tables, 4.12 and 4.13. These The GSA states that a standard motor coach commercial motor vehicle (CMV-bus) is 40' long. Motor Coach International Incorporated (MCI), standard vehicle is 45.5' long [66]. For the purpose of this study, this was averaged at 42.5'. In 2007, the average lengths of compact sedans and compact sport utility vehicles in America are 177.2 inches and 172.3 inches, respectively. Medium sedans and SUVs are 10 to 20 inches longer than their compact counterparts, while large cars are longer by a further 15 to 20 inches. Modern vehicles have increased not only in length but also in width and in weight. According to a 2007 study by Edmunds.com, compact sedan cars were longer by 2 inches, wider by 2 inches, and heavier by 374 pounds on the average than they were in 1997. The trend was also accurate for medium and large cars [67]. These sizes and recommended safe following distances are illustrated in table 4.13.

The density equation used and associated example used for illustrative purposes for this research uses DOT recommendation variant as follow:

Density equation (4.2)

$$Density = \frac{M'}{L' + S'}$$

Where:

- M' = Feet per mile (5280)
- L' = Length of the vehicle in feet
- S' = Safe following distance length[1] in feet

1. Given data inputs: 1 HWY second at 65 MPH is 103 feet, for POV's the rule is 2 seconds or 206 feet and for a CMV the rule is 4 seconds or 412 feet

Density equation example:

> If a CMV is 42.5' and the safe following distance is 4 seconds at 65 MPH or 412 feet, then the vehicle density is 11.6 CMV's per mile.

The DOT states the safe driving distance ranges between 2 and 4 seconds, with time increasing by vehicle weight and speed [68]. passenger vehicles are recommended at 2 seconds for anything over 40 MPH and CMV's traveling at 65 mph (average HWY transportation speed for bus) a recommended safe following distance of 4 seconds. Speed limits on affected roads are 70 MPH for ID and NV and 65 MPH for NM. Data developed herein has been normalized at 70 MPH for all three states passenger vehicles and 65 MPH for commercial vehicles, representative of actuals. Bus loading does not consider the driver in order to normalize the data across all transportation modalities.

Other used modality factors: the current INL Bus fleet consists of daily operation of 78 GSA Buses and 70 GSA vans. The balance of commute-based vehicles (approximating between 1300 and 1500 daily) are POV's. Other supporting commercial vehicles represent approximately 5% of the balance of traffic. Analysis from Table 4.13 reveals when POV's are used over buses traffic density doubles and then doubles again based on decreased following distance, or compaction. This is independent of occupant load. Using max bus and minimal POV's occupant loading amplifies safety and environmental performance over POV's by 26 times, 13 times if using average loading. With fuel type and quantity used as primary factors to calculate environmental impact, busing would be 50 times more superior per occupant load, on average. Cost of ownership considerations show busing at 5 times superior in fuel expenditures per average occupant load than fully loaded GSA vans, and 26 times more than POV's.

Table 4.13. Select Transportation Modality Data

Modality Type	CMV-Bus[5]	POV 1[1]	POV 2[2]	Van 1[3]	Van 2[4]
Occupant s per modality	36	1	3	5	8
Length of modality (ft)	42.5	14.5	14.5	17	19
MPH-Hwy	65	70	70	70	70
Safe following distance (sec)	4	2	2	2	2
Safe following distance (ft)	411	205	205	205	205
Net length (ft)	453	220	220	222	224
Compaction modality per mile	12	24	24	24	24
Road compaction (people per occupied mile)	419	24	72	119	188
Miles Occupied (Assume 100% loading) - INL	14.30	249.81	83.27	50.53	31.87
Normalization Factor	1.00	0.06	0.17	0.28	0.45
Average MPG	6	24	23	21	17
Average Gallons used per mile traveled per occupant	0.0046	0.0454	0.0151	0.0090	0.0056

1. Privately Owned Vehicle (POV) 1: 1 occupant Midsized, average economy
2. POV 2: 4 occupants version of POV 1
3. Van 1: Full size or minivan; assumed 5 occupants
4. Van 2: Full size 8 occupant van;
5. CMV-Bus: 55 passenger and 1 professional driver

The research boundary is entirely within the DOE three remote laboratory sites and their current bus use profile (for in use or potential) as detailed in Chapter 1. The road condition index for the three state region is better than the average for the nation. Additionally, the roads are typically flat and have reduced vegetation, with all three states having higher than average clear skies. Given the road condition indices for the three state region indicating conditions above the national average, road conditions are not be considered as a significant factor affecting safety or environmental impact factors.

Weather

Note to Weather section: ID, NV, and NM are near each other within the US, and on a global scale, they are in the same spot both in elevation and in proximate location, and as such ID data will roughly reflect those experienced within the other geographies considered.

Though weather related traffic slow-down was deemed the most impactful factor to commuters, it was found to be an insignificant factor pertinent to injury prevention, mortality, and environmental impact. AVCs are more likely to occur in dry weather, perhaps due to the fact that animals are less likely to move around during inclement weather. Carbaugh (1970) [69], found there were fewer deer sightings during precipitation. Ninety-five percent of fatal AVCs occurred during clear weather compared to 88 percent of all crashes. The proportion of accidents in clear weather is similar for GES (92 percent AVC and 85 percent all) and HSIS (92 percent of AVCs 83 percent of all). 91.7% of all AVC occur on two lane roads. These results reinforce those of other research that show collisions with large animals typically occur on straight, dry roads performed by Williams and Wells (2004) [70].

National Oceanic and Atmospheric Administration (NOAA) weather data illustrates all three biomes at similar temperatures with deviation in highs and lows at approximately 20 degrees from three proximate metropolitan areas adjacent the DOE remote sites, with all three states experiencing annual lows and highs (in degrees F) in January and July, respectively; Albuquerque, NM at 47 and 90, Las Vegas, NV at 58 and 104, and ID at 33 and 87, respectively [71].

Formula Development

Using a formulaic approach to illustrate an economic comparison has proven difficult due to location specific considerations, such as net operating costs, commuter volume, and distance. One approach I considered is outlines in the following formula 4.3 and Table 4.14. What I have found is that the costs of mortality coupled with the costs of operating can be captured in the in the Total Cost of Operating (TCO) equation:

Total Cost of Operating equation (4.3)

$TCO = M + O$

(a) Mortality Cost equation:

$$M = \frac{D * Rm * C2}{10^8 * Rr}$$

(b) Operating Cost equation:

$$O = \frac{D * U * C1}{(1 + Rf) * Rr}$$

Where:

- C1 = Cost of Operations Constant (per mile) (larger of IRS or calculation from actuals rate)
- C2 = Cost of Fatality (Calculated cost of fatality – see Table 4.8)
- D = Distance Constant (days driven + average experienced mileage)
- U = Transportation Units (Average of known or sampled units)
- Rr = Ridership (transportation unit loading)
- Rf = Fuel Variant Ratio (bio-fuel variant blend)
- Rm = Fatality Rate (Fatality rate per 100MVMT – see Table 4.7 and equation 4.1)

Using the data from these two formulas, calculating the TCO is possible, though problematic without significant context explaining what is and what is not associated with a formula like the one developed. Table 4.14 illustrates the net cost per user using the outlined formulas for TCO = M + O:

Table 4.14. Formulaic Result for Total Cost of Operating per Person					
	Van	POV (Std)	POV (Alt)	Bus	Bus (Alt)
C1[1]	$ 1.55	$ 0.54	$ 0.54	$ 6.90	$ 6.90
U	80	1500	1500	78	78
D	22,770	22,770	22,770	22,770	22,770
Rr	5	1.4	3	36	47
Rf	0.15	1	0.15	0.2	1
Rm[2, 3]	1.14	1.15	1.15	0.3	0.3
C2[4]	$ 3,341,468	$ 3,341,468	$ 3,341,468	$ 3,341,468	$ 3,341,468
M=	$ 173	$ 625	$ 292	$ 6	$ 5
O=	$ 6,138	$ 4,391	$ 3,564	$ 3,637	$ 1,671
TCO	$ 6,311	$ 5,016	$ 3,856	$ 3,643	$ 1,676

1. Bus per mile rates are a function of net costs divided by net miles
2. See Table 4.8 for state specific mortality rates by modality
3. Rates applied are average rates
4. See Table 4.7 for economic factors by accident type

The primary challenge with a formulaic approach is developing the values, many of which require direct observation and location specific knowledge, for instance;

- Finding the ridership rate, required me performing actual observation and dividing known personnel by observed POV's, GSA Vans, and INL Buses
- Developing the Relative Mortality Rates required data mining of the region to determine deviations from generalized and reported data with calculated roadway-specific mortality data and causal elements (i.e. rate of DWI's)

Added challenges are in the interpretation of the data; the Table 4.14 TCO results are the calculable economic factors and suggest based on the numbers alone that Van fleets are the most costly and fully loaded buses are superior. While this is partially true, key qualitative elements are needed to have a more complete result. One should interpret the result as the TCO value plus non-economic beneficial factors of retention, productivity, achieve EO mandates, environmental friendliness, and key value reinforcement (i.e. safety). The reason these qualitative Factors matter is that they have implied socioeconomic impact. For instance, (1) what is the economic potential from avoidance of environmental fines or negative publicity? (2) What is the assumed or real value of having the workforce arrive on time and rested? And

(3) what is the cost from loss of retention? These factors matter, and though difficult to develop fully into economic terms, they bear discussion, particularly if results are similar, as in Table 4.14 POV Alt & Bus. While there is value in normalizing factors into economic format, it simplifies the decision without context. A qualitative ranking allows for the data within a formulaic perspective to be shown with context, as in Table 5.1.

INL Transportation Research – Current State

This section focuses on added research performed by the INL bus element (Mission Support) and is not designed to outline transportation subcomponents being researched by other INL organizations. It is being conducted in concert with but independent of this research in four key areas consistent with the same corporate social responsibility focus areas of safety and environmental stewardship, as follows:

1. No Idle Bus – Solar panels affixed to the top of the bus provide power and battery storage capacity to maintain the comfort and safety systems of the bus without the expenditure of fuels and associated GHG emissions. This is consistent with the several environmental enhancements EOs placed on transportation systems in 2000.
2. Micro-Climate Data – INL transportation experts conduct road scout transits to and from the various INL site locations multiple times daily to collect data to inform the real time modeling of micro-climate data for the International Business Machines (IBM)/Watson modeling capabilities. This in-process modeling capability has significant international impact to better understand and predict weather patterns and anomalous conditions.
3. Fuel Conservation – INL provides user communities with a transportation simulator designed to inform behaviors associated with fuel conservation.
4. Emergency Response – due to the remote nature and location of the INL site from the employee communities, the INL has deployed an active tracking system (ZONAR) on the buses in order to better monitor bus performance and safety in a real time fashion. More importantly though, the system collects rider specific information such that at any point in transit-time a passenger can be located. This is particularly beneficial when locating personnel relative to emergency response and due to inclement weather.

The aforementioned research is unique and aligns well with the respective missions of the INL and DOE. It is this research context that supported the off-nominal research found in this study.

Summary of Data Presented

In summary, the data and associated analysis provide a robust transportation-type ranking, supported by publically available data. The mixed-methods approach to this research provided a flexible framework supporting several composite and adapted tables from journal and US Federal Department data. This data and analysis will be reliable for the target audience of this research and can be repeated if needed. One significant analytical hurdle occurred once the proposal for this work was accepted, many more sources were needed to collect and develop the analytic framework, and even more sources to validate the analytic results. The benefit of this unanticipated hurdle is that each of the key data factors stems from multiple sources for validation of accuracy. The following chapter will present the notional results as specific detail, referring back to this chapter as appropriate.

CHAPTER 5: SUMMARY OF FINDINGS, CONCLUSIONS, AND IMPLICATIONS

Introduction

This Chapter focuses on the development of a recommendation that can be duplicated by an independent third party and in terms and associated context, where decision makers can best understand a more comprehensive impact of developing, retaining, modifying, or eliminating any or all parts of the existing three laboratory mass transit system. Initial anecdotal data assumed as fact in years of previous discussion and economic analysis how have detail and fact to back up the claims for an assumed reduced negative biological impact from use of biofuels, the mortality and injury assumptions based on a bus being larger than a typical vehicle, and assumed economic benefit to the user, based on a heavily subsidized service.

Overview and Summary of the Study

The significance of this study is to provide a comprehensive, scientifically founded recommendation producing an integrated view of the DOE mass transit potential; specifically to provide a recommendation for the development, retention, modification, or termination of the DOE-supported bus service, currently in operation. The economic boundaries are the significant budget, affecting thousands of users, seven rural transit HWYs, and hundreds of direct support employees, at the three remote DOE laboratories as previously identified. The results will enable decision makers to make more complete decisions regarding the future use of the program. The evaluation criteria for a best value service for the Government is identified for this study as the greatest human safety optimized for least environmental impact with best use of funds as an influencing consideration.

Findings

Chapter 4 analytics provide the following key results:

- Safety is enhanced through the use of professional driver, increased vehicle size, and reduced traffic density. The data revealed that the commute corridors used by the three contractor populations are the safest in each of their respective states and are among the top safe rural transit corridors in the Nation. Mortality and fatality factors significantly improve through larger, crash and animal resistant vehicles.

- Environmental impact is sharply reduced by using fewer vehicles and biological based fuels. Additionally, due to the vegetation type and sparse density along the corridors; potential impact from divided habitat was found to be statistically insignificant, for large game animals.
- Economic factors support the use of mass transit on the basis of net costs to the affected populations and the Government; though due to the heavily subsidized cost of the several mass transit systems, they are a cost shift from the beneficial user to the Government. As a taxpayer, net reduced costs occur more significantly with the use of mass transit.
- While the formulaic view provides for a more comprehensive decision basis than does a purely economic based decision, this view presents weaknesses in context and background needed to make significant and defendable policy decisions.

A key result of this study is that traffic density per occupant mile was found to be so overwhelmingly dominant, that all other factors studied provided only minor shifts in results, and in only one case did the results change from those expressed here. The test was based on the question, what is the minimal bus loading needed to compete with a POV fully loaded? The loading was so low at around 15% that the service would never have been entered into, and as such, though the result is real, the likelihood is so remote that it must be ruled out as a factor, leaving buses as the highest density vehicle in the study ranking number one over fully loaded commute vans and similar POV, in that order for each category studied.

Perhaps the most enlightening result from the data analysis is the evolution and validation of an assumed optimization formula for superior transportation selection. Added factors that affected my ability to develop a comprehensive formula is in implied connection between cause and effect. For instance vehicle type selection assumes primacy of modality due to (1) a high density conveyance (2) using an environmentally friendly fuel (3) recorded, lower than normal mortality rates (as a comparison of total cost of the service including cost of fatalities against other types), (4) requirement of professional driving standards and certification, and (5) employment-level consequence for error, as the ‘best’ conveyance. Nuances such as who is paying the bill for service or exact fuel variant used play a role in this outcome, but a smaller one. Another significant discovery is that it’s not the size or weight of a bus that makes it safer for both occupant and non-occupant interaction, it’s the driver. What is significant about this is the assumption that drivers can be trained to be better, safer drivers, independent of vehicle type. The big psycho-social concern with this assumption is that the previous 50 – 60 years of data, suggest that even with enhanced vehicle design and active safety factors, without significant consequence or other personal interest, people will not drive safer or adopt safety based driving behaviors, despite the higher risk of the ultimate consequence, death.

Findings for the research herein were developed on the basis of superior performance ranking, based on modality (transit type) as shown in Table 5.1. Table 5.1 shows three primary divisions for ranking. It is my opinion that safety represents 50% of the decision weight based on the close tie to the organizations mission, the heavy reliance on personnel, and the desire to avoid non-praiseworthy media attention. My opinion is that while environmental impact has value equal to economics, in the case of this study, the environmental impact regardless of transportation type is very low, for a variety of factors; therefore the weight of environmental impact to the decision is scored at 15%. The final 35% of the decision is provided for best economic value. While my experience is that decision makers employ decisions based largely on economic factors only, it is my opinion that the beta error of a higher safety option being replaced by a lower safety option and something going wrong, results in an overwhelming impact that will out way any realized economic benefit.

Table 5.1 Notes: Based on superiority of buses over other transit types, and relative superiority of non-mass transit types as a function of occupant loading, ID and NV rank highest in overall value. NV uses a subcontracted resource and ID uses a Government provided service. Though NM has a limited busing and shuttle service using CMVs and professional drivers, there service is not for general employee commuting, and as such is ranked third overall. Bus-POV breakeven; breakeven occupant loading for Bus compared with average POV loading results vary, as the factors considered vary. Economic comparison is primarily a function of MPG, safety is a function of loading, weight, the use of a professional driver (found within the bus systems and vans functioning as a employee-provided shuttle), and environmental performance is a function of fuel used and recorded mortality rates. Anecdotally; production timeliness is optimized when employees show up at the same time, and employee rest is improved when not driving.

Table 5.1. Modality Performance Ranking														
		Highest Safety per Occupant Load (50%)					Lowest Environmental Impact (15%)				Best Economic Value (35%)			
Transportation Type	Occupant Count	Best Occupant Loading	Lowest Traffic Overall Density	Lowest Mortality - Relative Fatality Rate	Lowest BAC Accident Rate	Weather Controlled Impact[2]	Lowest Flora Impact (Fuel Type Used)[3]	Lowest AVC Rates[4]	EO Compliance[5]	Fuel System (in-use) Performance	Best Value for Citizens	Best Financial Value for the Government[6]	Best Financial Value for the Government[7]	Best Road Condition per Traffic Density per Occupant[8]
Bus Maximum Loading	55	1	1	1	1	1	1	1	1	1	1	3	1	1
Bus Average Loading	36	2	2	2	1	1	2	1	1	1	1	4	2	2
Van Maximum Loading	8	3	3	3	1	2	3	2	1	2	2	2	2	2
Van Average Loading[1]	5	4	4	4	2	3	4	3	2	3	3	3	3	3
POV Maximum Loading	3	5	5	5	3	3	5	3	7	2	4	1	4	4
POV Average Loading	1.4	6	6	6	3	4	6	3	7	3	5	1	5	5
POV Minimum Loading	1	7	7	7	3	4	7	3	7	3	6	1	6	5

1. BAC value assigned personally operated vans are included with POV's for recorded BAC violations
2. Impact felt primary in the form of slowdown and non-accident, single vehicle slide-off
3. Values can shift between Van and POV ranking as alternative fuels are used
4. Calculated rate as specific data was unavailable
5. POV's do not apply as occupant loads are too small to meet the EO and associated IRS and GSA definitions of qualifying commuter vehicle
6. Government funds expenditure for the service provided
7. Lowest overall financial impact (all factors considered)
8. Function of road system wear based on miles and vehicle weight. Buses at 4:1 impact for Vans & POV's

Research Questions Answered

From within the previous four chapters, each of the key research questions and focus areas have been consolidated and addressed specifically, though data detail is found throughout Chapter 2 through four Tables and Figures. Tables and Figures from the previous four chapters provide specific data consolidation supporting the Chapter 4 and 5 analyses. Table 5.1, illustrates the relative performance rankings of the transportation types against key factors developed from the several research questions within this study. The research questions begin with the proof of or disproof of the H0:

There is not a quantifiable difference in bio-economic impact between busing versus carpooling with regard to enhanced safety, reduced environmental impact, or positive economics per user unit.

> The research and analytic results herein disprove the H0; there are in fact several and significant quantifiable difference between busing and POV or van-pooling, specific to environmental, economic, and human safety impacts. Most significant impacts resulted from B20 versus petroleum fuels and in mortality rate reduction.

Foundational Question: Quantifiable Bio-economic Impact

Is there a quantifiable difference in bio-economic impact from the use of mass transit versus personal vehicles on commuter transit HWYs at the three DOE remote laboratory sites? If yes, should the DOE modify the several mass transit programs at their three remote laboratory sites? If no, should the DOE discontinue the service offering?

> Yes, and as a result, the DOE should as an extension of their secondary responsibilities, expand and develop this service for the balance of the employee populations supporting the remote sites, from all localities with supporting populations significant to fill bus units at 65% or more.

Support Question 1: Human Safety and Mortality

Question 1a: Is there a statistically proven safe way for employees to travel to and from their respective work locations; resulting in reduced loss of life, including wildlife, and mitigation of statistically significant human factors for extended driving?

> Yes, busing is superior in every category considered significant, except for direct Government outlay of funds to support the service.

Question 1b: Is there a significant safety discriminator due to transportation type for human, animal, or plant life?

> Yes, see the answer provided for the H0.

Support Question 2: Environmental Impact Reduction

Question 2a: Is there a statistically significant decrease in negative effect to animal and plant life within the defined transportation thoroughfares; environmentally conscious specific to use of biofuels and reduced pollution of vegetated HWY shoulders?

> Yes, though the use of a more robust bio-fuel blend (i.e. B100) would provide another step change in air and surface water quality. Secondarily, yes as a result of busing units providing greater interstitial space for animal cross-HWY transit, slower HWY speeds, and fewer overall vehicles on the roads at the peak times, thus reducing vehicle-vehicle and AVC potentials.

Question 2b: Is there a significant environmental impact discriminator between the use of biodiesel for buses versus petroleum based fuel for passenger vehicles per unit of transported personnel?

> Yes, see question 2a.

Support Question 3: Economic Impact

Is there a quantifiable reduction in economic impact to tax payers and to the employees who use the respective services?

Yes, though the answer has a divided conclusion. For users, the use of buses is economically superior to every other studied transportation type. For the Government (the taxpayer steward), the net impact of all biologic and mortality economic factors perform equal to or superior for buses versus every other studied transportation type, though department specific budgets illustrate an imbalanced cost-benefit. For instance, the DOE would experience a larger funds outlay to develop, expand, or enhance the service, while the DEQ would experience fewer impacting environmental inquiries and the DOT and local municipalities, insurance providers, and supporting medical support services would see the impact reduction in the form of fewer mortality related expenses.

Support Question 4: Stakeholder Decision Support

Question 4a: As an employee, which is the best transportation system to use ('best' is defined as economic benefit optimized for safety); how much safer are people and animals due to transportation type?

The best transportation type for safety is busing, for many scientifically founded and anecdotal factors. The several anecdotal factors associated with 'how much safer' people and animals are, requires further research.

Question 4b: As the DOE and its managing contractors, which is the best transportation system to use ('best' is defined as lowest economic impact optimized for both human safety and environmental impact)?

See question 3.

The H0, Foundational Question, and associated four supporting questions, now answered work to support the performance ranking found in Table 5.1. These questions and their respective answers provide decision makers and stakeholders with perspective for making their respective transportation decisions.

Conclusions and Recommendations

Given the H0-defeating assumption, that the use of a mass transit system is superior to the use of personal vehicles in factors deemed significant for comparison and impact, the use of statistical analysis was limited to the actual comparison of mass transit system actual-data versus the average commuter personnel vehicle using various and broad-reaching data sources. This study examined the overall mass transit bus system in the three state region, with actual data from the respective State DOT and the respective DOE contractors as supporting validation to adapt the national and statewide statistics to actual experience along the targeted commuting corridor along the Nations rural transit HWYs.

My recommendation is to expand the bus transit service to the populations of these remote DOE sites. Though increased cost to the DOE will occur as a result of this recommendation, it can be offset nationally through:

- Reduced injury and fatality accidents
- Perception of a benefit to attract and retain high potential talent
- Known and quantified environmental impact reduction
- Anecdotally providing the contractor community their workforce populations to the worksite at consistent and aligned scheduled times

Finally, the respective locales benefiting from these services will have one less item to report on within the media. This recommendation, based on the data analysis, does not discriminate between a commercially provided services or a Government operated service. The results rank buses as superior in all key categories, and as such, the recommendation is to more fully utilize them, regardless of the providing source.

One added factor affecting this recommendation is that it is my opinion as a scientist that contractual vehicles in the several prime contracts should include mandatory language for mass transit service. The bus service, based on the factors presented herein should not be considered or offered as optional as funding plays a diluting role relative to environmental stewardship and enhanced worker safety, in addition to providing a direct and tangible community service.

Implications

The implications of this study is that formerly assumed and frequented information now has a data driven fact base for support, and to better understand what the non-financial claims mean. A second implication is the now visible view that buses are many times safer than other transportation types studied.

Further Recommended Study and Analysis

Given the safety and environmental focus of this bio-economic study to compare transit types to rank those types along a spectrum, a natural next level comparison would be to compare high speed rail against the findings of this research to determine if rail overcomes busing or if busing stays remains superior. For future researchers, it should be noted that notional analysis suggests rail as superior when compared against busing over a longer life-cycle horizon, such as thirty years, when considering the full impact of lifecycle operating and ownership costs. Secondarily, though I found no difference in the overall performance between Government-supported busing operations and the balance of busing as reported by the DOT, which was not the sole focus of this study and could be a natural extension to better address the open question of make or buy for the transit system by the Government.

Summary

This study was entered into to address questions regarding why a bus service should be in place and if it should be retained. The results address key safety, environmental, and economic factors with defendable and repeatable data and analyses, and as such this research and associated results defeat the H0 and provide a clear answer to the question, are buses superior to other transportation modes. The answer has been shown to be yes.

REFERENCES

[1] United States Department of Transportation, Bureau of Transportation Statistics, Federal Motor Carrier Safety Administration, Table 5-Trends. 2010.

[2] United States Department of Transportation, National Highway Traffic Safety Administration. National Center for Statistics and Analysis Injured persons and crashes. 2017.

[3] United States Internal Revenue Service. Publication 15-B (2017), Employer's Tax Guide to Fringe Benefits; https://www.irs.gov/publications/p15b

[4] Google Maps. 2017; Available from: https://www.google.com/maps.

[5] United States Department of Transportation. Transportation and Climate Change Clearinghouse. 2017.

[6] United States Environmental Protection Agency. Energy Independence and Security Act. 2007, Federal Register.

[7] United States Government Publishing Office. Defining a Commuter Highway Vehicle. 2001; Vol 66 No 8.

[8] United States Department of Transportation, Federal Highway Administration. Our Nation's Highways, Selected Facts and Figures. 1998.

[9] United States Department of Agriculture. Agriculture Information Bulletin Number 795, Transportation Equity Act for the 21st Century (TEA-21), E.R. Service, Editor. 2005.

[10] United States Department of Transportation, National Personal Transportation Study, Policy and Government Affairs, Office of Highway Policy Information. 1995.

[11] Lowrey, A. Your Commute Is Killing You. 2011; Available from: http://www.slate.com/articles/business/moneybox/2011/05/your_commute_is_killing_you.html

[12] Plumer, B., Commuting in the U.S. is hellish — but at least it's not getting worse. 2013, The Washington Post.

[13] United States Department of Commerce, Census Bureau. American Community Survey (ACS). Available from: https://www.census.gov/programs-surveys/acs/.

[14] United States Department of Transportation, Bureau of Transportation Statistics, from table 6-1, Transportation Fatalities by Mode: 200, 2010-2013 2015.

[15] United States Department of Transportation, National Highway Traffic Safety Administration, 2015 Motor Vehicle Crashes: Overview; Traffic Safety Facts. 2016.

[16] Sandow, E., O. Westerlund, and U. Lindgren, Is your commute killing you? On the mortality risks of long-distance commuting. Environment and Planning A, 2014. 46(6): p. 1496-1516.

[17] United States Department of Energy, Energy Information Administration, Short-Term Energy Outlook (STEO), in Independent Statistics & Analysis. 2015.

[18] Khattak, A.J., Human Fatalities in Animal-Related Highway Crashes in TRB 2003 Annual Meeting. 2003.

[19] United States Department of Transportation, National Safety Council, Injury Facts. 2015.

[20] Turrio-Baldassarri, L., C.I. Battistelli, L. Conti, R. Crebelli, B. De Berardis, A.L. Iamiceli, M. Gambino, S. Iannaccone. Emission comparison of urban bus engine fueled with diesel oil and 'biodiesel' blend. Sci Total Environ, 2004. 327(1-3): p. 147-62.

[21] Argonne National laboratory, The Greenhouse gases, Regulated Emissions, and Energy use in Transportation Model; GREET v1.2.0.11425. 2015.

[22] California Environmental Protection Agency, Air Protection Agency; Low Carbon Fuel Standard. 2017.

[23] United States Department of Energy. Energy Efficiency and Renewable Energy, Alternative Fuels Data Center, Biodiesel Vehicle Emissions. 2017.

[24] United States Department of Energy. Energy Information Administration, Annual Energy Outlook 2015 with projections to 2040. 2015.

[25] Blottnitz, H. and M.A. Curran, A review of assessments conducted on bio-ethanol as a transportation fuel from a net energy, greenhouse gas, and environmental life cycle perspective. Journal of Cleaner Production, 2007. 15(7): p. 607-619.

[26] Balat, M. and H. Balat, A critical review of bio-diesel as a vehicular fuel. Energy Conversion and Management, 2008. 49(10): p. 2727-2741.

[27] Hill, J., E. Nelson, D. Tilman, S. Polasky, and D. Tiffany, Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. Proc Natl Acad Sci U S A, 2006. 103(30): p. 11206-10.

[28] Sheehan, J., V. Camobreco, J. A. Duffield, M.S. Graboski, and H. Shapouri., Life cycle inventory of biodiesel and petroleum diesel for use in an urban bus: a joint study by the Department of Agriculture, N.R.E.L. (NREL), Editor. 1998.

[29] United States Department of Energy, Energy Information Administration. Frequently asked questions. Available from: https://www.eia.gov/tools/faqs/

[30] Barrett, M., A. Lantin, and S. Austrheim-Smith, Storm water pollutant removal in roadside vegetated buffer strips. Highway Facility Design 2004; Including 2004 Thomas B. Deen Distinguished Lecture, 2004. 1890(1890): p. 129-140.

[31] Demirbas, A., Political, economic and environmental impacts of biofuels: A review. Applied Energy, 2009. 86(1): p. S108-S117.

[32] Teddlie, C. and A. Tashakkori, A general typology of research designs featuring mixed methods. Research in the Schools, 2006. 13(1): p. 12-28.

[33] Teddlie, C. and F. Yu, Mixed Methods Sampling A Typology With Examples. Journal of Mixed Methods Research, 2007. 1(1): p. 77-100.

[34] Leech, N. and A. Onwuegbuzie, A typology of mixed methods research designs. Quality & Quantity, 2007. 43(2): p. 265-275.

[35] Daley, C.E. and A.J. Onwuegbuzie, Attributions toward violence of male juvenile delinquents: a concurrent mixed-methodological analysis. J Soc Psychol, 2004. 144(6): p. 549-70.

[36] Tashakkori, A. and C. Teddlie, Mixed methodology: combining qualitative and quantitative approaches. Applied Social Research Methods Series. Vol. 46. 1998, Sage, Thousand Oaks, CA.

[37] Teddlie, C. and A. Tashakkori, Major issues and controversies in the use of mixed methods in the social and behavioral sciences. 2003, Thousand Oaks, CA: Sage.

[38] United States Department of Energy. Corporate Average Fuel Economy Act (CAFE). 2017; Available from: www.fueleconomy.gov.

[39] Heron, M., National Vital Statistics Report Deaths: Leading causes for 2009. 2012; as cited by the United States Centers for Disease Control

[40] United States Department of Transportation, Federal Highway Administration. Fatality, injury, and crash rates: 1970-2015: Policy and Government Affairs, in Office of Highway Policy Information. 2017.

[41] United States Department of Transportation, National Highway Traffic Safety Administration. National Center for Statistics and Analysis, Fatalities: 1975-2015. [cited 2017 February]; Available from: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812376.

[42] United States Department of Transportation, National Highway Traffic Safety Administration from data supplied by Department of Health and Human Services. National Center for Health Statistics, and individual state accident reports (adjusted to 30-day deaths). 1960-70.

[43] United States Department of Transportation, Federal Highway Safety Administration. Highway Statistics Fatality, injury, and crash rates: 1970-2015: Ibid., (Washington, DC: Annual Issues), table VM-1, and similar tables in earlier editions. Available from: http://www.fhwa.dot.gov/policyinformation/statistics.cfm.

[44] United States Department of Transportation, Federal Highway Administration. Highway Statistics (Washington, DC: Annual Issues), table VM-202. 2017; Available from: http://www.fhwa.dot.gov/policyinformation/statistics.cfm.

[45] United States Department of Transportation, National Highway Traffic Safety Administration. National Center for Statistics and Analysis, Traffic Safety Facts Early Edition 2009 (Washington, DC: 2010), table 4. Available from: http://www-nrd.nhtsa.dot.gov/Cats/index.aspx.

[46] United States Department of Transportation, National Highway Traffic Safety Administration. Personnel Communications. 2013, 2014, 2016, and 2016.

[47] United States Department of Transportation, Federal Highway Administration. Traffic Safety Facts, Research Note: Passenger Vehicle Occupant Fatality Rates by Type and Size of Vehicle (Washington, DC: 2009), table 4, 1997-2004 2010; Available from: http://www-nrd.nhtsa.dot.gov/Cats/index.aspx

[48] Kordani, A.A., O. Rahmani, A.S.A. Nasiri, and S.M. Boroomandrad, Effects of adverse weather conditions on vehicle breaking distance of highways. Civil Engineering Journal, Vol 4 (1) p.46-57. 2018

[49] United States Department of Transportation, Bureau of Transportation Statics. 2016 Transportation Profile, Highway Traffic Fatalities and Fatality Rates.

[50] United States Department of Transportation, Bureau of Transportation Statistics. 2000, Highway Traffic Fatalities and Fatality Rates, Table 2-1 of Transportation Profile. Available from:
https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_02_01.html_mfd.

[51] United States Department of Transportation, National Highway Traffic Safety Administration. Traffic Safety Fact Sheet, Alcohol-Impaired Driving. Available from: http://www-nrd.nhtsa.dot.gov/Cats.

[52] United States Department of Transportation, Federal Highway Administration. Wildlife-vehicle collision reduction study, report to congress. 2008.

[53] Pynn, T.P. and B.R. Pynn, Moose and other large animal wildlife vehicle collisions: implications for prevention and emergency care. J Emerg Nurs, 2004. 30(6): p. 542-7.

[54] New Mexico Department of Transportation, Monthly Fatality Tracking Report 2010. 2015.

[55] United States Department of Transportation, Federal Highway Administration. Highway Statistics, HM-20. 2015.

[56] Road Management and Engineering, Vehicle-wildlife collisions increasing: how to avoid this happening to you. Road Management and Engineering 2005.

[57] Canegie Mellon University, Scott Institute for Energy Innovation. Policy Maker Guide: Which Alternative Fuel is Best for Transit Buses 2013; Available from: https://www.cmu.edu/energy/education-outreach/public-outreach/17-104%20Policy%20Brief%20Buses_WEB.pdf.

[58] Conover, M.R., W.C. Pitt, K.K. Kessler, T.J. DuBow, and W.A. Sanborn; Review of Human Injuries, Illnesses, and Economic-Losses Caused by Wildlife in the United-States. Wildlife Society Bulletin, 1995. 23(3): p. 407-414.

[59] United States Department of Transportation, National Highway Traffic Safety Administration. National Crash Database. 2017; Available from: https://www.nhtsa.gov/research-data.

[60] Idaho Department of Fish and Game. Looking for the 2016 deer and elk outlook? 2016 [cited 2018 02/04]; Available from: https://idfg.idaho.gov/2015-deer-elk-outlook.

[61] United States Department of Energy. Clean City Alternative Fuel Price Report. 2017.

[62] Proc, K., R. Barnitt, R.R. Hayes, M.A. Ratcliff, R.L. Mccormick, L. Ha, 100,000-Mile Evaluation of Transit Buses Operated on Biodiesel Blends (B20). Powertrain and Fluid Systems Conference and Exhibition. 2006: Toronto, Canada.

[63] United States Department of Commerce, Census Bureau. American Community Survey 1-year data, 2011-2016 2017; Available from: https://www.census.gov/data/developers/data-sets/acs-1year.html.

[64] United States Department of Commerce, Census Bureau. 2013 American Community Survey 1-Year Estimates. 2015; Available from: https://www.census.gov/programs-surveys/acs/.

[65] United States Department of Transportation, Federal Highway Administration, 2015 Motor Vehicle Crashes: Overview. 2015.

[66] Virginia Department of Motor Vehicles, Commercial Driver License Manual, 2005 CDL Testing System. 2005. p. 1-19. 1-23, 1-24, 3-8.

[67] Kowaluk, M. What is the average length of a car? 2017; Available from: https://www.reference.com/vehicles/average-length-car-2e853812726d079d#.

[68] United States Department of Transportation, Federal Motor Carrier Safety Administration. Traffic volume #1, equations 3, 4 and 8 Available from: fhwa.dot.gov.

[69] Carbaugh, B.T., Activity and Behavior of White-Tailed Deer (Odocoileus Virginianus) Along an Interstate Highway in a Forest Region of Pennsylvania. 1970, The Pennsylvania State University: State College, PA.

[70] Williams, A.F. and J.K. Wells, Characteristics of vehicle-animal crashes in which vehicle occupants are killed. Traffic Injury Prevention, 2005. 6(1): p. 56-9.

[71] United States National Oceanic and Atmospheric Administration. 2016 customized data tables develop for ID, NV, and NM.

[72] United States Department of Energy. Bus Profile, 2015.

APPENDIX A: Generalized Busing Data

Table A.1. US Registered Vehicle Types [50]

State	Buses	All Motor Vehicles	Bus to All Motor Vehicles Ratio	DOE % of Bus Use
Idaho	3687	1219851	0.3%	~ 5%
Nevada	3440	1557064	0.2%	~ 3%
New Mexico	1837	1244637	0.1%	< 1%
US Total	746125	225821241	0.3%	N/A

Table A.2. Select US Bus Profile Data

	1960	1970	1980	1990	2000	2010	2011	2012	2013	2014
	INVENTORY									
Number of operating companies (intercity)	143	71	61	31	15	U	U	U	U	U
Number of vehicles (1,000), all buses[3]	272	378	529	627	746	846	666	765	865	872
Number of employees[4] (SIC based, 1,000) - urban & rural	41	43	38	26	25	N	N	N	N	N
	EMPLOYEES[5] (NAICS based, 1,000)									
Interurban and rural bus transportation	38	41	36	25	23	18	18	18	18	17
School and employee bus transportation	N	N	81	114	153	200	199	200	201	205
Charter bus industry	N	N	15	26	38	31	31	30	30	31
	PERFORMANCE									
Vehicle-miles, all buses (billions)[6]	4.3	4.5	6.1	5.7	7.6	13.8	13.8	14.8	15.2	16.0
Rural HWY, total	2.3	2.5	3.0	3.4	4.5	5.6	5.7	5.7	5.7	5.5
Interstate rural	N	.3	.5	.6	1.0	1.5	1.7	1.7	1.5	1.5
Other arterial rural	N	1.0	1.0	1.0	1.3	2.0	2.0	2.0	2.1	2.0
Other rural	N	1.3	1.5	1.9	2.2	2.0	2.1	2.0	2.1	2.0
Urban HWY[b], total	2.0	2.0	3.0	2.3	3.1	8.1	8.1	9.0	9.5	10.5
Passenger-miles (billions), all buses[6]	N	N	N	121.4	190.9	291.1	292.2	312.8	321.5	339.2
Average miles traveled per vehicle (1,000), all buses[6]	16	12	12	9	10	16	21	19	18	18

Fuel consumed (billion gallons), all buses[6]	.8	.8	1.0	.9	1.1	2.2	2.2	2.0	2.1	2.2
Average fuel consumption per vehicle (1000 gallons), all buses[6]	3.0	2.2	1.9	1.4	1.5	2.3	2.3	2.3	2.4	2.6
Average miles traveled per gallon of fuel consumed, all buses[6]	5.3	5.5	6.0	6.4	6.8	7.2	7.1	7.2	7.2	7.2
	SAFETY - FATALITIES[7]									
Occupant fatalities, all buses[7]	N	N	46	32	22	44	54	39	48	44
School buses	N	N	14	13	16	15	9	13	11	11
Cross country buses	N	N	23	2	3	15	31	15	17	19
Transit buses	N	N	6	3	1	3	4	1	2	2
Other and unknown	N	N	3	14	2	11	10	10	18	12
Fatalities in vehicular accidents[e], all crashes involving buses[8]	N	N	329 (R)	286 (R)	323 (R)	247	243	252	282	233
	SAFETY - FATALITY RATES									
Fatality rate (Occupant) per 100 million vehicle-miles, all buses[6,7]	N	N	0.8	0.6	0.3	0.3	0.4	0.3	0.3	0.3
Fatality rate (Occupant) per 10,000 registered vehicles, all buses[3,7]	N	N	0.9	0.5	0.3	0.5	0.8	0.5	0.6	0.5
Vehicle involvement rate (Fatal Crashes) per 100 million vehicle-miles, all buses[6,8]	N	N	6.4	5.9	3.8	1.8	1.8	1.7	1.9	1.5
Vehicle involvement rate (Fatal Crashes) per 10,000 registered vehicles, all buses[3,8]	N	N	7.4	5.4	3.9	2.9	3.6	3.3	3.3	2.7

Adapted from DOT; Bureau of Transportation Statistics [72]

KEY: N = data do not exist; R = revised; U = data are not available.

Appendix A annotation notes:

a. In 2003, the US Federal Motor Carrier Safety Administration implemented a program to improve reporting by Class I intercity bus carriers. This accounts for the large increase in Number of operating companies between 2002 and 2003, and as a result the large increase in Operating revenues and Operating expenses. For all years, New Jersey Transit has been excluded from the totals because of its status as a publicly run carrier.
b. Urban consists of travel on all roads and streets in urban places of 5,000 or greater population
c. Number of revenue passengers data for 1960 to 1980 are for both regular route and charter buses of all classes. 1990 to 2001 data are for regular route and charter Class I Carriers only. For 2002 to 2004, this category includes charter, tour, sightseeing, airport shuttle, contract and private commuters, and scheduled services.
d. Average revenue per passenger mile data for 2002 to 2004 is Greyhound Lines passenger service revenue per passenger-mile.
e. Includes all fatalities that occurred in an accident in which a bus was involved.

Data sources used to develop this statistical table for the Department of Energy, Bureau of Transportation Statistics with support data developed from sources 1- 8 below; https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_bus_profile.html

1. 1960-99: Eno Transportation Foundation, Transportation In America, with Historical Compendium (Washington, DC: 2001). 2000-01: Ibid., Transportation in America, 19th Edition (Washington, DC: 2002)
2. 1960-95: Interstate Commerce Commission, Annual Report of the ICC (Washington, DC: Annual Issues), Appendix F, tables 1 and 6. 1996-2002: US Department of Transportation, Bureau of Transportation Statistics, Selected Earnings Data, Class I Motor Carriers of Passengers (Washington, DC: Annual Issues). 2003: US Department of Transportation, Federal Motor Carrier Safety Administration, personal communication, Feb. 16, 2005.
3. US Department of Transportation, Federal Highway Administration, Highway Statistics (Washington, DC: Annual Issues), table MV-10, available at http://www.fhwa.dot.gov/policyinformation/ as of May 6, 2016.
4. 1960-2002: US Department of Labor, Bureau of Labor Statistics, Employment, Hours, and Earnings from the Current Employment Statistics Survey, SIC codes: "413 Intercity and

rural bus transportation" and "415 School buses," available at http://www.bls.gov/data/archived.htm as of January 2005.

5. 1960-2014: US Department of Labor, Bureau of Labor Statistics, Employment, Hours, and Earnings from the Current Employment Statistics Survey, NAICS codes: "4852 Interurban and rural bus transportation," "4854 School and employee bus transportation," and "4855 Charter bus industry," available at http://www.bls.gov/ces/data.htm as of Sept. 21, 2016.
6. Adapted from million miles to billion miles from: 1960-95: US Department of Transportation, Federal Highway Administration, Highway Statistics, Summary to 1995, FHWA-PL-97-009 (Washington, DC: July 1997), table VM-201A, available at http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.cfm as of July 16, 2010. 1996-2014: Ibid., Highway Statistics (Washington, DC: Annual Issues), table VM-1, available at http://www.fhwa.dot.gov/policyinformation/ as of May 6, 2016.
7. US Department of Transportation, National Highway Traffic Safety Administration, Traffic Safety Facts (Washington, DC: Annual Issues), tables 75 and 95 and similar tables in previous issues, available at http://www-nrd.nhtsa.dot.gov/Cats/listpublications.aspx?Id=E&ShowBy=DocType as of July 2016.
8. US Department of Transportation, Federal Motor Carrier Safety Administration, Large Truck and Bus Crash Facts, table 25, available at http://www.fmcsa.dot.gov/facts-research/art-public-reports.aspx as of Sept. 21, 2016.

APPENDIX B: US Public Roads Lengths for Idaho, Nevada, and New Mexico

Table A.3. US Public Roads Length					
Rural Systems					
State	Interstate	Arterial	Collector	Local	Total
Idaho	519	3,124	9,737	31,694	45,185
Nevada	448	2,226	4,691	24,934	32,299
New Mexico	847	4,226	7,669	48,011	60,752
Urban Systems					
State	Interstate	Arterial	Collector	Local	Total
Idaho	122	1101	773	4,161	6,157
Nevada	205	1245	1,194	7,640	10,283
New Mexico	165	1419	1,138	5,637	8,359
Rural to Urban Ratio					
State	Interstate	Arterial	Collector	Local	Total
Idaho	4.3	2.8	12.6	7.6	7.3
Nevada	2.2	1.8	3.9	3.3	3.1
New Mexico	5.1	3.0	6.7	8.5	7.3
Total of Rural & Urban Systems					
State	Interstate	Arterial	Collector	Local	Total
Idaho	612	4,249	10,611	32,611	48,082
Nevada	596	3,471	5,612	30,460	40,139
New Mexico	1,000	4,963	9,188	55,620	70,772
US total	47,575	417,232	803,807	2,846,848	4,115,462
Percent of US roads represented by ID, NM, & NV					3.9%

Miles by Functional System 2016; adapted from US DOT FHWA, Highway Statistics, Chart HM-20

APPENDIX C: Pictorial Illustrations of Roadway Conditions

NEW MEXICO

Picture 1. NM: Albuquerque to Los Alamos; vegetation: western wheatgrass. Trip Savvy at tripsavvy.com; 5 top scenic drives around Albuquerque (Google search 1-1-2018)

Picture 2. NM: Santé Fe to Los Alamos. On the Road to Los Alamos from Santa Fe Stock Photo; Getty Images (Google search 1-1-2018)

Picture 3: NM: Los Alamos; Vegetation: Juniper varieties - alligator, common, one-seed, rocky mountain. Visit Us: University of New Mexico: Los Alamos; The University of New Mexico (Google search 1-1-2018)

NEVADA

Picture 4. NV: N. Las Vegas to Mercury; Vegetation: Creosote and California juniper. Atomic testing viewing area historic site overlooking Frenchman Flat on Wednesday, Jan., 11; Las Vegas Review-Journal (Google search 1-1-2018)

Picture 5. NV: Outside the NNSS; Vegetation: California juniper. You Are Now Entering the Nevada National Security Site (No Trespassing) (Google search 1-1-2018)

Picture 6. NV: Mercury; Vegetation: California juniper, small yucca. YouTube; What Goes on in the Mysterious Town of Mercury, NV? (Google search 1-1-2018)

IDAHO

Picture 7. ID: Arco to Idaho Falls; Vegetation: Wyoming big sagebrush, blue bunch wheatgrass. Busoperations.inl.gov (Google search 1-1-2018)

Picture 8. ID: Blackfoot to Scoville; Vegetation: Wyoming big sagebrush, blue bunch wheatgrass, and Thurber needle grass. ID Department of Transportation Junction 33/22 NE View; Jan 1, 2018 (Google search 1-1-2018)

Picture 9. ID: Outside INL; Vegetation: various grasses, sage. INL Site Signs Get Makeover; www.inl.gov/article/inl-site-signs-get-a-makeover/ (Google search 1-1-2018)

APPENDIX D: Web links for Referenced DOE and Operating Contractors

- DOE-ID: Department of Energy – Idaho Operations Office; https://www.id.energy.gov/
- INL: Idaho National Laboratory, operated by Battelle Energy Alliance, LLC; https://www.inl.gov/about-inl/general-information/organization/
- ICP: Idaho Cleanup Project, operated by Fluor Idaho, LLC; https://fluor-idaho.com/
- LANL: Los Alamos National Laboratory, operated by Los Alamos National Security, LLC; http://lanl.gov/
- NNL: Naval Nuclear Laboratory, operated by Bechtel Marine Propulsion Corporation; https://navalnuclearlab.energy.gov/
- NNSS: Nevada National Security Site, operated by Bechtel Nevada Corporation; http://www.nnss.gov/