Asset Valuation: A Performance Measure for Comprehensive Infrastructure Asset Management

by

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AUTHOR'S DECLARATION

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

STATEMENT OF CONTRIBUTION

A version of the methodology outlined in chapter 5 and the case study implementation in Chapter 6 have been submitted and presented at the Canadian Society of Civil Engineers (CSCE) conferences in 2016 and 2017. Part of the data analysis section to develop the Markov models presented in Chapter 6 of this thesis has been submitted and presented as a journal paper at the Transportation Research Record (TRR). All papers published and or presented have been co-authored with my supervisor, where I am the lead author and my contributions include the driving of the main methodologies, data analysis, application of the case studies and writing the initial papers.

Abstract

Asset valuation is an essential component of effective asset management. It is an important method to demonstrate proper management of public assets and effective utilization of government's budgets. Several government regulatory bodies mandate agencies to report their Tangible Capital Assets' (TCA) values within their annual statement. For example, the Canadian Public Sector Accounting Board (PSAB), the Governmental Accounting Standard Board (GASB) and the New Zealand International Financial Reporting Standards (NZ IFRS), to name a few.

Although some limited research has been conducted on incorporating asset value into asset management systems, there is no comprehensive work done to date to incorporate asset valuation in asset management. An integration method is imperative to manage assets in the most optimized cost-effective ways while maintaining or enhancing the value of these assets. Integrating asset value in asset management strengthens the asset management framework by integrating financial and engineering reporting. In addition, agencies have traditionally made investment decisions for individual assets separately. Independent management systems have traditionally been developed to manage assets, in particular pavements and bridges, the two main transportation assets. The lack of integration between management systems may be due to restrictions associated with funding and/or limitations to the agency's ability to compare data objectively across asset types. Deciding how to best allocate limited resources across these various asset classes to provide acceptable performance poses a persistent and difficult challenge for agencies. Asset value holds a great promise to be incorporated in asset management as a performance measure that translates infrastructure condition in monetary terms that can be easily communicated and understood by the stakeholders (agency, policy makers, users, etc.). Therefore, asset value can be viewed as a common performance measure for integration mechanism between competing asset management systems.

The objective of this research is to develop a methodology that integrates asset value as a performance measure in asset management decision making. This thesis introduces an asset management methodology that aims to arrive at an optimum value-based asset management plan of maintaining infrastructure assets taking into account budgetary and performance constraints. To achieve this objective, an Asset Value Index (AVI) that integrates asset value and value-driver performance measures and associated thresholds and Level of Service (LOS) requirements is proposed. The Multi-Attribute Utility Theory (MAUT) is used to develop the proposed AVI. In order to incorporate asset value in asset management and develop the AVI, a comprehensive and analytical analysis of various asset valuation methods is conducted. Based on the analysis, challenges of incorporating asset management are identified and addressed by the proposed Asset Value Loss ratio (AV_L) as an integration means.

To demonstrate the proposed methodology, a case study from the Ministry of Transportation of Ontario (MTO) second generation Pavement Management System (PMS2) is presented. An overview of MTO road assets network is presented and analyzed. In addition, the various components of the proposed methodology are demonstrated through the case study. Furthermore, the outcome of the implementation of the proposed AVI is compared to optimization output, Do-Nothing output as well as needs assessment output. Furthermore, building on the proposed methodology presented, a value-based cross asset management methodology is presented using the AVI as a common integration measure. A case study of pavements and bridges based on data obtained from the 7th International Conference of Managing Pavement Assets (ICMPA 7) is used to illustrate the proposed methodology.

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Last but not least, I owe an eternal debt of gratitude and appreciation to my family for the unconditional love, support, encouragement and patience. Special thanks to my lifelong mentors and ever-loving parents; I owe the two of you the world.

Dedication

I dedicate this thesis to my father, my mother and my family.

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List of Abbreviations

AADT	Annual Average Daily Traffic
AC	Asphalt Concrete
AHP	Analytical Hierarchy Process
AIREA	American Institute of Real Estate Appraisers
ANOVA	Analysis of Variance
AT	Alberta Transportation
AVI	Asset Value Index
$\mathbf{AV_L}$	Asset Value Loss
$\mathbf{AV_{L,LOS}}$	The minimum Asset Value Loss for the Specified Level of Service
BMS	Bridge Management Systems
BNI	Bridge National Index
BV	Book Value
CCPP	Canadian Council of Public Private Partnership
CICA	Canadian Institute of Chartered Accounts
COV	Coefficient of Variance
DMI	Distress Manifestation Index
EPWIP	Equivalent Present Worth in Place
ESAL	Equivalent Single Axel Load
FHWA	Federal Highway Administration
GASB	Government Accounting Standard Board
ICMPA 7	7th International Conference of Managing Pavement Assets
IRI	International Roughness Index
KPI	Key Performance Indicator
LCCA	Life Cycle Cost Analysis
LOS	Level of Services
MAUT	Multi-attribute utility theory
MCDM	Multi-Criteria Decision Making
MTO	Ministry of Transportation of Ontario
NPW	Net Present Worth
NSV	Net Salvage Value

PCI	Pavement Condition Index
PMS	Pavement Management System
PMS2	MTO Second Generation of Pavement Management System
PPP	Public Private Partnership
PSAAB	Public Sector Accounting and Auditing Board
RC	Replacement Cost
RMSD	root-mean-square deviation
RMSE	root-mean-square error
ROW	Right of Way
RSI	required supplementary information
RSL	Remaining Service Life
SPC	Special Purpose Company
TCA	Tangible Capital Assets
TPI	Tender Price Index
TPM	Transition Probability Matrix
WDRC	Written Down Replacement Cost
WSM	Weighted Sum Method

Chapter 1

Introduction

1.1 Background

Capital infrastructures can be generally classified as follows: transportation infrastructures, water supply, wastewater management, vertical infrastructures (such as buildings, schools, and hospitals), and electric/power systems. Transportation infrastructure assets typically represent the largest components of capital infrastructure assets. Canada has over 1,000,000 km of roads with the national highway system composed of 38,000 km of important provincial and national highways (Transport Canada 2012; TAC 2013). In Canada, about 90 % of goods are transported via trucks (TAC 2013); therefore, the Canadian economy is dependent on good pavement infrastructure. It is estimated that the road infrastructure in Canada has an asset value between $120 billion to $160 billion (Canada 2004).

The Canadian Centre of Policy Alternatives (CCPA) published a report highlighting the Canadian infrastructure gap (Mackenzie 2013) indicating that the fiscal commitment to infrastructure was in steady decline over the last four decades until the infrastructure led stimulus program in the mid-2000s, Figure 1.1.

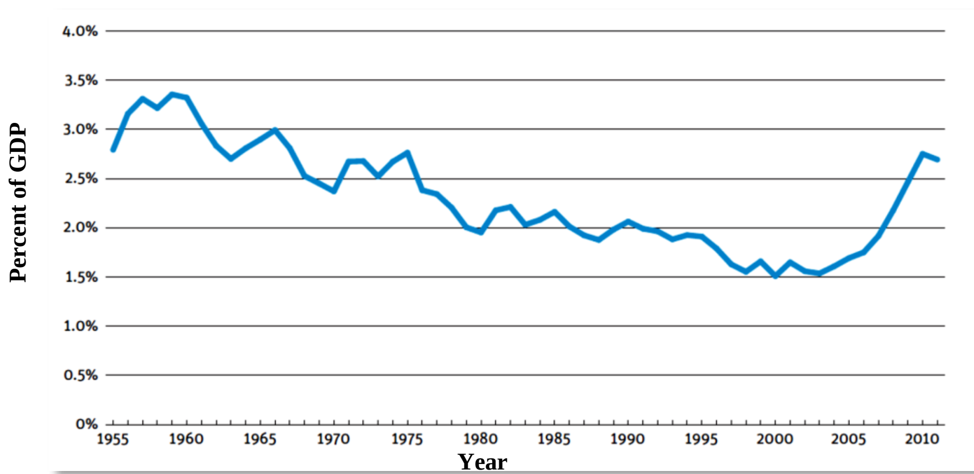


Figure 1.1 Investment, Percent of GDP, Canada General Government (Mackenzie 2013)

On the other hand, the Canadian Infrastructure Report Card reported that one third of Canadian municipal infrastructure is in poor condition; with 40% of roads in fair, poor and very poor condition, Figure 1.2 (Canadainfrastructure 2016).

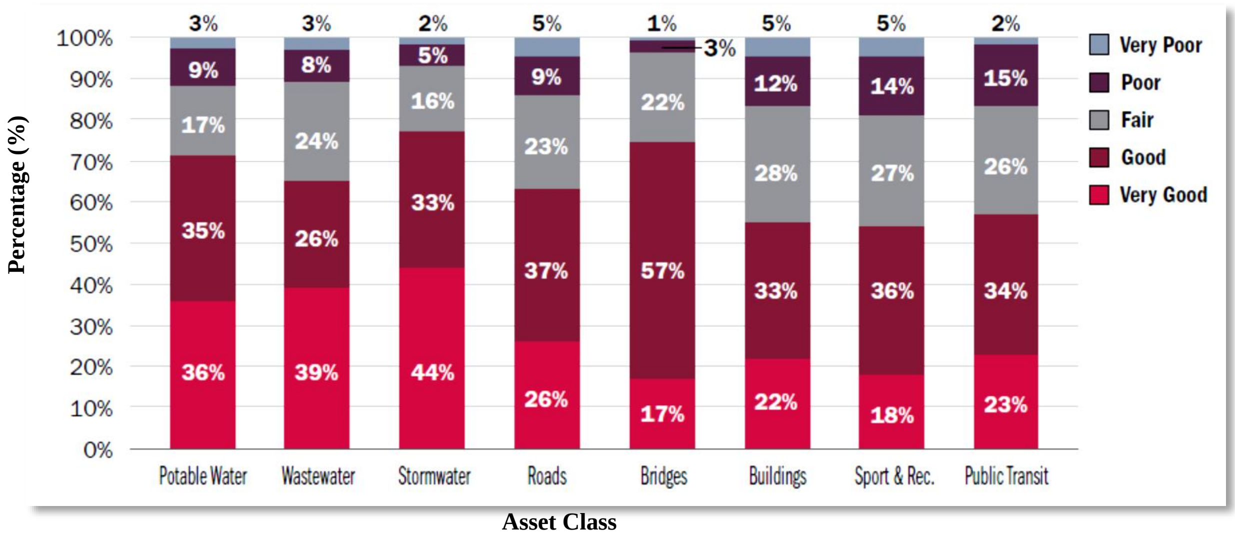


Figure 1.2 Summary of Infrastructure Condition Rating (Canada Infrastructure 2016)

The challenges of reduced budgets, aging and deteriorating infrastructure, increasing traffic loading, increases the demand in implementing effective asset management to manage infrastructure assets cost effectively at acceptable levels of service. In addition, the challenge of maintaining the assets at the highest possible condition while investing the minimum amount of money will always keep agencies searching for innovative approaches (Piñero 2003). As a result, agencies have increased private sector involvement through warranty contracts (Queiroz 1999) and Public Private Partnership (PPP) initiatives.

Asset valuation is an essential component of effective asset management (TAC 2013). It is an important method to demonstrate proper management of public assets and effective utilization of tax payers' money. In addition, it allows agencies to demonstrate justifications of funds needed to preserve the agency's assets (Lugg 2005). Asset valuation is used in standard reporting, depreciation schedules, auditor requirements and condition assessments (Byrne 1994).

Several government regulatory bodies mandate agencies to report their Tangible Capital Assets' (TCA) values within their annual statement. For example, the Canadian Public Sector Accounting Board (PSAB), the Governmental Accounting Standard Board (GASB) and the New Zealand International Financial Reporting Standards (NZ IFRS), to name a few.

Asset value is used in performance based contracts, PPP, as shown in the example of the New South Wales (NSW) 2,115 lane-km network ten-year PPP contract (Yeaman 2007) which included specification of an annual increase of asset value up to 4% in the basis of written down replacement cost.

Asset valuation has gained movement over the last few years. In the literature, there is focus to better understand the asset valuation methods and applicability to different civil infrastructures as well as development or improvement of new methods. In addition, several research activities have been undertaken in efforts to integrate asset valuation to the existing asset management practices (Alyami and Tighe 2016; Amekudzi et al. 2002a; Cowe Falls et al. 2001, 2004a, 2006; Herabat et al. 2002; McNeil 2000; Ningyuan et al. 2013; Porras-Alvarado et al. 2015; Sirirangsi et al. 2003)

1.2 Research Motivation

The latest Pavement Asset Design and Management Guide (TAC 2013) stated that research into developing a comprehensive protocol concerning the most appropriate valuation method(s) for various types of transportation infrastructure is necessary. In particular, for reporting and accounting of TCA, and as an element of an integration platform within an asset management framework. In addition, the guide recommended to develop processes and tools for cross-asset comparison and capital planning to strengthen the existing asset management framework (TAC 2013).

Although some research has been introduced, there is no comprehensive work done to date to incorporate asset valuation in asset management systems. An integration method is imperative to manage assets in the most optimized cost-effective ways while maintaining or enhancing the value of these assets. In other words, it is integrates asset value and valuation concepts and techniques as a performance measure in asset management state-of-the-practice.

As indicated earlier, several government regulatory bodies mandate agencies to report their TCA values within their annual statement. Using financial/ accounting methods alone in reporting asset values may result in underestimating asset values. If the underestimated asset values are used as the basis of annual budget allocation, it may result in insufficient funding to preserve assets and therefore impact the overall network (Cowe Falls 2004).

In addition, agencies have traditionally made investment decisions for individual assets separately. Independent management systems have traditionally been developed to manage assets, in particular pavements and bridges, the two main transportation assets (TAC 2013). The lack of integration between management systems may be due to restrictions associated with funding and/or limitations to the agency's ability to compare data objectively across asset types (Proctor and Zimmerman 2015). Deciding how best to allocate limited resources across these various asset classes to provide acceptable performance poses a persistent and difficult challenge for agencies. Asset value holds a great promise to be incorporated in asset management as a performance measure that translates infrastructure condition in monetary terms that can be easily communicated and understood by the stakeholders (agency, policy makers, users, etc.). Therefore, asset value can be viewed as a common performance measure for integration mechanism between competing asset management systems.

Furthermore, the increased involvement towards PPP or performance based type of contracts to manage and maintain infrastructure assets raises the question of how to identify the optimum or practical asset value criteria in asset management and performance based specifications that provide the required level of service.

1.3 Research Hypothesis

The hypotheses for this research are as follow:

- Integrating asset valuation in asset management as a performance measure strengthens the overall asset management framework. That is, to manage assets to maintain required level of service while maintaining or improving asset values.
- Asset value can be used as an integration mechanism for cross-asset management trade-off and fund allocation.
- Incorporating asset valuation in asset management will result in more comprehensive and effective reporting and accounting of TCA.
- Integrating financial/ accounting reporting and engineering reporting of assets results in a more efficient and effective capital planning and budget allocation.
- Asset valuation index can be developed and incorporated in asset management and cross asset management priority programming and fund allocations.

1.4 Scope and Objective

The main objective of this research is to develop an asset management methodology to integrate asset value as a performance measure in asset management decision making. This is important to manage assets in the most optimized and cost-effective ways while maintaining or enhancing the value of these assets.

As such, the objective is to develop a decision making support system that arrives to a value-based asset management plan of maintaining infrastructure assets taking into account performance and budgetary constraints. To meet this objective, an Asset Value Index (AVI) that integrates asset value and key performance measures is proposed. Integrating asset value as a performance measure in asset management decision making introduces the need to deploy a Multi-Criteria-Decision Making (MCDM) method that incorporates various performance measures such as condition, asset value and asset utilization. The utility theory is used to capture the asset value considering various performance measures (attributes) to aid decision makers to objectively develop a value driven asset management plan. A case study based on data obtained from the Ministry of Ontario (MTO) Pavement Management System (PMS2) is used to demonstrate the proposed methodology.

In addition, this research aims to develop a methodology using the proposed AVI index in cross-asset management as common basis for trade-off analysis between competing infrastructure assets. A case study based on mixed asset data obtained from the 7th International Conference of Managing Pavement Assets (ICMPA7) Challenge is used to implement the proposed methodology.

Another objective of this research is to develop a reporting protocol of TCA based on the findings of this research and implementing the proposed AVI to provide a means for evaluating asset values to be preserved or enhanced. This provides a reporting method that integrates both financial/ accounting and engineering aspects of asset valuation to produce efficient and effective capital planning and budget allocation. The research methodology and steps undertaken are outlined in the following section.

1.5 Research Methodology

The research methodology followed in this research is presented in Figure 1.3. The first part of this research is to conduct a comprehensive literature review of asset valuation in the context of asset management. This includes a literature review of asset valuation methods and financial reporting requirements, specifically in North America. In addition, the literature review explores efforts in incorporating asset value in life cycle costing, performance modeling, decision making, and prioritization and optimization.

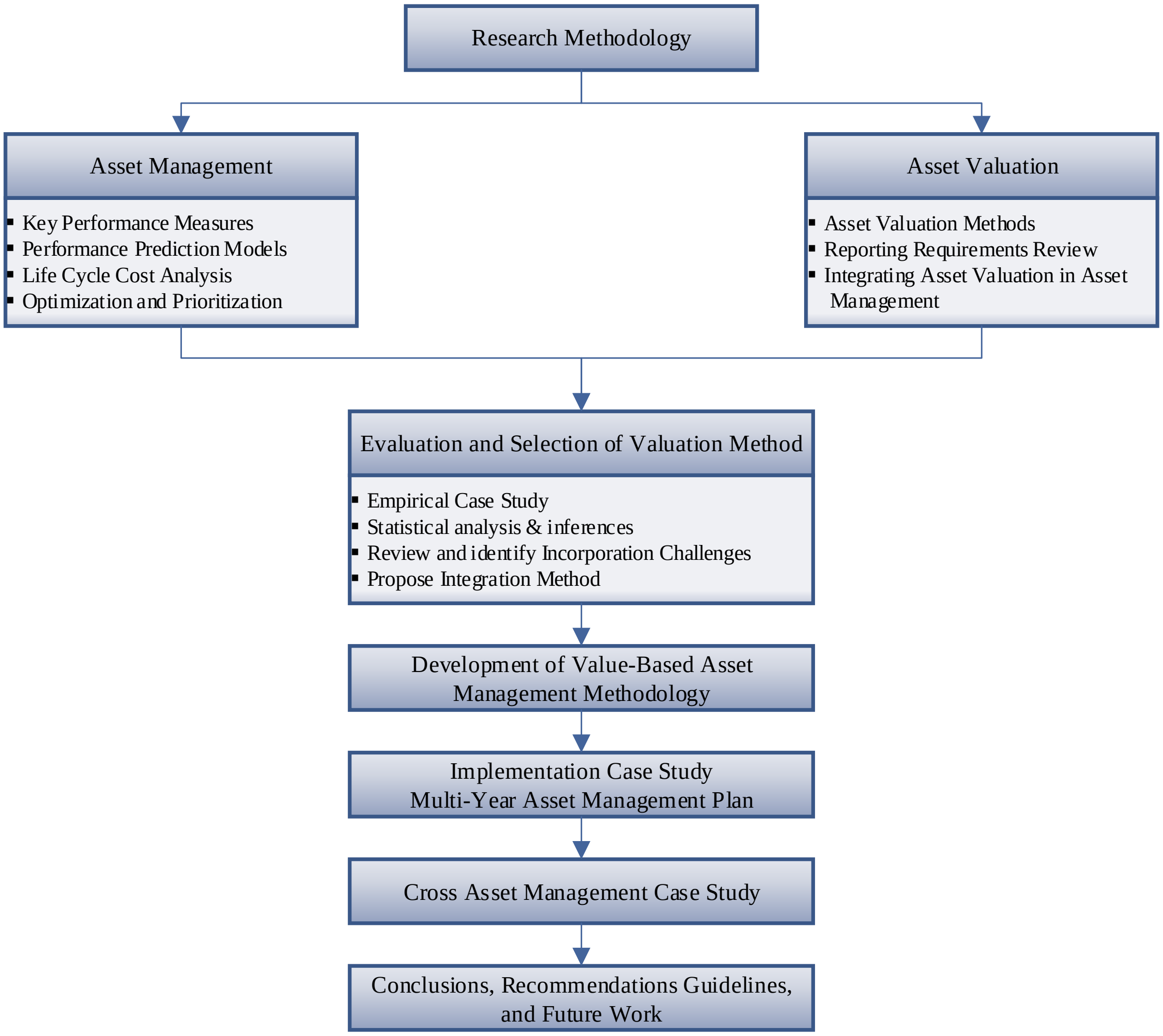


Figure 1.3 Research Methodology

A comprehensive review and analysis of common asset valuation methods is conducted. Using data from MTO's PMS2, a detailed comparative analysis is performed to evaluate and develop a methodology to integrate asset value in asset management state-of-the-practice.

Building on asset management state-of-the-practice, a methodology to incorporate asset valuation as a performance measure in asset management framework is developed. To do so, an Asset Value Index (AVI) that incorporates value-based performance measures is proposed. A case study using data from MTO's PMS is presented to demonstrate and evaluate the proposed methodology. Furthermore, a case study based on data obtained from the 7th International Conference of Managing Pavement Assets (ICMPA 7) is presented to illustrate the application of the proposed methodology for cross-asset management and trade-off. Finally, guidelines and reporting protocol are presented.

1.6 Thesis Organization

Chapter 1: The chapter provides an introduction to the research thesis, motivation and hypothesis of this research. In addition, this chapter presents the objectives, scope and methodology of this thesis.

Chapter 2: The chapter presents a comprehensive literature review of asset management and asset valuation in the context of asset management. In addition, key components of asset management systems are discussed including: performance measures, performance modeling, cross asset management, decision making and asset management in PPP.

Chapter 3: This chapter provides an overview of common valuation methods, application and analysis of values. Observation of the valuation methods and challenges are identified and presented.

Chapter 4: This chapter introduces valuation concept as an integration tool in asset management decision making. Furthermore, this chapter presents a framework for asset value reporting and specifications using the proposed concept.

Chapter 5: This chapter presents a conceptual asset management methodology that aims to arrive to an optimum value-based asset management plan of maintaining infrastructure assets taking into account budgetary and performance constraints.

Chapter 6: This chapter demonstrates the proposed methodology through a case study from the Ministry of Transportation of Ontario (MTO) second generation Pavement Management System (PMS2). An overview of MTO network is presented and analyzed. In addition, the various components of the proposed methodology are demonstrated through the case study.

Chapter 7: Building on the proposed methodology presented in Chapter 5 and Chapter 6, this chapter introduces a value-based cross asset management methodology. A case study of pavements and bridges based on data obtained from the 7th International Conference of Managing Pavement Assets (ICMPA 7) is used to illustrate the proposed methodology.

Chapter 8: This chapter presents research conclusions, contributions, and future research work.

Chapter 2
Literature Review

2.1 Asset Management Overview

Transportation asset management has gained momentum over the last two decades. Asset Management in basic terms is a systematic business process that employs strategic, engineering and economical means to provide a holistic approach to manage infrastructure assets to meet specified performance measures' level of services. There are many definitions of Asset Management in the literature; however, a widely used definition is that of the Federal Highway Administration (FHWA) US Department of Transportation (FHWA 1999), also adopted by Transportation Association Canada (TAC) (FHWA 1999; TAC 2013).

> "Asset management is a systematic process of maintaining, upgrading and operating physical assets cost-effectively. It combines sound business practices and economic theory, and it provides tools to facilitate a more organized logical approach to decision making. Thus, asset management provides a framework for handling both short- and long-range planning."

Other definitions of Asset Management include:

> "Strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their lifecycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision-making based upon quality information and well defined objectives" (NCHRP 2009);
>
> "A strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost.'' MAP 21 (US Department of Transportation 2012);

> “A systematic process of maintaining, upgrading and operating assets, combining engineering principles with sound business practice and economic rationale, and providing tools to facilitate a more organized and flexible approach to making the decisions necessary to achieve the public’s expectations” (OECD 2001);
>
> “Systematic and coordinated activities and practices of an organization to optimally and sustainably deliver on its objective through the cost-effective lifecycle management of assets” (IIMM 2011)
>
> “Asset management is the process of organizing, planning, designing and controlling the acquisition, care, refurbishment, and disposal of infrastructure and engineering assets to support the delivery of services. It is a systematic, structured process covering the whole life of physical assets.” (AAMCoG 2011);
>
> “Asset management is a strategic approach that identifies the optimal allocation of resources for the management, operation, preservation and enhancement of the highway infrastructure to meet the needs of current and future customers.”(Surveyors Society County 2004).

From the definitions, it can be noted that implementing asset management necessitates implementing sound business practices and economic theory. It can be viewed as a strategic system which all network management systems feed into (TAC 2013). It is a decision making tool or a framework that spans over an extended time horizon (FHWA 1999). In other words, implementing asset management is the development of business plans and programs of maintaining, upgrading and operating infrastructure assets over a specified time horizon. Therefore, as in any business practice, it is important to understand the value of the assets to be managed.

A generic framework is illustrated in TAC pavement design and management guide shown in Figure 2.1(TAC 2001, 2013). A widely used asset management system framework is that found in the FHWA Asset Management Premier shown in Figure 2.2 (Mahoney 1990).

An asset management system should be (Mahoney 1990):

- Customer focused
- Mission driven
- System oriented
- Long-term in outlook
- Accessible and user friendly
- Flexible

Asset management system should include (FHWA 1999):

- Strategic goals
- Inventory of assets (physical and human resources)
- Valuation of assets
- Quantitative condition and performance measures
- Measures of how well strategic goals are being met
- Usage information
- Performance-prediction capabilities
- Relational databases to integrate individual management systems
- Consideration of qualitative issues
- Links to the budget process
- Engineering and economic analysis tools
- Useful outputs, effectively presented
- Continuous feedback procedures

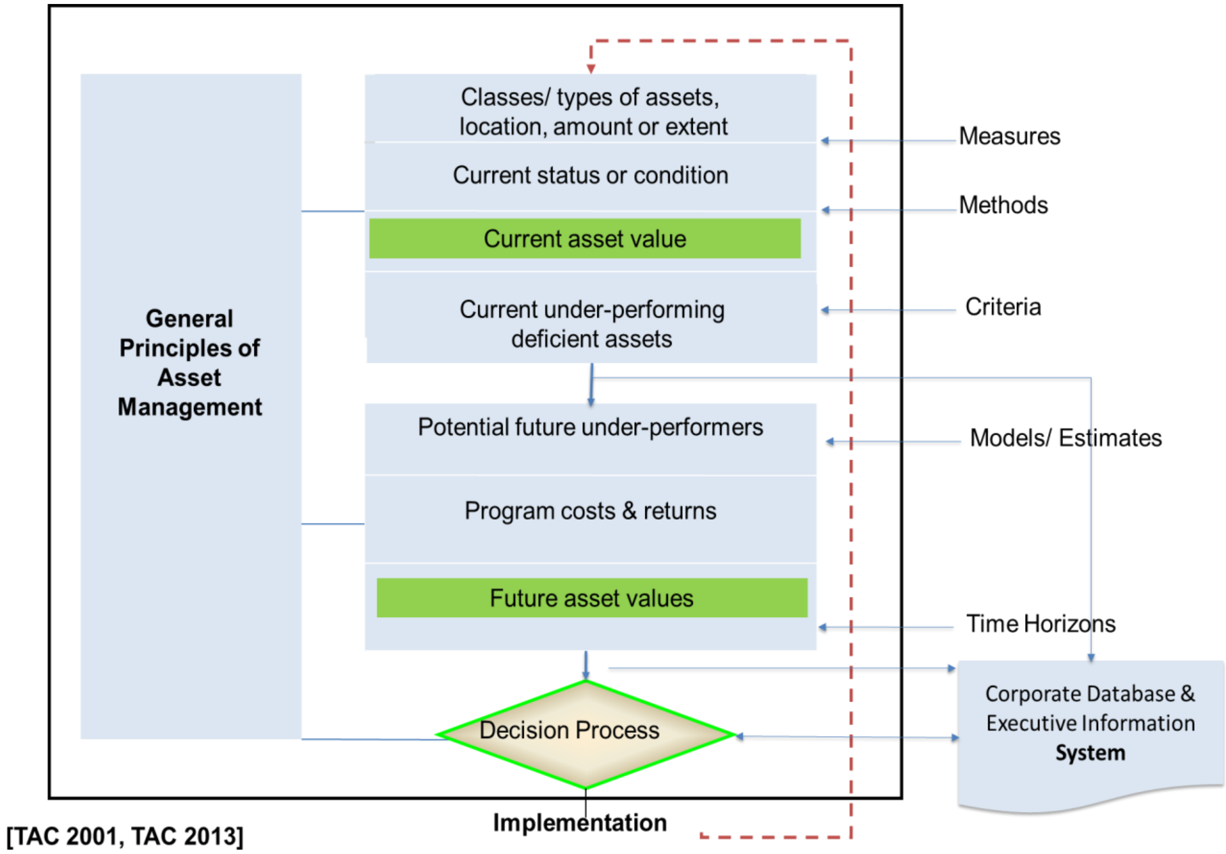


Figure 2.1 Overview Framework for Asset Management (TAC 2013)

Provided that the Asset management system is implemented, evaluated, updated and supported, the benefits of implementing asset management include, but are not limited to (TAC 1999, 2013):

- Effective tools for communication, coordination and information exchange within the agency and between management levels and asset types;
- Use of objective, measurable Key Performance Indicators (KPIs) for level of service, condition, safety, efficiency and productivity;
- Ability to estimate the impacts of different funding levels, or different standards, on level of service, condition and safety of the assets;
- A corporate database with access to data and information as needed;
- Use of state-of-the-art technologies and processes; and

- An environment for innovation, skills development and ongoing training.

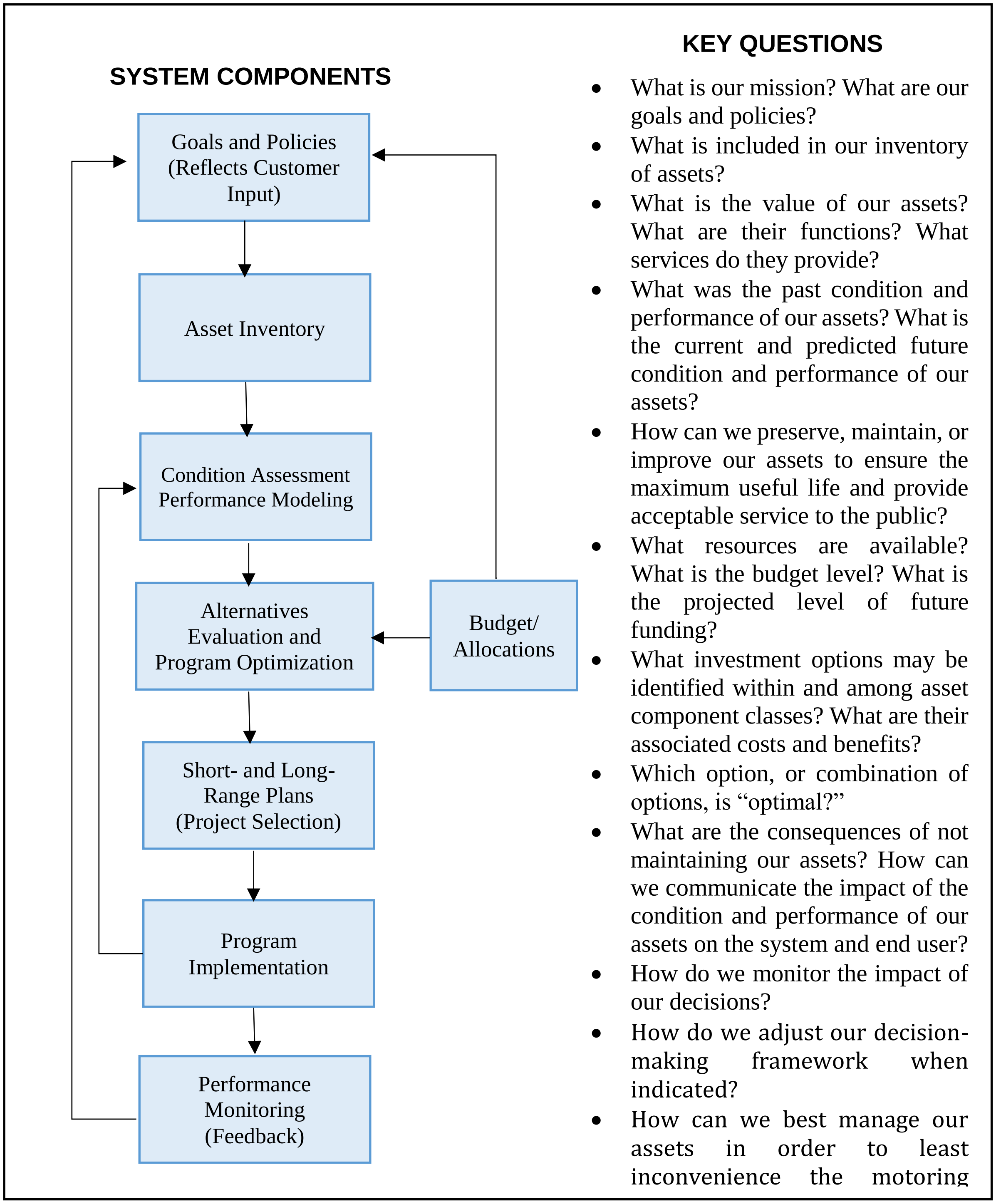


Figure 2.2 Asset Management Framework Overview (Adopted from FHWA 1999, TAC 2013)

2.2 Asset Valuation in the Context of Asset Management

Asset valuation is an essential component of effective asset management (TAC 2013). It provides a means for evaluating assets whose value is to be preserved or enhanced (Amekudzi et al. 2002b) by calculating the current and future asset values (Cowe Falls et al. 2004b). In addition, "Value does not exist in the abstract and must be addressed within the context of time, place, potential owners and potential users" (Smith and Parr 1989).

The American Institute of Real Estate Appraisers (AIREA) defines asset valuation as the process of estimating the value of a specific asset at a given date, and it measures the relative value or wealth of asset over time (AIREA 1987). Marston et al. defined asset valuation in the context of engineering as "the art of estimating the fair monetary measure of the desirability of ownership of specific properties for specific purpose…engineering valuation is the art of estimating the value of specific properties where professional engineering knowledge and judgment are essential. … based fundamentally upon [the asset's] ability to produce some kind of useful service during its expected future life in service...." (Marston et al. 1963).

There are two accounting bases of asset valuation: financial accounting and management accounting (Cowe Falls et al. 2001; PSAG 2007).

- Financial accounting, where historical cost (as built) is the preferred starting basis and current or book value which is established by depreciating or amortizing the historical cost.
- Management accounting, where current value is normally established on a written down replacement cost (WDRC) basis.

Asset valuation goes beyond accounting (financial reporting); it presents an engineering/ management accounting that can be used in the decision making such as evaluating various alternatives and associated benefits or liabilities.

There are various valuation methods that can be utilized to estimate infrastructure asset values such as book value, replacement cost, and written down replacement cost. Table 2.1 presents examples of asset valuation methods and basic definitions. It is recognized that there is no universally accepted method by the international community. However, it is noted that the book value, the replacement cost and the written down replacement cost methods are commonly used in highway infrastructure valuation (Cowe Falls et al. 2004b; Dewan and Smith 2005; McNeil et al. 2000; OECD 2000).

Table 2.1 Asset Valuation Methods and Basic Definition (Adapted from (Amekudzi et al. 2002b; TAC 2001)

Asset Valuation Method	Overview
Book Value	Present value based on historical costs depreciated to the present (commonly used for financial accounting purposes)
Replacement Cost	Present value based on cost of replacing/rebuilding the asset
Written Down Replacement Costs	Present value based on current replacement cost depreciated to asset's current condition (commonly used for management accounting purposes)
Equivalent Present Worth in Place	The worth "as is". The book value adjusted for inflation, depreciation, depletion and wear; i.e., the (accounts for changes in prices and usage; applicable to comparing with other investments)
Productivity Realized Value	The value in use. Net present value of benefit stream for remaining service life (provides a reflection of relative importance of the asset)
Market Value	Price buyer is willing to pay
Net Salvage Value	Cost to replace the facility less the cost of returning it to 'new condition' Cost of materials
Option Value	Value of asset in specific circumstances (Used by private sector)

Asset valuation methods can be classified according to the time frame for asset valuation into past-based, current-based, and future-based methods (Amekudzi et al. 2002b; Cowe Falls et al. 2004b). Past-based asset valuation methods use historical expenditures to determine the asset value, such as book value / historical costs (BV/HC). Current-based methods use current data to determine the value, such as replacement cost (RC), written down replacement cost (WDRC), etc. Future-based methods use future data, such as productivity realized market value, salvage value (see Figure 2.3).

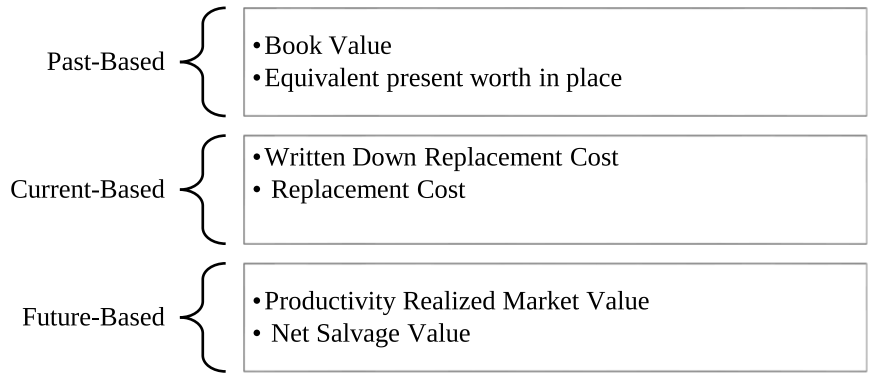


Figure 2.3 Asset Valuation Classification and Examples

In addition to the methods presented above, other methods include: option value, cost approach, and relative value. Table 2.2 summarizes the various asset valuation methods highlighting some of the advantages and disadvantages of the valuation methods.

Table 2.2 Evaluation of Various Asset Valuation Methods (C 1998; Cowe Falls et al. 2004b)

Method	Features	Pros	Cons
Book Value BV	-Commonly used for financial accounting purposes -Uses historical records of procurement (first cost plus any subsequent costs), depreciated to present worth -Provides direct comparisons in time series progressions	- Data are generally available. -Relatively simple	-Does not account for changes in prices. -Neglects usage. -Neglects technology and service standard changes. - Results can be misleading for older assets such as bridges, land.
Replacement Cost	Commonly used by public agencies for underground services (water distribution, storm and sanitary sewers), and various public infrastructure	-Quite straightforward to calculate -Can be communicated and understood easily	-Can be misrepresentative (eg. relatively new asset in good condition would be worth the same as an old, deteriorated asset)
Written Down Replacement Cost WDRC	- Commonly used for management accounting purposes - Uses current market prices to rebuild/replace - Current condition used to establish write down value	-Reflects current prices and technology - Easily understandable - Can compare assets - Basics for budgeting	- Conjectural on replacement costs (subject to external market forces) - Question of how to handle an upgraded/ improved replacement

Method	Features	Pros	Cons
Equivalent Present Worth In Place EPWP	- Accounts for changes in prices and usage - Represents worth "as is" - Applicable to comparing with other investments - Based on historic costs adjusted for inflation, depreciation, depletion and wear	- Uses generally available data - Accounts for changes in prices and usage - Useful for comparing rates of return with other investments - Basis for budgeting, especially maintenance, within life cycle analysis	- Neglects changes in technology and service standards - Requires a number of conjectural assumptions
Productivity Realized Value PRV	- Represents value in use (what it is worth not to lose it) - Reflects relative importance of the asset	- Realistic reflection of importance of the asset - Basis for budgeting	- Requires various assumptions and non-market estimates - Subject to market forces, in particular, supply and demand if parallel service exists
Market Value MV	- Price buyer is willing to pay	- Simple concept - Applicable to public agency disposal or sell off of assets	- Conjectural until offer is actually received - Limited applicability (e.g., few highway agencies sell assets) - Volatile as it is subject to market forces
Net Salvage Value	Represents value of materials including disposal costs	-Uses generally available data	-Difficult to predict future construction prices -Subject to market forces, in particular, supply and demand if parallel service exists

Other research efforts were conducted to develop or modify the asset valuation methods. Porras-Alvarado et al. developed a methodology that takes into account social and economic factors to increase or decrease asset value based on the replacement cost method (Porras-Alvarado et al. 2015). Dojutrek et al. proposed three different methods to establish asset value including: elemental decomposition and multi-criteria (EDMC), replacement-downtime-salvage (RDS) method, and decommission-and-reuse (D&R) method (2012). The EDMC method establishes asset value based on cost, remaining service life, and the condition of the individual components of an asset. The RDS method considers only the life-cycle costs, including user cost during work zones and recycling benefits or disposal costs. The D&R method establishes value based on the real-estate value of the land occupied by the asset.

In the transportation infrastructures context, asset valuation- or asset management in general, are implemented to fixed and unfixed tangible assets within or out of the right of way (ROW) (TAC 2013; TAC 2001). Example of fixed assets within the ROW include: pavements, bridges, signs, signals, and so on. Fixed and unfixed assets out of the ROW include: maintenance depots (Ex. salt sheds and fuel tanks), material stockpiles, laboratories, communication equipment, computer hardware and other such assets. In addition, Haas and Raymond identified other non-tangible assets such as intellectual property, land, etc. (Ralph Haas 1999) Table 2.3.

Table 2.3 Fixed and Unfixed Tangible Assets Within Or Out Of the ROW (Haas and Raymond 1999)

Category	Asset
Fixed Assets (Within R.O.W)	Pavement
	Bridges
	Drainage Structures
	R.O.W. (land and landscaping/vegetation)
	Grading (Cut/Fill)
	Signs
	Signals and Loop Detectors
	FTMS Cameras E Guiderail and Barrier Wall
	CA Fences and Noise Barrier
	KA Culverts
	Pavement Markings
	Lighting
	Sidewalks (including bike paths)
	Curb and Gutter
	Utilities (Cable, Hydro, Gas, Phone, Water)
	Weigh Scales and Weigh in Motion Devices
Unfixed & Fixed Assets (Outside R.O.W	Quarries and Pits
	Yards etc. (e.g. Regional or District Buildings, Salt Sheds, Fuel Tanks etc.)
	Buildings (Central Offices)
	Material Stockpiles
	Laboratories
	Communication Equipment
	Computer Hardware
	Vehicles and Equipment
	Parts Inventory
Other Assets	Human Resources
	Intellectual Property (software, libraries, guidelines, methods, procedures, and data)
	Organization/Management Structure
	Image/Goodwill
	Cash/liquidity

2.2.1 Reporting Requirements

Agencies are required to account and report their tangible capital asset values in their financial statements and balance sheets. Of particular interest to this research is the Canadian Public Sector Accounting and Auditing Board (PSAAB) requirements and the Government Accounting Standard Board (GASB) in the United States.

The Canadian Institute of Chartered Accounts (CICA) has a comprehensive "Public Sector Accounting and Auditing Handbook" (CICA 1998), which indicates that "Financial statements are prepared by a government to report on its financial condition and result of operations … information required to make assessments of and judgments on government financial operations and management." Also, it indicates that "Financial statements should include … a statement of tangible capital assets … and the change in that investment in the period." Section PS 1350 defines tangible assets as: non-financial assets having physical substance that: a) are held for use in the production or supply of goods and services, for rental to others, for administrative purposes or for the development, construction, maintenance or repair of other tangible capital assets; b) have useful economic lives extending beyond an accounting period; c) are used on a continuing basis; and d) are not for resale in the ordinary course of operations. (PS 3150.05). The CICA has suggested that asset valuation should be based upon net book value for both financial and management accounting: "Governments that use the expenditure basis of accounting … a statement of tangible capital assets that reports the net book value… Governments that use the expense basis of accounting should… report the net book value…."

GASB Statement No. 34 in 1999, "Basic Financial Statements for State and Local Governments" requires state and local agencies to report the value of the assets they own (GASB 1999). GASB requires that the value may be reported as the historical cost minus depreciation, or using a modified approach (Amekudzi et al. 2002; McNeil 2000). GASB modified approach is that infrastructure assets are not required to be depreciated if:

- The government managing those assets is using an asset management system that has certain characteristics
- The government can document that the assets are being preserved approximately at (or above) a condition level established and disclosed by the government.

"Qualifying governments will make disclosures about infrastructure assets in Required Supplementary Information (RSI), including the physical condition of the assets and the amounts spent to maintain and preserve them over time." (McNeil 2000)

2.2.2 Integrating Asset Valuation in Asset Management

Several research activities have been undertaken in an effort to integrate asset valuation to the existing asset management practices. Cowe Falls et al. introduced an asset valuation framework for highway assets, Figure 2.4, which follows the asset management framework of Figure 2.1 (Cowe Falls et al. 2001). The proposed framework suggests that in order to estimate the current asset value, the following questions are to be addressed: What assets do we have and where are they? What is their condition or status? What valuation method should be used and what is their value?"(Cowe Falls et al. 2001)

Herabat et al. introduced the application of cost-based approach for pavement asset valuation integration with pavement management system, Figure 2.5 (2002). The framework and the cost approach were applied on the Thailand Pavement Management System (PMS). The generic cost approach is applied based on replacement costs and accrued depreciation over time. The cost approach captures the value of pavements based on their performance, which deteriorates over time, as well as the impacts of different maintenance activities applied to the pavements and other relevant variables such as the cost of materials, gasoline prices, and traffic volume. It was concluded that the cost approach focuses more on accounting principles than on economic principles; however, it is imperative that pavement valuation methods extend to include economic principles as well (Herabat et al. 2002).

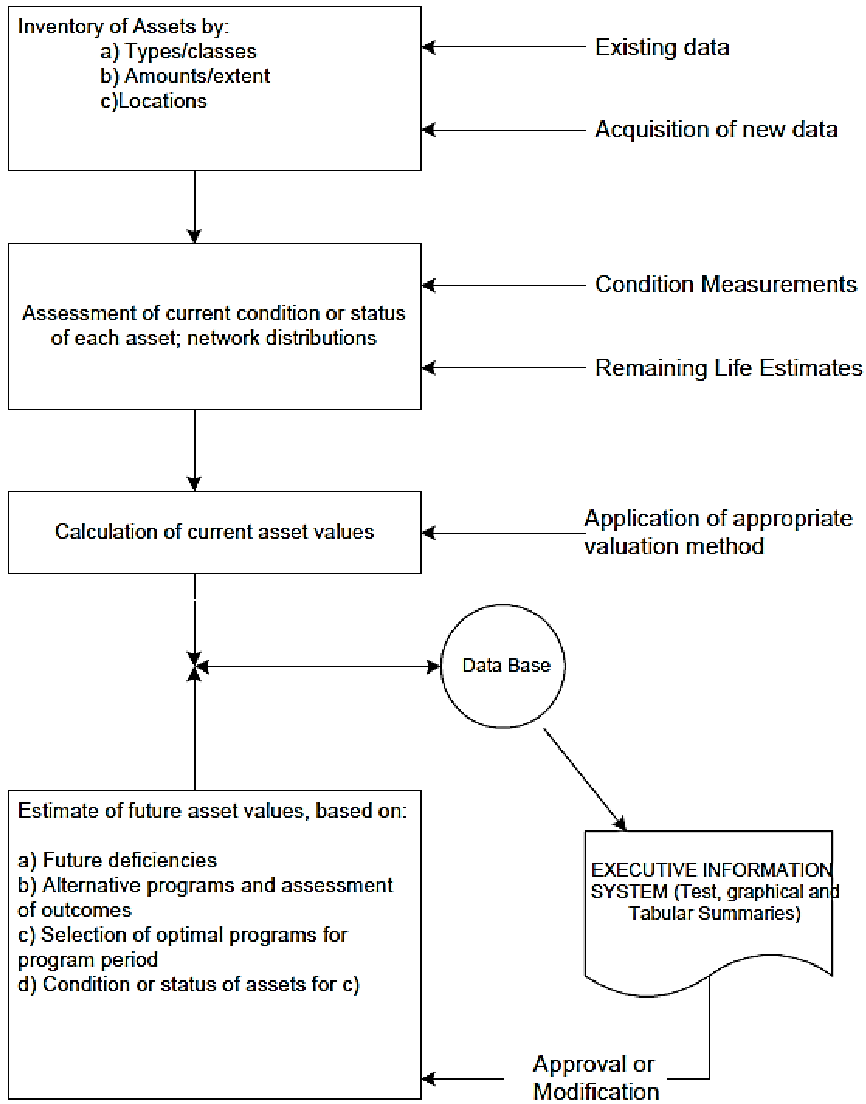


Figure 2.4 Asset Valuation Framework (Cowe Falls et al. 2001)

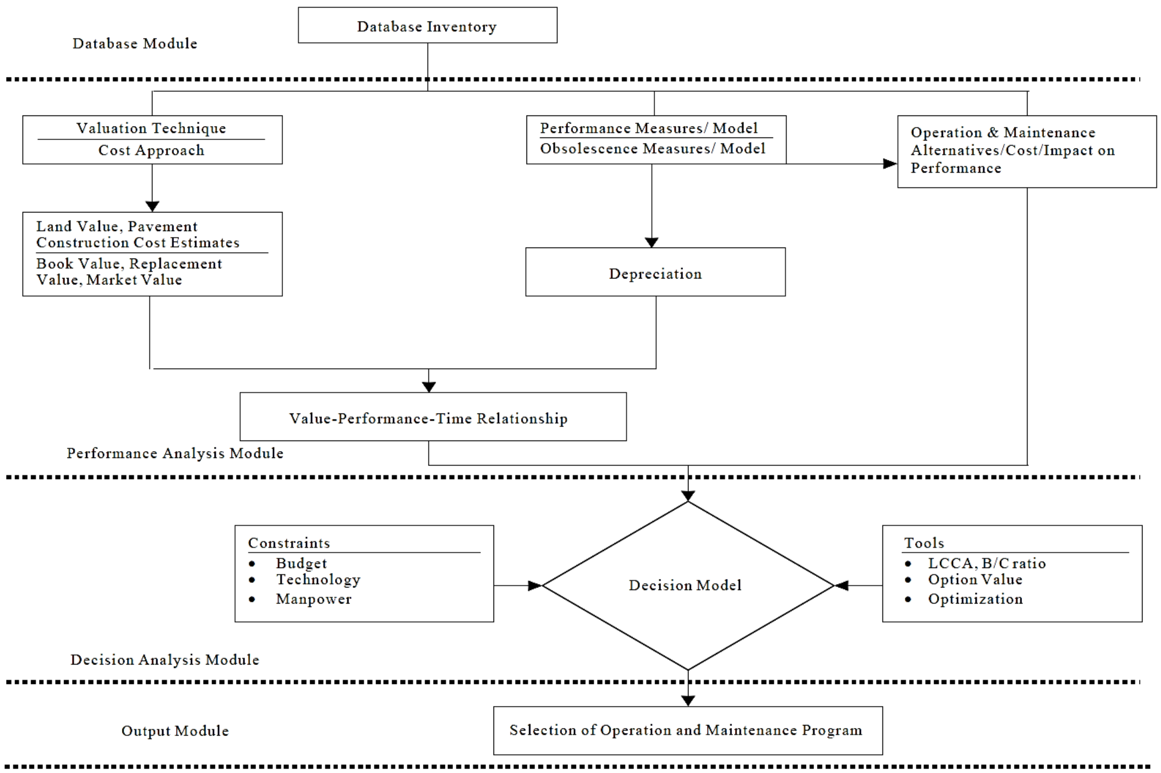


Figure 2.5 Integration of Cost Approach Valuation in Pavement Management Systems (Herabat et al. 2002)

Cowe Falls et al. introduced the concept of Asset Service Index (ASI) as a potential integration mechanism in asset management systems (2006). The index is calculated as the deviations from the expected value as a result of neglect, or changes in use that could accelerate or decelerate deterioration. ASI would be reported as a plus value indicating over-performing or a minus value indicating underperforming. The concept of the ASI is illustrated in Figure 2.6. The asset condition is represented in terms of remaining service life (RSL) by comparison either with the predicted point at which the condition reaches a minimum acceptable level or with age and adjusted by the replacement cost (RC). The ASI index is calculated as follows (Cowe Falls et al. 2006):

$$ASI = [(RC) * RSL/ EL]_{Actual} - [(RC) * RSL/ EL]_{model} \qquad \text{Equation 2.1}$$

Where; RC = replacement cost, RSL = remaining service life, and EL = expected life

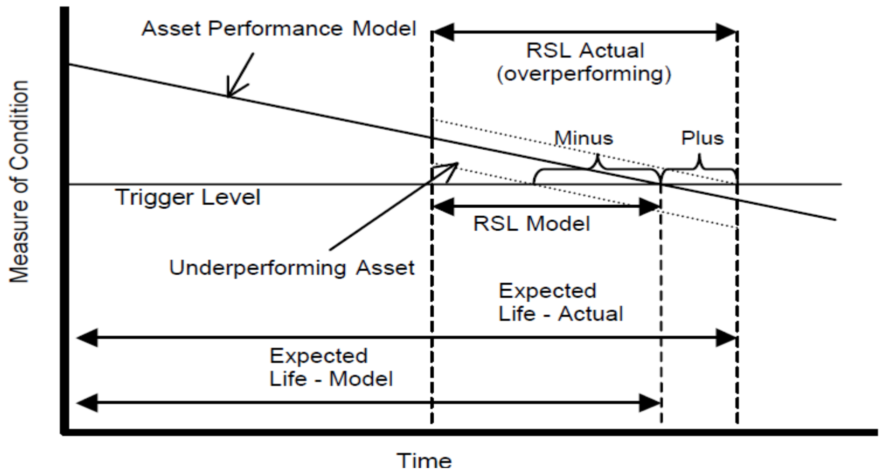


Figure 2.6 Asset Service Index Concept (Cowe Falls et al. 2006)

Li et al. studied the impact of using alternative performance measures in pavement condition assessment and valuation of pavement assets using Ministry of Transportation of Ontario Pavement Management System (2014). The performance measures studied include Pavement Condition Index (PCI), Riding Comfort Index (RCI) and Distress Manifestation Index (DMI). The study concluded that using alternative performance measures resulted in variation impact to the network evaluation and maintenance programing including the current and future conditions, identifying rehabilitation needs, and calculating asset values (Li et al. 2014).

The Transportation Research Board (TRB) issued a research need statement highlighting the need to develop standard calculation methodologies to characterize the asset value for use in funding allocation, life cycle cost analysis and engineering evaluation (TRB 2016).

2.3 Performance Measures

Performance measurement represents a very important underpinning of successful application of Asset Management (Cambridge Systematics et al. 2006). Effective asset management requires performance measures that are objectively based, consistent, quantifiable and sensitive to changes in technology or policy. Moreover, the performance measures should incorporate institutional, economic, environmental, safety, technical and functional considerations, as well as user expectations (TAC 2013).

Asset management decision making is guided by its performance measures and the associated targets or thresholds. Therefore, it is important that the required performance measures and the associated level of service to be achieved are properly identified. Figure 2.7 presents a hierarchical framework to derive practical and usable performance measures linked to realistic policy objectives.

Lichiello in his Guidebook for Performance Measurement has defined performance measurement as "the specific representation of a capacity, process, or outcome deemed relevant to the assessment of performance. A performance measure is quantifiable and can be documented." (Lichiello and Turnock 2002). For a performance measure to be effective, the following questions should be considered (SAIC 2006):

- Is the performance measure specific?
- Is the performance measure measurable?
- Is the performance measure achievable?
- Is the performance measure results oriented?
- Is the performance measure timely?
- Does the measurement meet with the agency's objectives and desires?
- Has the performance been measured before?
- Dose the measurement conflict with the agency's standard specifications?
- Does the measurement aim to improve performance?

Figure 2.7 Hierarchical Structure Linking Policy Objectives to Performance Indicators and Implementation Targets (Adopted from Haas et al. 2009)

2.4 Performance Modeling

The management of assets over time horizon involves development of optimized multi-year plans for the maintenance and rehabilitation utilizing the available funds. To develop these plans, it is important not only to understand the current condition of the complete network, but also to understand how their condition will change over time (TAC 2013).

Performance modeling as a means of studying the feasibility of different maintenance and rehabilitation activities gained some attention among agencies and researchers (Haas et al. 1994; Li 2005; Panthi 2009; TAC 1997, 2013). It is used to predict performance and deterioration of assets as a function of time, and therefore, predict service life of said asset. Various types of distress, such as roughness, rutting, etc., or indexes based on combinations of such distresses such as Bridge National Index (BNI) and Pavement Condition Index (PCI), can be used as input for these models (FHWA 2002a). Figure 2.8 illustrates how performance modeling is used to predict future deterioration of pavement, expected improvements due to application of maintenance or rehabilitation activity and determining the "need year" of application.

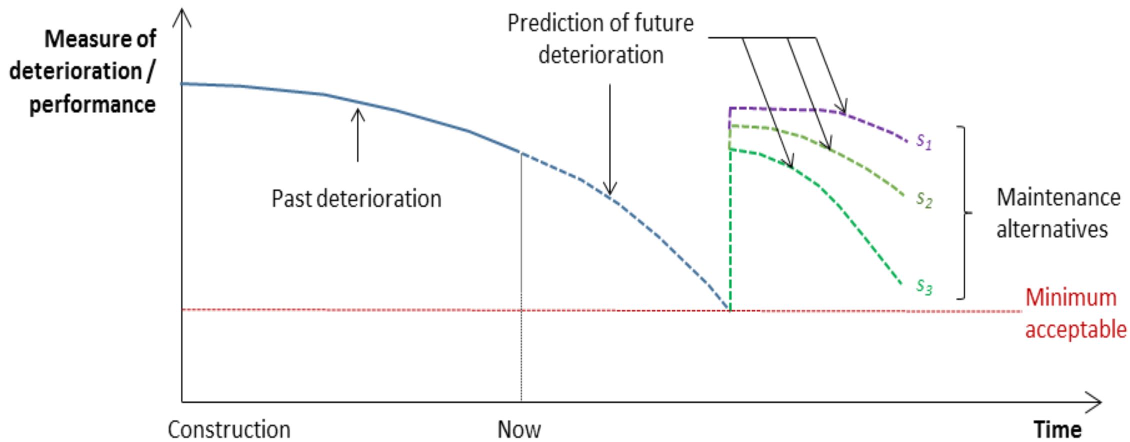


Figure 2.8 Deterioration Modeling and Impact of Maintenance or Rehabilitation Activities on Pavement (adopted from FHWA 2002a)

There are various deterioration models proposed in the literature. Based on the modeling approach, performance modeling is classified into four groups (Haas et al. 1994; TAC 1997, 2013): Mechanistic, Empirical, Mechanistic-Empirical, and Subjective. Table 2.4 summarizes the four types.

Furthermore, deterioration models can be generally classified into two groups according to the techniques they use, including: deterministic and probabilistic. (FHWA 2002a; Haas et al. 1994; Li 1997, 2005; Mahoney 1990; Moynihan et al. 2009). For the deterministic models, a condition is predicted as a precise value on the basis of the mathematical function of observed conditions (Robinson and McDonald 1991) and the future condition of a pavement section is predicted as the exact serviceability value or pavement condition index with the past information of the pavement (Durango 2002). On the other hand, the probabilistic models predict the performance of a pavement by predicting the probability of when the pavement would fall into a particular condition state (Durango 2002). Most deterministic models in the literature are classified to be mechanistic or empirical and they include primary response, structural performance, functional performance, and damage models (FHWA 2002a; Mahoney 1990). Probabilistic model examples include survival curves and Markov process models shown in Table 2.5.

Table 2.4 Deterioration Modeling Approaches (Adopted from TAC 1997)

Modeling Approach	Description
Mechanistic	Based on some primary response behavior such as stress, strain, etc.
Empirical	Using regression, where the dependent variable of observed or measured structural or functional deterioration is related to one or more independent variables like subgrade strength, axle load applications, pavement layers thicknesses and properties, environmental factors, and their interaction.
Mechanistic-Empirical	Where measured structural or functional deterioration, such as distress or roughness, is related to a response parameter through a transfer function or regression equations
Subjective	Or probabilistic, where experience is "captured" in a formalized or structure way, using semi-Monrovian transition process models, or Bayesian, for example, to develop deterioration prediction models

Table 2.5 Types of Performance Models (Adopted from (FHWA 2002a)**)**

<table>
<tr><th colspan="4">Deterministic Models</th><th colspan="3">Probabilistic Models</th></tr>
<tr><td rowspan="2">Primary Response
• Deflection
• Stress
• Strain
• Etc.</td><td rowspan="2">Structural
• Distress
• Pavement Condition</td><td rowspan="2">Functional
• PSI
• Safety
• Etc.</td><td rowspan="2">Damage
• Load Equivalent</td><td rowspan="2">Survivor Curve</td><td colspan="2">Transition Process Models</td></tr>
<tr><td>Markov</td><td>Semi- Markov</td></tr>
</table>

Deterministic models are developed using regression, empirical, and combined mechanistic-empirical methods. The selection of a mathematical form to be used for the pavement performance models must fit the observed data and the regression-statistical analysis (Li 1997). A common feature among different types of deterministic models is that they have usually been developed using a large number of long term observed field data and processed through regression analysis (Li 1997).

On the other hand, most probabilistic models are developed to characterize the uncertain behavior of pavement deterioration processes (Li 2005; Panthi 2009). The Markov model has proved to be an effective performance modeling tool among various researchers (Butt et al. 1987; Haas et al. 1994; Li 1997; Madanat et al. 1995; Tighe 1997). The Markov model is commonly used based on its ability to capture the probabilistic behavior of pavement and the time dependent uncertainty deterioration process as well as for different maintenance and rehabilitation activities (Panthi 2009). The model is based on the change of a pavement from a given state to another over a period of time. The Markov model is classified, according to various assumptions, as homogeneous and non-homogeneous. The homogenous Markov model assumes that variables (such as load, traffic, environment, etc.) are constant throughout the analysis period (Li 1997). On the other hand, non-homogenous Markov models consider the rate of change incurred at each different stage. Markov chain models are developed using time-based (estimate the probability of time needed to transition from one state to another) or state-based models (estimate the probability of transition from one state to another in a predetermined period of time). The different types of models along with advantages and disadvantages are presented in Table 2.6.

Table 2.6 Advantages and Disadvantages of Different Models (adopted from Panthi 2009)

Model	Advantages	Disadvantages
Regression	• Microcomputer software packages are now widely available for analysis which makes modeling easy and less time consuming • These models can be easily installed in a PMS • Models take less time and storage to run	• Needs large database for a better model. • Works only within the range of input data • Faulty data sometimes get mixed up and induces poor prediction. Needs data censorship • Selection of proper form is difficult and time taking
Survivor Curve	• Comparatively easy to develop • It is simpler as it gives only the probability of failure corresponding to pavement age	• Considerable error may be expected if small group of units are used
Markov	• Provides a convenient way to incorporate data feedback • reflects performance trends regardless of non- trends	• No ready made software is available • Past performance has no influence • It does not provide guidance on physical factors which contribute to change • Needs large computer storage and time

Model	Advantages	Disadvantages
Semi-Markov	• Can be developed solely on subjective inputs • Needs much less field data • Provides a convenient way to incorporate data feedback • Past performance can be used	• No ready-made software is available • Needs large computer storage
Mechanistic	• Prediction is based on cause and- effect relationship, hence gives the best result	• Needs maximum computer power, storage and time • Uses large number of variables (e.g. material properties, environment conditions, geometric elements, loading characteristics etc.) • Predicts only basic material • Responses
Mechanistic-empirical	• Primarily based on cause- and- effect relationship, hence its prediction is better • Easy to work with the final empirical model • Needs less computer power and time	• Depends on field data for the development of empirical model • Does not lend itself to subjective inputs • Works within a fixed domain of independent variable • Generally works with large number of input variables (material properties, environment conditions, geometric elements, etc.) which are often not available in a PMS
Bayesian	• Can be developed from past experience and limited field data • Simpler than Markov and • Semi-Markov models • Can be suitably enhanced using feedback data	• May not consider mechanistic behavior • Improper judgment can lead to erroneous model

2.5 Priority Programming and Optimization

"Needs analysis, priority programming and decision making for pavement preservation and rehabilitation should be integrated into a yearly management cycle of network inventory update, condition analyses, planning, budgeting, engineering and implementation activities" (Tighe and Hass 2001).

Selection of feasible maintenance, preservation and rehabilitation treatment alternatives can be based on engineering judgment, local experience or agency policies (TAC 1997). These decisions are commonly incorporated into pavement management systems using decision trees or other expert systems such as neural networks (TAC 2013).

In pavement management systems, priority programing involves four steps: Integrating information, identification of needs, priority analysis, and output reports. Various priority programming methods are established ranging from simple to more complex mathematical programming (Haas et al. 1994). Table 2.7 indicates the different classes of methods and some advantages and disadvantages.

Table 2.7 Classes of Priority Programming Methods (Haas et al. 1994)

Class of Method	Advantages and Disadvantages
Simple subjective ranking of projects based on judgment	Quick, simple; subject to bias and inconsistency; may be far from optimal
Ranking based on parameters, such as serviceability, deflection, etc.	Simple and easy to use; maybe far from optimal
Ranking based on parameters with economic analysis	Reasonably simple; should be closer to optimal
Optimization by mathematical programming model for year-by-year basis	Less simple; maybe close to optimal, effects of timing is not considered
Near optimization using heuristic and marginal cost-effectiveness	Reasonably simple; can be used in a microcomputer environment, close to optimal results
Comprehensive optimization by mathematical programming model taking into account the effects	Most complex; can give optimal program (max. of benefits)

Many transportation agencies have successfully implemented planning and prioritization of needs, incorporating incremental cost-effectiveness analysis, on large highway networks (TAC 2013). The analysis of the feasibility of different treatment alternatives involves three major elements:

- Selection of alternatives that are feasible, which depends on various factors such as the condition, geometric constrains, type of pavement, etc.
- Prediction of deterioration of the treatments

- Identifying associated cost, or cost benefit analysis, cost effectiveness, etc.

Optimization is a branch of mathematics concerned with finding the optimum alternative to complex problems in accordance with established objectives and constraints (Thompson 1994). The optimization method is used to select alternatives to satisfy a specific objective function that is subject to certain constrains. The formulation of these models varies from optimization and dynamic optimization (Haas et al. 1994).

2.6 Multi-Criteria Decision Making Methods in Asset Management

Asset managers and decision makers are faced with the challenge of managing assets based on competing performance measures and LOSs for different asset categories. That is due to (Bai et al. 2008) : 1) the different management systems (or program areas) have their particular performance criteria, 2) projects in each asset category may have additional impact types besides the dominant performance criterion for that system. Various methods are available to address such problems including: Analytical Hierarchy Process (AHP) and Multi-Attribute Utility Theory (MAUT).

2.6.1 Analytical Hierarchy Process

The AHP method is a theory of relative measurements of intangible criteria (Saaty 1980). The AHP is a Multi-Criteria Decision Making (MCDM) process that can consider both quantitative and qualitative factors. Various researchers used the AHP method asset management to prioritize maintenance and rehabilitation alternatives for infrastructure assets (Abu Dabous and Alkass 2008; Farhan and Fwa 2009, 2011; Ramadhan et al. 1999; Smith and Tighe 2006). In addition, the AHP method is usually applied to establish the relative weights for different decision criteria (Sharma et al. 2008).

2.6.2 Multi-Attribute Utility Theory

Multi-Attribute Utility Theory (MAUT) method is widely used in the area of asset management (Bai et al. 2008; Van Dam and Thurston 1994; Porras-Alvarado et al. 2015; Pudney 2010). The MAUT method was developed by Keeney and Raiffa (1976) based on Neumann and Morgenstern utility theory (Von Neumann, J., & Morgenstern 1947). MAUT is a systematic, theoretically based decision-making process (Van Dam and Thurston 1994). It is a mathematical framework for analyzing and quantifying choices involving multiple competing outcomes using utility theory. The axioms states the following (Van Dam and Thurston 1994; Keeney and Raiffa 1976; Von Neumann, J., & Morgenstern 1947):

- Preferences exist and are transitive,
- Preference is monotonic over the domain of interest,
- Probabilities of outcomes exist and can be quantified,
- Preferences are linear with probability,
- Ranking of preferences over any pair of attributes is independent of the other attributes, and the utility function is independent

In asset management decision making, performance measures are of different measurement units; for example, Pavement Condition Index (PCI), Annual Average Daily Traffic (AADT), etc. The MAUT is a great candidate that can unify the units through the use of the utility functions (Keeney and Raiffa 1976; Labi 2014). Therefore, a vital component of this method is the development of utility functions of the various performance measures. Utility is a way of establishing value through ranking the order of relative preference between sets of consequences (De Neufville 1990). In other words, utility functions captures the decision-makers' preferences regarding the levels of each decision criterion (Keeney and Raiffa 1976; Labi 2014). Scaling techniques are used to develop utility functions for the performance criteria. Scaling methods can be classified as non-preference-based methods, and preference-based methods (Labi 2014). Non-preference-based methods include rudimentary techniques, linear scaling, and monetization, while preference-based methods include direct rating method (Labi 2014). Scaling (normalizing) of all possible outcomes for each performance measure is performed separately. Typically, utility functions take shapes of monotonically-increasing, monotonically-decreasing, concave and convex (Bai et al. 2008; Labi 2014) Figure 2.9.

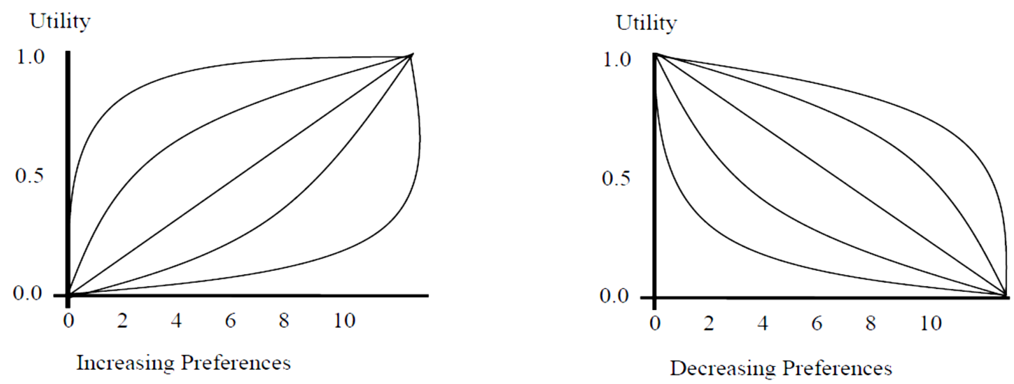


Figure 2.9 Typical Utility Functions Shapes

2.7 Cross- Assets Management

Agencies have traditionally made investment decisions for individual assets separately. Independent management systems have traditionally been developed to manage assets; in particular pavements and bridges, the two main transportation assets (TAC 2013). Therefore, Pavement Management Systems (PMSs) and Bridge Management Systems (BMSs) are often operated separately. This lack of integration between management systems may be due to restrictions associated with funding and/or limitations of the agency's ability to compare data objectively across asset types (Proctor and Zimmerman 2015). Deciding how best to allocate limited resources across these various asset classes to provide acceptable performance poses a persistent and difficult challenge for agencies.

A recent report published by AASHTO (Proctor and Zimmerman 2015) identified three levels of cross-asset management that differ in their complexity and quantified sophistication: cross-asset trade-offs, cross-asset allocation, and cross-asset optimization. Cross-asset trade-offs represent the simplest and most common of the three concepts. Under this approach, resources are transferred between asset classes in order to maximize perceived utility. In this definition it is important to highlight that utility is perceived and not measured nor quantified. This means that although cross-asset trade-offs can be data-driven, it is somewhat informal and dependent upon the judgment of a few individuals. Cross-asset allocation is the next most sophisticated decision process, as it relies on a simultaneous quantification of benefits of asset classes. Under this approach, all the investment candidates in the different asset classes will be assessed and ranked using a common benefit indicator. Some of the indicators that could be used in this evaluation are benefit/cost ratio, multi-criteria decision analysis and risk/reward-based allocation. Finally, cross-asset optimization represents a further refinement of cross-asset allocation. By using recursive mathematical computations, cross-asset optimization determines the maximum utility for a given set of investments constrained by a set of performance parameters (Proctor and Zimmerman 2015).

Previous studies have attempted to analyze different approaches for optimal cross-asset allocation. Fwa and Farhan (2012) proposed a two-stage optimization process. In the first stage, an individual asset system optimization was performed searching minimal maintenance cost for each asset class. The set of solutions obtained for each asset class will then be considered in a second optimization stage dealing with the cross-asset allocation. The objective of the second optimization stage is to achieve an equitable allocation of the budget by maintaining equivalent amounts of performance improvements between asset classes. In this two-stages optimization, Fwa and Farhan (2012) considered different performance indexes for each asset class (e.g. PCI for pavements and BHI for bridges) and searched for an equitable allocation of the budget by minimizing the gap between each asset class condition and their threshold performance. Dehghani et al. (2013) proposed a cross-asset resource allocation framework that considers functional, structural and environmental performance indicators to estimate the optimal budget to invest in each asset. When applying this framework, Dehghani et al. (2013) found that the weights assigned to each indicator changed the optimal resource allocation. Wang and Chou (2015) proposed an optimization model considering integer and constraint programming aimed to optimize project scheduling by coordinating projects among different assets. In this application, the objective was to maximize the total benefits of the projects, assessed in terms of the asset condition and the vehicle operating cost. In order to integrate different assets in this optimization process, Wang and Chou (2015) considered a common condition index based on a five-point scale, named asset condition index (ACI) for all the asset classes. The main limitation of implementing this approach is that transportation agencies are currently using different and independent performance indexes for each asset class (Alyami et al. 2017).

2.8 Asset Management in Public Private Partnership

Over the past two decades, there has been a moment towards the Public Private Partnership (PPP) contract model for delivery of large-scale capital projects (Abdel Aziz 2007; FHWA 2005; Johnston et al. 2015; Siemiatycki 2009). In Canada, between 1990 and 2016, about 245 PPP projects has been constructed or are in the planning and delivery stages; 58 of which are in the transportation sector (CCPPP 2016a), Figure 2.10.

The Canadian Council of Public Private Partnership (CCPP) define PPP as follows (CCPPP 2016b): "A cooperative venture between the public and private sectors, built on the expertise of each partner, that best meets clearly defined public needs through the appropriate allocation of resources, risks and rewards."

Agencies may use PPP contracts for project delivery, or to carry asset management, as a means to transfer risk, expedite delivery and take advantage of economies of scale (TAC 2013). There are various types of contracts under the PPP model ranging from Design-Build (DB) to full privatizations (CCPPP 2016b; Fathali and Ibrahim 2015; Grimsey and Lewis 2004). The type of contracts can be classified based on the extent of the public and the private involvement and the degree of risk allocations as shown in Figure 2.11 (CCPPP 2016b).

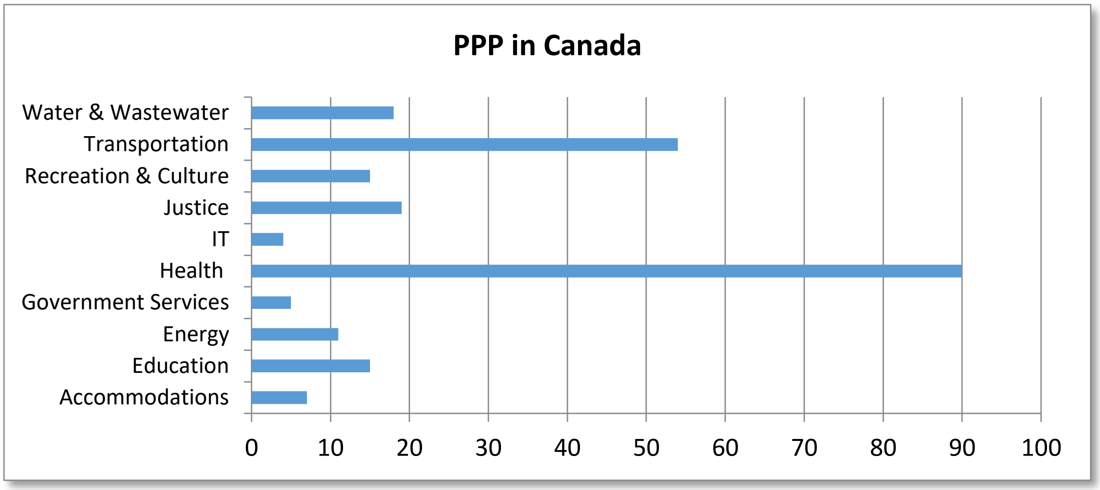


Figure 2.10 Canadian PPP Projects by Sector (CCPPP 2016)

The PPP delivery model differs significantly from the traditional Design-Bid-Build (DBB) model. In DBB contracts, the owner agency specifies techniques, materials, methods, quantities, along with the time period for the contract (The World Bank 2005). In contrast, in the PPP model, the agency specifies certain clearly defined performance measures and Level of Services (LOSs) to be met over the contract period. Payment under the PPP model can be service based, availability based, or combination of both and the payment mechanism is linked to the contractor meeting the specified performance specifications (Abdel Aziz 2007; FHWA 2016; The World Bank 2014).

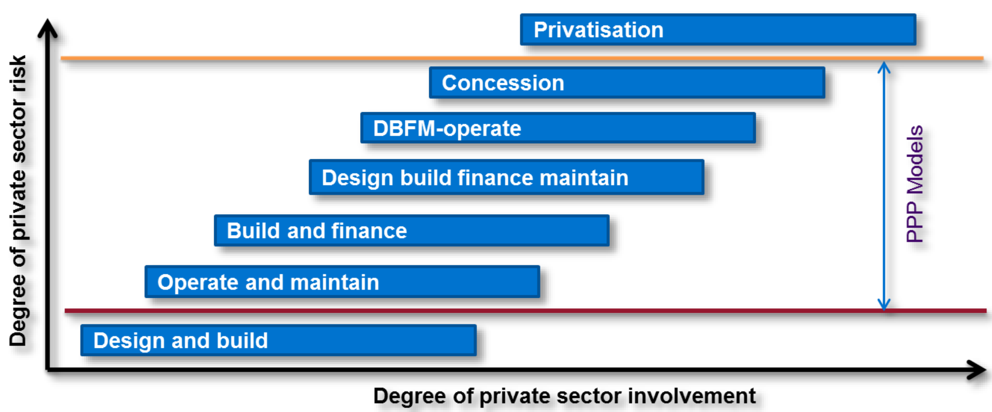


Figure 2.11 PPP Model – Adopted from (CCPPP 2016b)

Figure 2.12 below graphically illustrates the life cycle of an asset under the traditional and the PPP models (Alyami and Tighe 2017). Under the traditional procurement, the agency procures the different phases of the asset's life cycle from detailed design to construction contract procurement. During the operational phase of the asset, the agency typically monitors the asset within its asset management system and procures maintenance and rehabilitation contracts; subject to need assessments, program prioritization and budget availability (Alyami and Tighe 2017).

On the other hand, under the PPP model, the design, construction and maintenance are combined or stand-alone contracts under the consortium, Special Purpose Company (SPC), with an approved contract value at the financial close of the agreement. The PPP model allows for asset management processes to be implemented from early stages of design to handback; providing an opportunity to develop optimum design, construction and maintenance program cost-effectively.

Asset value is used in PPP, as shown in the example of the New South Wales (NSW) 2,115 lane-km network ten-year PPP contract (Yeaman 2007), which included specification of an annual increase of asset value up to 4% in the basis of written down replacement cost.

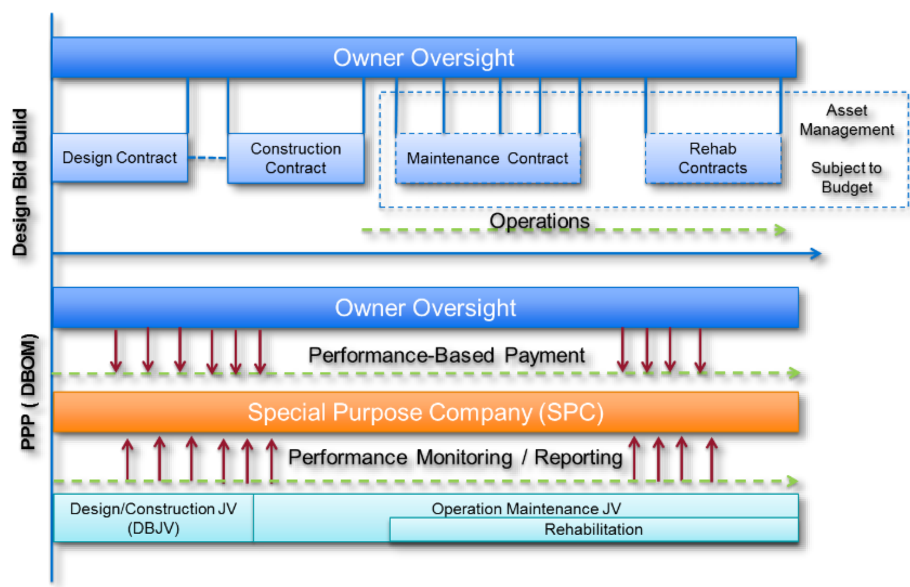


Figure 2.12 Asset Management – Traditional vs. PPP Projects (Alyami and Tighe 2017)

2.9 Summary, Research Gaps and Opportunities

2.9.1 Summary

In this chapter, a comprehensive literature review of asset valuation and asset management is conducted highlighting the framework main components. A review of performance measures in the context of asset management is presented. Performance measurement represents a very important underpinning of successful application of asset management. Asset management decision making is guided by its performance measures and the associated targets or thresholds. Therefore, this research takes into account the importance of properly identifying required performance measures and the associated level of service in developing the integration methodology. In addition, a review of deterioration modeling and the application of deterioration modeling as a means of studying the feasibility of different maintenance and rehabilitation activities is conducted. Deterioration modeling is of particular importance to this research as it is used in the development of the AVI and in development of multi-year asset management plans. Prioritization and optimization methods are discussed as well as the concept of cross asset management and trade-off analysis. In addition, a review of multi-criteria decision making methods is outlined including the AHP and MAUT methods.

2.9.2 Research Gaps and Opportunities

Agencies (public or private) who are managing infrastructure assets rely on external funding from the stakeholders, such as goverments and taxpayers. As such, agancies are madated to report their TCA values within their annual statements. Given the challenge of reduced budgets and available funding, it is becoming increasingly important that the agencies implement efficient and effective asset management systems that justify investement needs and implications on their assets and system as a whole. However, there is a gap in understanding asset value and its association and impact to asset management decision making framework. Therefore, a comprehansive review of common asset valuation methods and reporting in infrastructure asset management is paramount. Furthermore, TRB issued a research need statement highlighting the need to develop standard calculation methodologies to characterize the asset value of pavements for use in funding allocation, life cycle cost analysis and engineering evaluation. This need has not been addressed to date in the literature. In addition, a methodology to establish the asset value requirement is needed to identify the optimum or practical asset value criteria in asset management and performance based specifications that provide the required level of service.

Asset valuation is an essential component of effective asset management. It is an important method to demonstrate proper management of public assets and effective utilization of tax payers' money. However, using the current valuation methods in reporting asset values as basis of fund allocation and decision making in asset management poses a few challenges. First, it is recognized that there is no universally accepted method by the international community for reporting asset value. In addition, there are various valuation methods that can be utilized to estimate infrastructure assets' values; each requires different set of data and results in different values. Moreover, the current valuation methods are prone to fluctuation due to the changes in market unit prices. As such, may result in underestimating or over-estimating asset values regardless of any asset management stewardship.

Limited research has been introduced to incorporate asset value into asset management systems; however, there is no comprehensive work done to incorporate asset valuation in asset management practices. An integration method is imperative to address the aforementioned challenges. It is imperative to develop a methodology that integrates asset value in asset management planning and fund allocation. In other words, to manage assets in an optimized cost effective way to maintain required LOS, while maintaining or enhancing asset values.

Chapter 3
Asset Valuation: Application and Analysis

3.1 Introduction

This chapter provides an overview of common valuation methods, application and analysis of values. Statistical analyses are conducted to evaluate the valuation methods. The evaluation methodology is presented in the following section.

3.2 Methodology

In order to evaluate the various valuation methods, a sample case study from Ministry of Transportation of Ontario (MTO), Second Generation Pavement Management System (PMS2) is utilized. Detailed overview of the PMS2 is presented in Chapter 5.

The sample extracted for the purpose of this analysis includes 93 pavement sections (10% of the original data set). The sample is selected randomly using Monte-Carlo sampling and includes:

- Pavement historical condition data from 1992-2010
- Section information including age, pavement type, area, function.

As noted in the previous chapter, there are various valuation methods that can be used to calculate assets value. Each method requires a different set of data and results in different values. The valuation methods analyzed in this study and the required input variables for calculations are presented Table 3.1. The purpose of this analysis is to calculate the asset value of the sample section using the various methods. In this analysis, asset values are calculated using historical performance and unit prices. Using historical performance, rather than the predicted one, allows to analyze the various asset valuation methods using actual condition performance and unit prices. The unit prices used are based on Ontario Tender Price Index (TPI) with the base year of 1992, Figure 3.1. (MTO 2012)

Table 3.1 Asset Valuation Methods and Data Requirements (adopted from Li et al. 2014; Cowe Falls et al. 2004)

Valuation Method	Initial Construction ($)	Current Construction ($)	Maintenance/ Rehabilitation ($)	Performance Condition	**Age**
Book Value	X		X		X
Replacement Cost		X			
Written Down Replacement Cost		X		X	
Net Salvage Value		X		X	X
GASB-34	X		X		X
EPWIP	X		X	X	

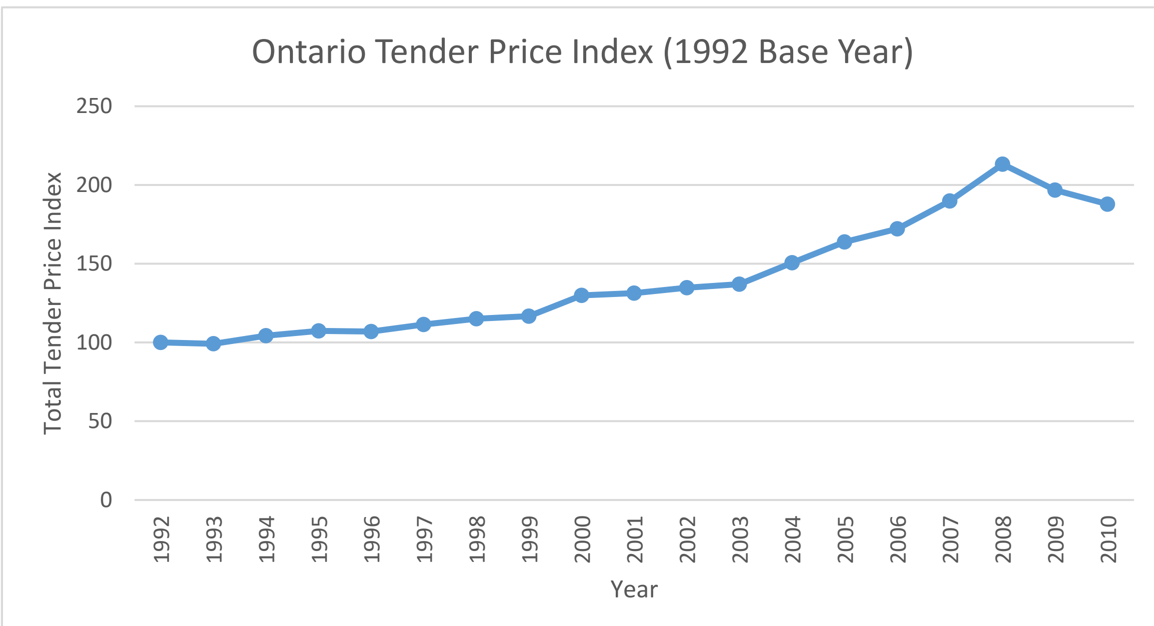


Figure 3.1 Ontario Tender Price Index (TPI) - 1992 to 2010 (MTO 2012)

To use historical costs to develop base year costs, in this case 2010, the historical costs are adjusted to base year by removing the inflation (in other words converting nominal dollars to real dollars in 2010) using price index by the following equation (FHWA 2003):

$$Dollars_{base\ year} = Dollars_{data\ year}\ x\ \frac{Price\ Index_{base\ year}}{Price\ Index_{data\ year}} \quad \text{Equation 3.1}$$

As shown in Table 3.2, along with historical maintenance rehabilitation and construction unit costs, age and pavement condition are key input variables to the valuation methods. The age histogram of the data selected for this study is presented in Figure 3.2. Performance condition for the sample sections is presented in Figure 3.3.

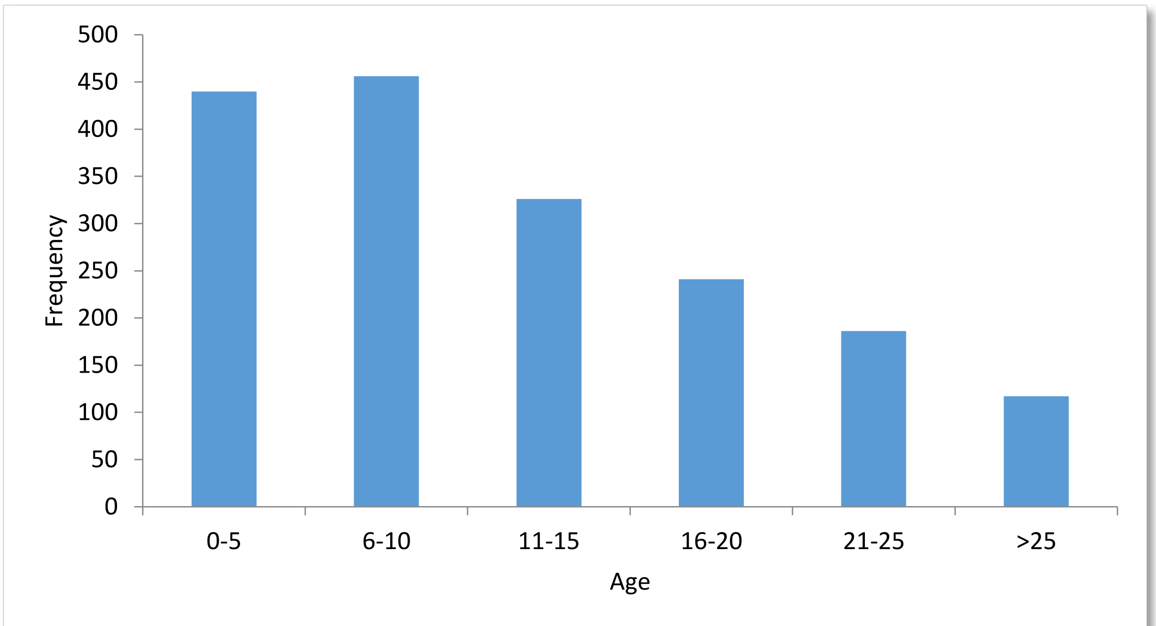


Figure 3.2 Sample Section Age Histogram

As presented in Figure 3.2, most pavement sections are within an age range lower than 15 years. This indicates that a rehabilitation has occurred before the pavement reaches a 15 years cycle. However, some sections did not receive rehabilitation treatments up to and beyond a 25 years cycle. This is also evident in Figure 3.3 as it shows that the average pavement PCI of the network is between 70 and 80. However, as shown in the lower whisker, some sections were not rehabilitated and therefore deteriorated up to and below a PCI of 40.

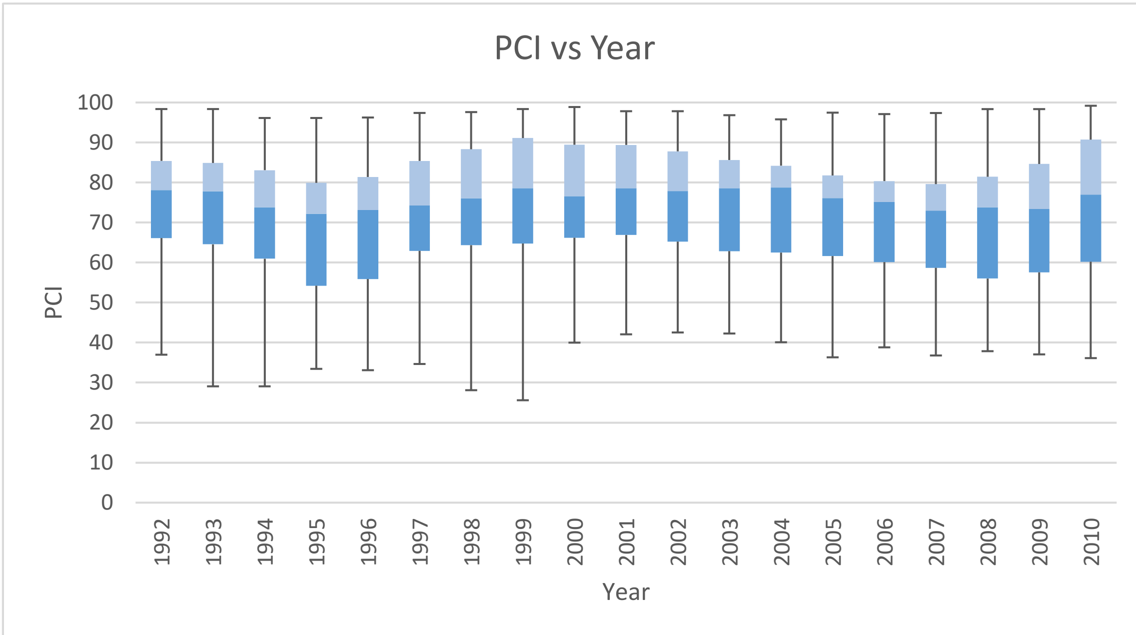


Figure 3.3 Sample Network PCI Box-Plot

The total asset value is calculated using each method over the analysis period. In addition, the asset value over the analysis period is presented as box plots showing the median, the 25^{th} and the 75^{th} percentiles. The whisker lines on the box plots extend to the largest and smallest observed data at the 95^{th} and 5^{th} percentile.

3.3 Valuation Methods

3.3.1.1 Replacement Cost

Replacement Cost (RC) can be defined as the cost required to build the same asset at the same location and ROW. It is a Current-based method that uses the current market costs to calculate the cost as follows:

$$RC = AC * A \qquad \text{Equation 3.2}$$

Where

AC = Average Cost ($) per Unit Area

A= Area

Although this method is straightforward and can be communicated easily, it lacks the incorporation of the asset condition. In other words, two similar assets with different conditions will have the same value based on this method. The methods can be used to predict future values; however, it is subject to the variation of the market for future costs. The total network RC values are presented in Figure 3.4, and the box-plot is presented in Figure 3.5.

As noted in Figure 3.4 and Figure 3.5, the total RC values fluctuate over the analysis period due to the changes in the unit prices reflected in the TPI. The RC method does not take into account the asset management stewardship as it does not take into account any other variables such as condition and age.

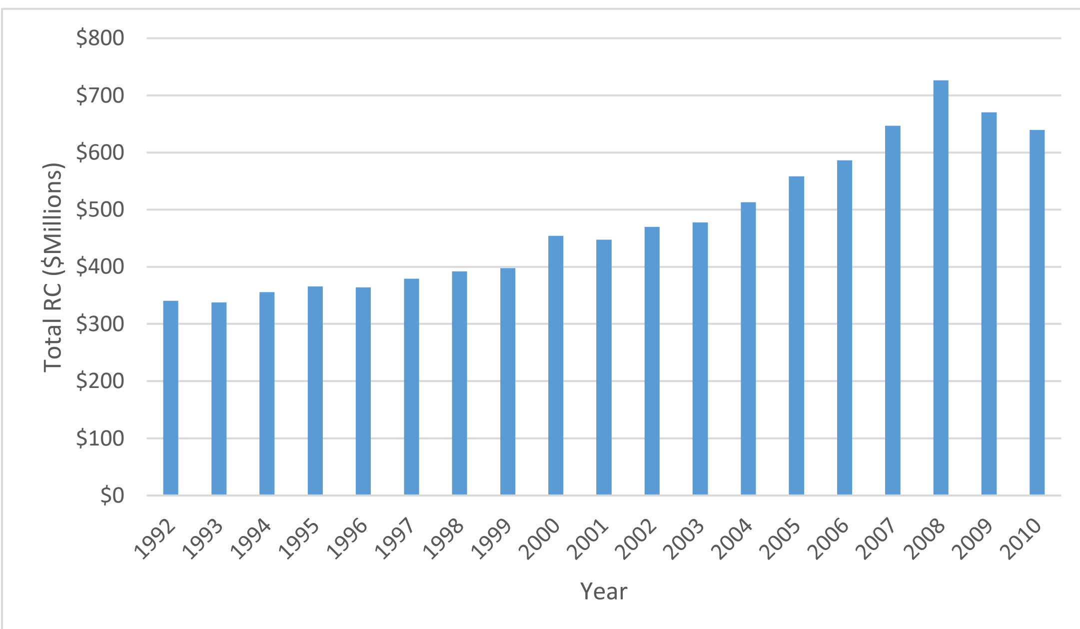


Figure 3.4 Total Network RC values

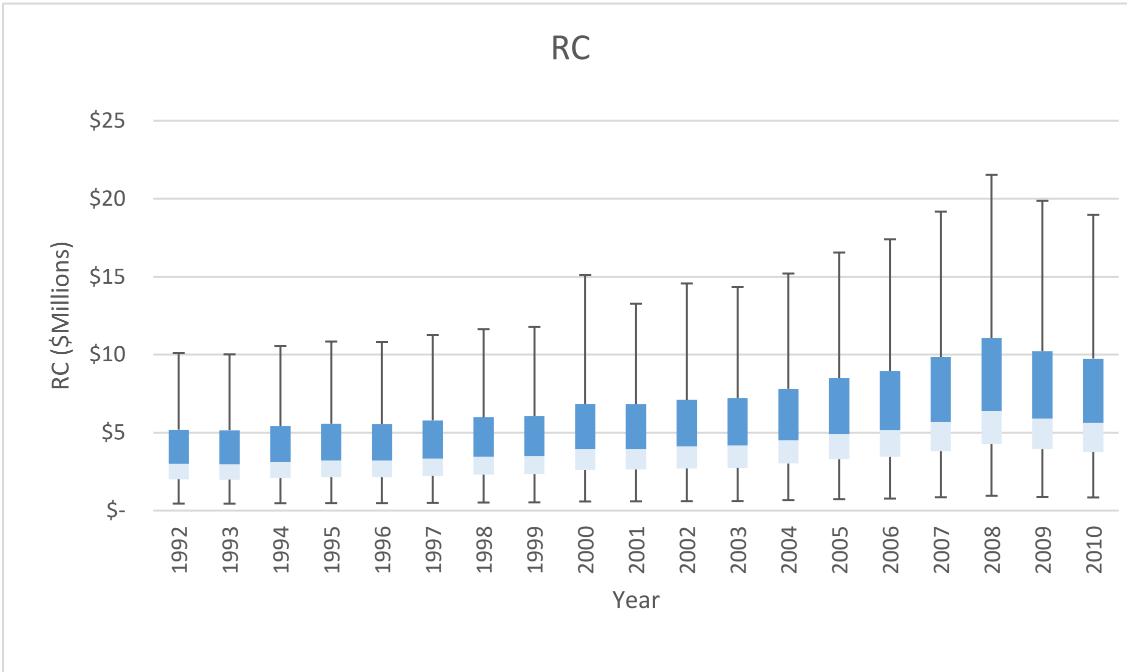


Figure 3.5 RC values Box-Plot

3.3.1.2 Written Down Replacement Cost

The Written Down Replacement Cost (WDRC) is the RC adjusted to incorporate the asset current condition. In other words, it is the present cost to build or replace the asset adjusted to account for the asset condition. Similar to the RC, this method is subject to the variation of the market future replacement costs if used to estimate future asset values. The WDRC can be calculated as follows:

$$WDRC = AC * A * C \qquad \text{Equation 3.3}$$

Where

AC = Average Cost ($) per Unit Area

A = Asset Area

C = Condition (reduced to decimal fraction of 1)

The method is used to calculate the asset values as presented in Figure 3.6. In addition, the WDRC box-plot is presented in Figure 3.7.

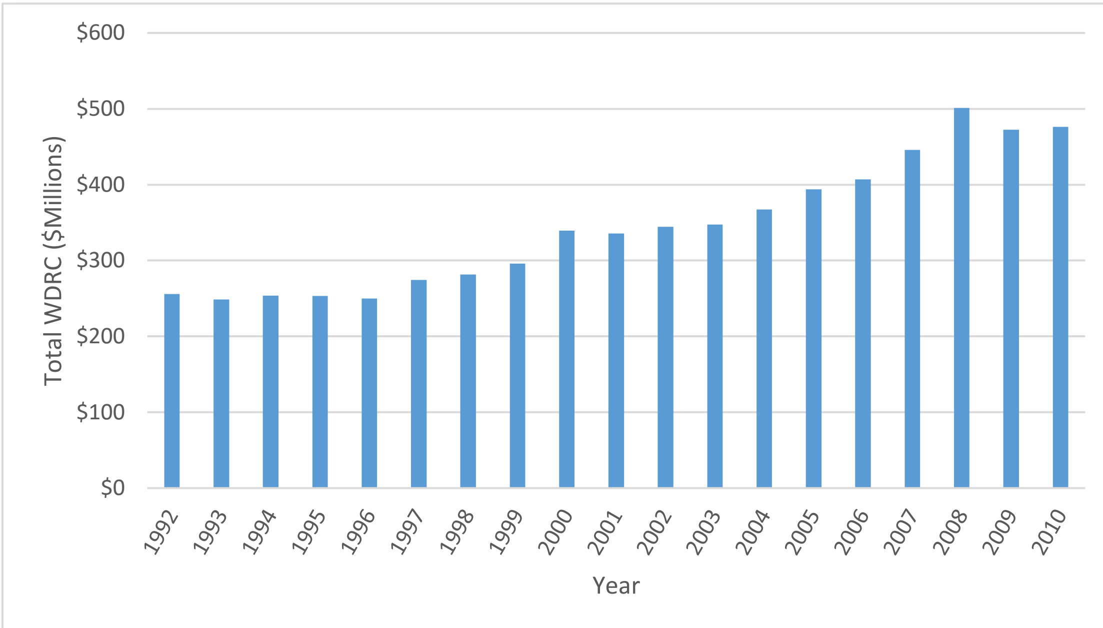


Figure 3.6 Network Total WDRC

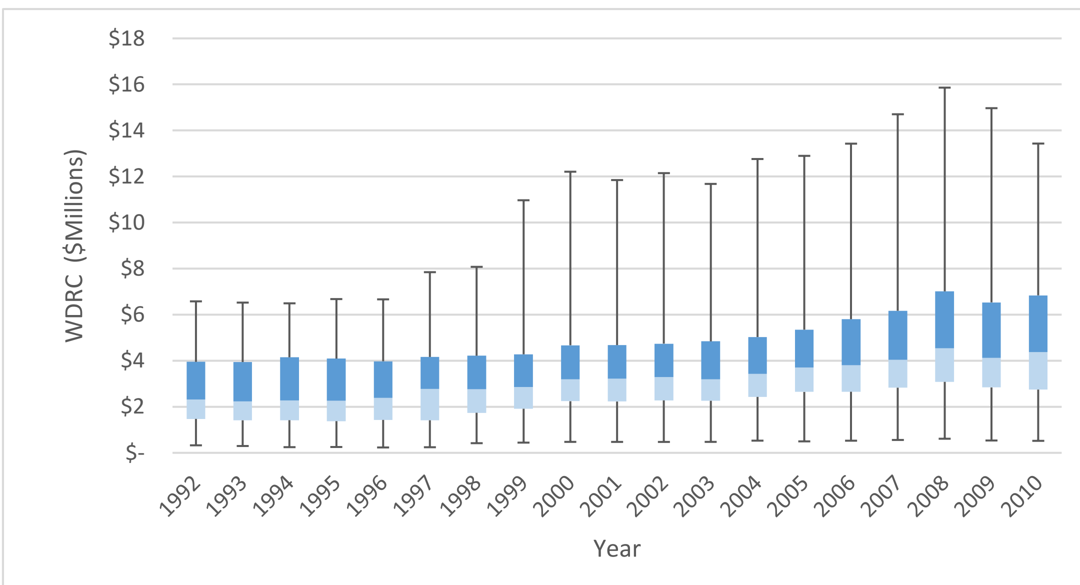


Figure 3.7 WDRC Box-Plot

As noted in Figure 3.6, the WDRC is lower than the RC values as it is written down by a factor of the current condition. Similar to the RC method, the WDRC is impacted by unit prices fluctuation. In other words, the value may increase or decrease due to increase or decrease of unit prices regardless of any asset maintenance or rehabilitation.

The WDRC is a function of the network condition and as shown in Figure 3.7, the WDRC values have a similar trend to the network PCI, Figure 3.3. In this case study, an actual condition is used to calculate the asset value; however, when using this method to predict future values, it is also subject to variability in the performance prediction model.

3.3.1.3 Book Value

The Book Value (BV) is defined as the asset's historical costs depreciated to the present. It is a past-based method that takes the historical costs and depreciates it to the present based on consumption of the asset. Historical costs include construction costs or cost to acquire the asset, rehabilitation and maintenance costs. The BV can be estimated for the future by carrying the depreciation forward to the future year where the BV to be estimated in accordance with Equation 3.4 (Cowe Falls 2004). However, the challenge is to forecast future maintenance and rehabilitation intervention and timing.

$$BV = HC * Depreciation\ factor \qquad \text{Equation 3.4}$$

Where:

HC = Historical Costs ($) (Initial Construction Cost (or Cost to Acquire) + Maintenance Costs + Rehabilitation) *all costs are depreciated*

The BV is dependent on historical cost, which may or may not be available depending on available records of the asset management system. In this case, complete historical information records are not available to calculate the BV of the assets. However, the BV for the year 2010 is included in the data record. The 2010 BV was used and adjusted using the inflation index to estimate the BV for the network. In addition, based on the available data of the last rehabilitation applied, the BV was adjusted accordingly moving backward to subtract the historical cost. Figure 3.8 and Figure 3.9 present the total BV of the network and the BV box-plot, respectively.

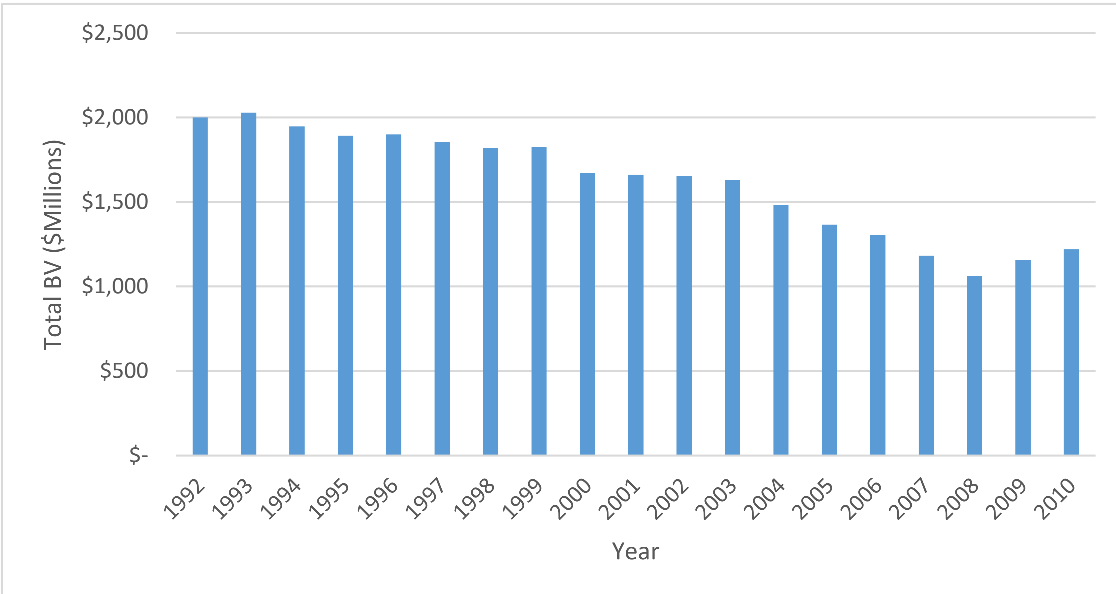


Figure 3.8 Network Total BV

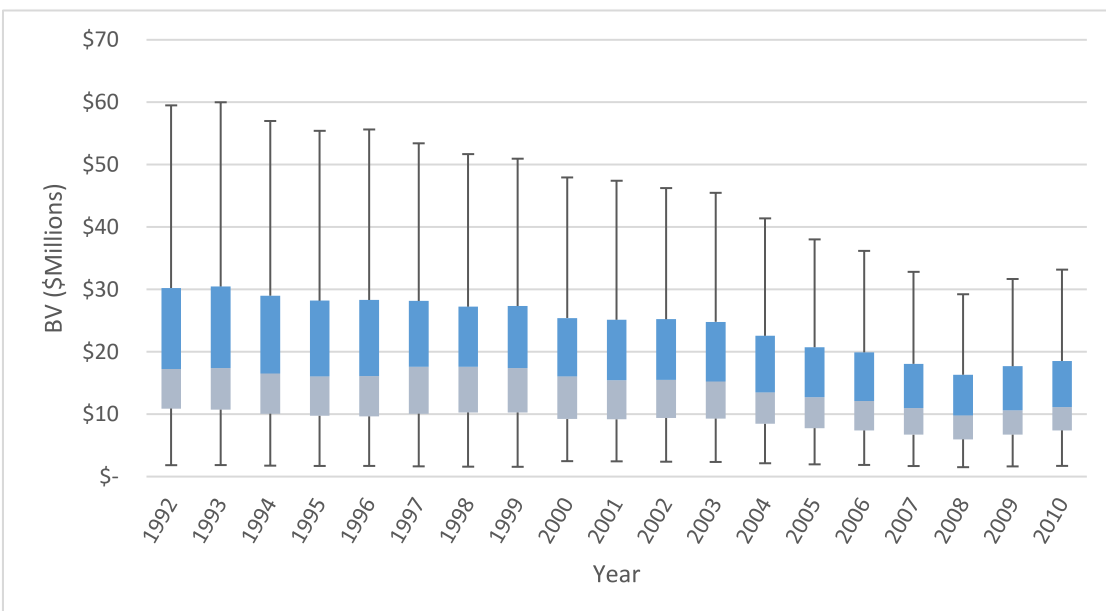


Figure 3.9 Network Book Value Box-Plot

As expected, the Total BV increases over time as more rehabilitation is applied. As shown in the network performance earlier, Figure 3.3, there was an overall increase in the network PCI due to rehabilitation, for example in years 1997 to 2002. This is reflected in Figure 3.9 where an increase in the BV average is seen to account for the increase in historical costs, i.e. rehabilitation.

3.3.1.4 Equivalent Present Worth in Place

The Equivalent Present Worth in Place (EPWIP) can be defined as the book value adjusted for inflation, depreciation, depletion and wear. The method has more application in mechanical assets that operate in controlled environments. The EPWIP can be calculated as follows:

$$EPWIP = BV * (DV1 + DV2) \qquad \text{Equation 3.5}$$

Where

BV = Book Value ($)

DV1 = adjustment for asset deterioration

DV2 = adjustment for depletion of the asset (in case of material stockpile)

In this case study, the BV presented in the previous section is adjusted for deterioration based on sections PCI, while depletion is neglected. The total EPWIP and Box-Plot are presented in Figure 3.10 and Figure 3.11, respectively.

Similar to the BV method, the EPWIP method accounts for the change in unit prices and application of maintenance and rehabilitation. In addition, the method accounts for the change in asset condition due to deterioration as noted in Figure 3.11; the trend shown in box-plot follows that of the network condition presented in Figure 3.3.

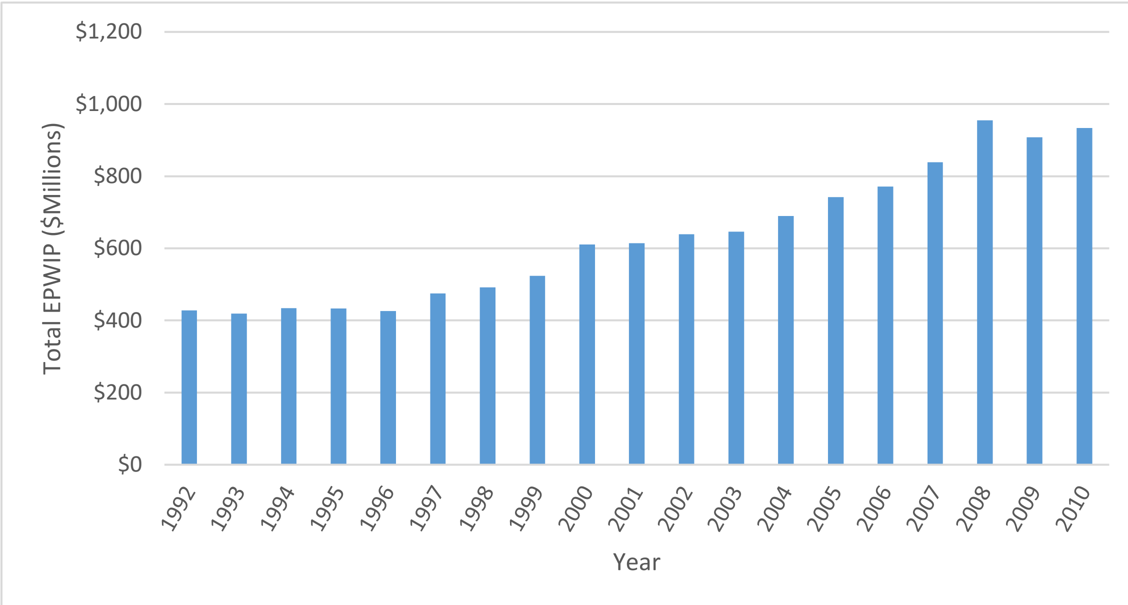


Figure 3.10 Network Total EPWIP Values

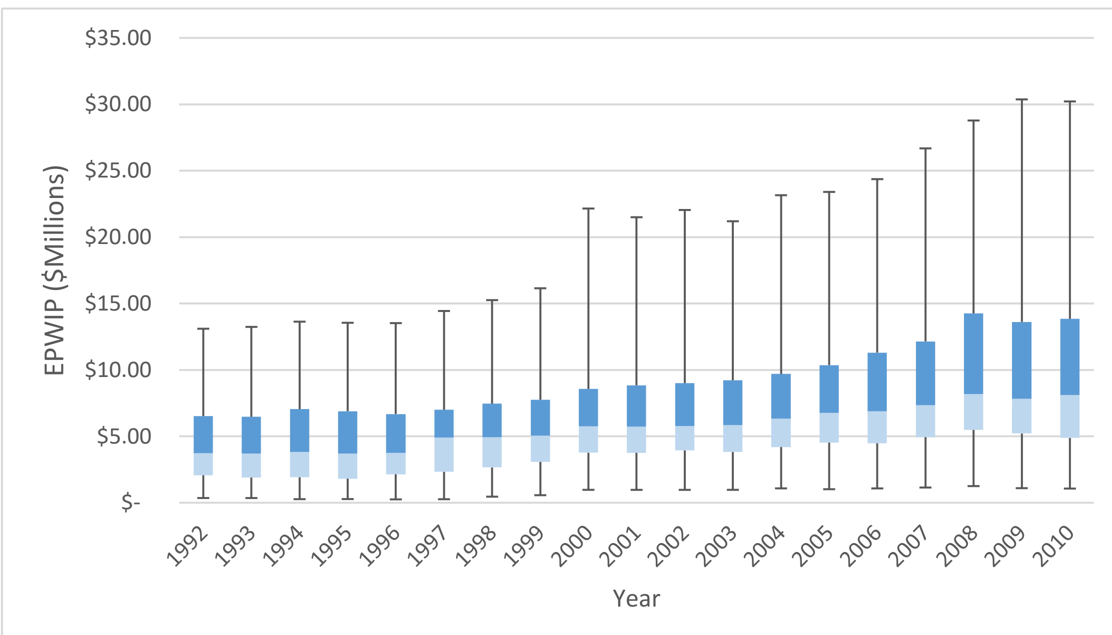


Figure 3.11 Network EPWIP Box-Plot

3.3.1.5 Net Salvage Value

The Net Salvage Value (NSV) is recognized as a preferred method for valuation of rail assets in Canada (Cowe Falls 2004). However, de Solminihac et.al. applied the NSV to the low volume road network in Chile to study the impact of different budget scenarios on the network asset value (de Solminihac et al. 2007).

NSV is defined as the cost to replace the asset less the cost of rehabilitation needed to return it to 'new condition' as follows:

$$\text{NSV} = RC - R \qquad \text{Equation 3.6}$$

Where

RC = Replacement cost ($) (cost to build a new asset)

R = Rehabilitation cost ($) (bring asset to brand new condition)

To calculate the asset value using this method, some assumptions are made regarding the rehabilitation decisions. It is therefore imperative to establish the criteria for applying a rehabilitation to a given section. MTO has established target and trigger PCI values for its network as presented in Table 3.2. Based on the trigger and target values, the decision tree for minor rehabilitation, major rehabilitation and reconstruction is developed as presented in Figure 3.12.

Table 3.2 MTO Target and Trigger PCI (MTO 2013)

Target PCI							Trigger PCI
Road Function	Good	%	Fair >	%	Poor >	%	
Freeways	75	70	66	30	65	0	65
Arterial	75	65	56	30	55	5	55
Collector	70	65	51	30	50	5	50

The rehabilitation methods are classified to minor rehabilitation, major rehabilitation, and reconstruction. The treatment is specific to the road function. For example, for a Freeway, a minor rehabilitation is an overlay of two lifts while a major rehabilitation is mill and two lift overlay.

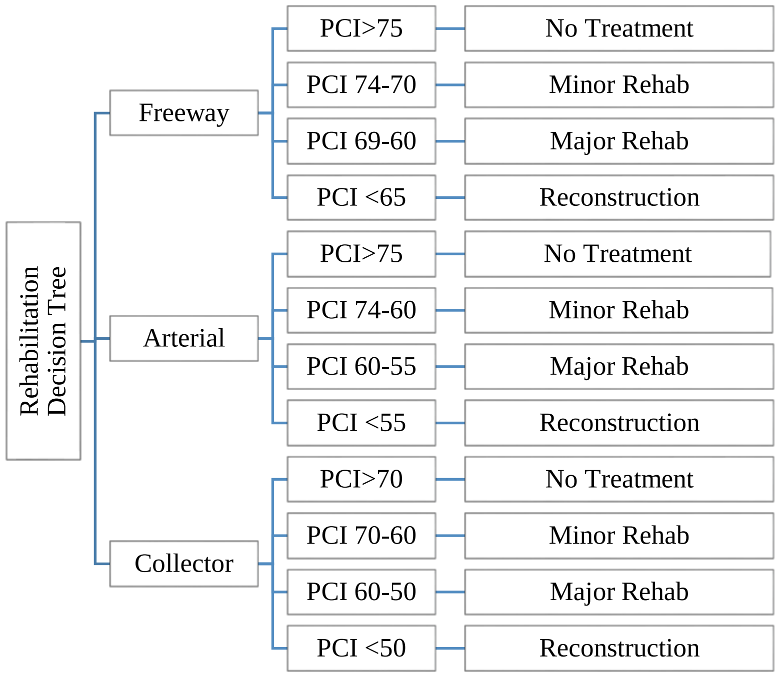


Figure 3.12: Pavement Rehabilitation Decision Tree

The total NSV for the network is calculated following equation 3.6 based on the decision tree developed. The total network NSV and box-plot are presented in Figure 3.13 and Figure 3.14, respectively.

The NSV takes into account the condition of the asset by means of the rehabilitation cost to restore the asset to new condition. As such, the NSV increases as the asset condition increases due to the application of maintenance and rehabilitation as seen in Figure 3.14 when referenced to the network PCI, Figure 3.3. However, the opposite is not necessarily accurate as the rehabilitation needed (depending on the decision tree) remains the same as long as the asset falls in the same condition bracket. Furthermore, the NSV, similar to RC methods, is impacted by the unit price fluctuations as shown in Figure 3.13.

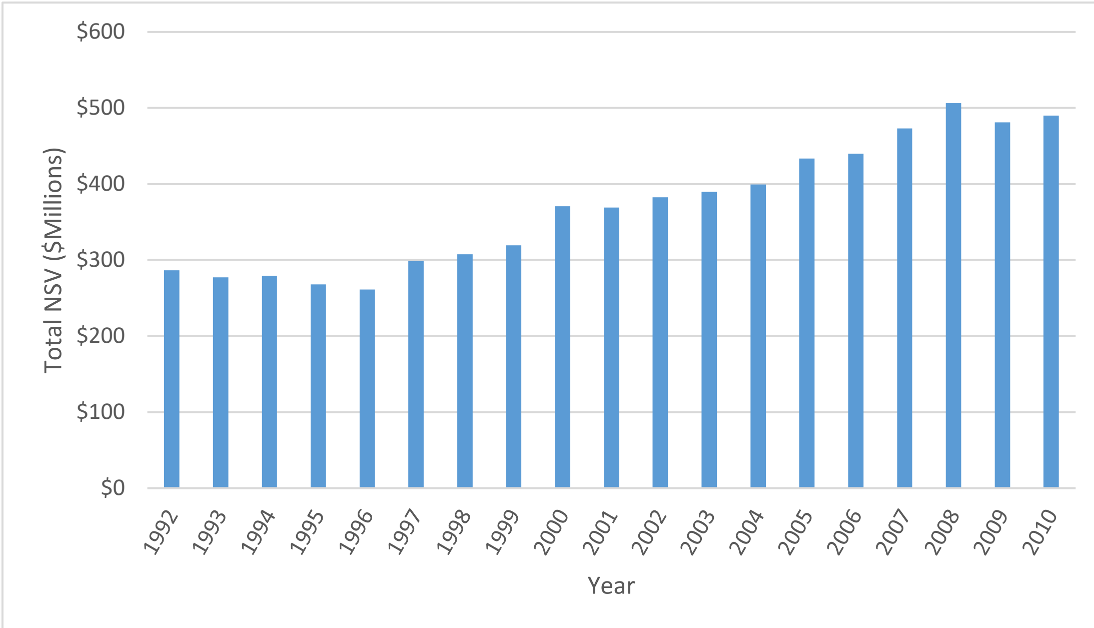


Figure 3.13 Network Total NSV

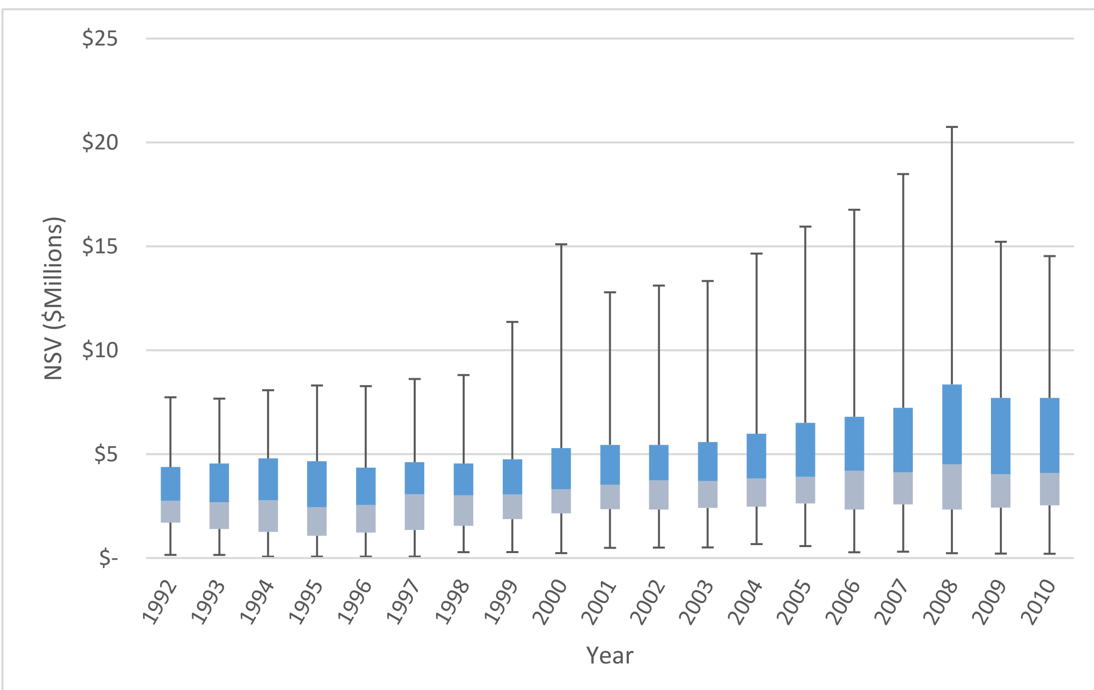


Figure 3.14 Network Net Salvage Value Box-Plot

3.3.1.6 GASB- 34

The GASB method calculation is based on historical costs. If record of the historical costs are not available, then the estimated historical costs are calculated by deflating the replacement costs adjusted for the useful life of the asset and remaining service life (Cowe Falls 2004). The depreciated historical cost using the GASB-34 method is used in this study and can be calculated as follows (McNeil 2001):

$$\text{GASB-34 Value} = RC \; x \; \frac{Price\ Index_{Const}}{Price\ Index_{year}} \; x \; \frac{life - Age}{Life} \qquad \text{Equation 3.7}$$

Where

RC = Replacement Cost ($)

Life = Total useful life of the asset (Assumed 25 years for pavement)

Age = Current pavement age

As shown in equation 3.7, the GASB method differs from the WDRC method in that it uses the price index rather than performance deterioration to depreciate the replacement cost. The network asset value was calculated using the GASB-34 methods following equation 3.7. The network total value over the analysis period is presented in Figure 3.15. In addition, a box-plot of the network asset value is presented in Figure 3.16.

The GASB method is the RC depreciated based on the asset age. As such the GASB-34 method results in considerably lower values than the RC method, as shown in Figure 3.15. Age is a key variable to the asset value using this method; therefore, the asset value is higher for “younger” assets regardless of other factors such as their function, location or condition. In addition, the asset value using this method reaches zero as the asset reaches its expected life, as reflected in the lower whisker value of the box plot, Figure 3.16. On the other hand, some assets were reconstructed resulting in their age assumed to be reset to a new value and therefore there were spikes in the asset value, represented by the upper whisker in Figure 3.16.

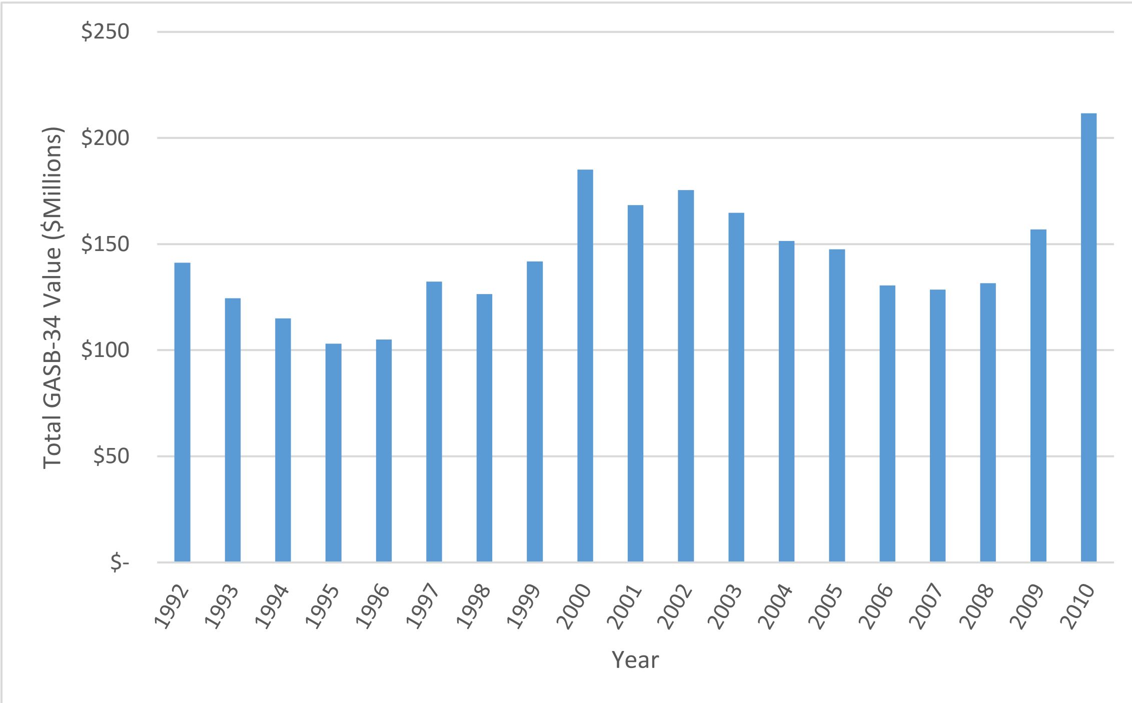


Figure 3.15 Network Total GASB-34 Value

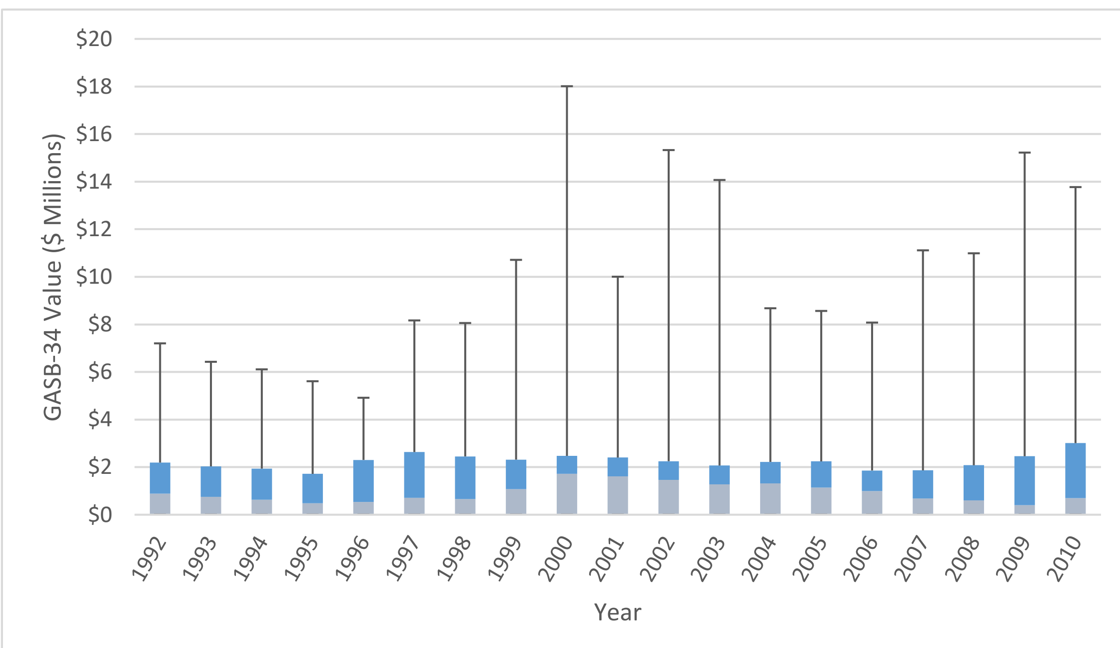


Figure 3.16 Network GASB-34 Value Box Plot

3.4 Analysis and Discussion

In the previous section, each method is used to calculate the asset value of the network over the analysis period. In this section, the various valuation methods are also analyzed in comparison among and between each other at a given year, and also over the analysis period. To evaluate the relationship between the various methods, several statistical inferences and correlation are conducted.

The descriptive statistics of the various valuation methods for years 1992, 2000 and 2010 are presented in Table 3.3, whereas the remaining analysis years asset valuation descriptive statistics are presented in Appendix A. In addition, for clarity of presentation, Figure 3.17 shows the asset values using the different methods at the beginning, mid-point and the end of the analysis period, while Figure 3.18 shows the box-plot for the same analysis points.

Table 3.3 Descriptive Statistics of the Valuation Methods

		RC	WDRC	NSV	BV	EPWIP	GASB
1992	Mean	$3,662,068.50	$2,753,070.43	$6,089,791.53	$3,081,124.76	$4,597,985.29	$2,122,130.98
	Std.	$2,092,755.32	$1,603,494.36	$3,896,484.39	$1,907,850.66	$3,050,098.43	$1,737,012.68
	CV	**0.57**	**0.58**	**0.64**	**0.62**	**0.66**	**0.82**
2000	Mean	$4,775,625.52	$3,567,492.93	$8,564,953.11	$3,866,982.99	$6,426,006.62	$2,680,185.43
	Std.	$2,730,019.33	$2,065,307.55	$5,214,173.56	$2,419,816.99	$3,973,908.90	$2,122,079.73
	CV	**0.57**	**0.58**	**0.61**	**0.63**	**0.62**	**0.79**
2010	Mean	$6,879,195.67	$5,121,889.64	$13,122,247.08	$5,267,297.95	$10,039,411.13	$3,626,634.95
	Std.	$3,931,240.87	$3,196,887.15	$7,661,850.81	$3,896,724.68	$6,853,064.80	$3,301,090.00
	CV	**0.57**	**0.62**	**0.58**	**0.74**	**0.68**	**0.91**

As shown in Table 3.3, all valuation methods, except the GASB method, exhibit similar variability as presented in the Coefficient of Variance (CV). The GASB method produces zero values (i.e. when assets reach the end of its assumed useful life), and results in higher variability of the data as indicated by its high CV. As noted in Figure 3.17, and Figure 3.18, all assets gained value over the analysis period, due to the adjustment for inflation.

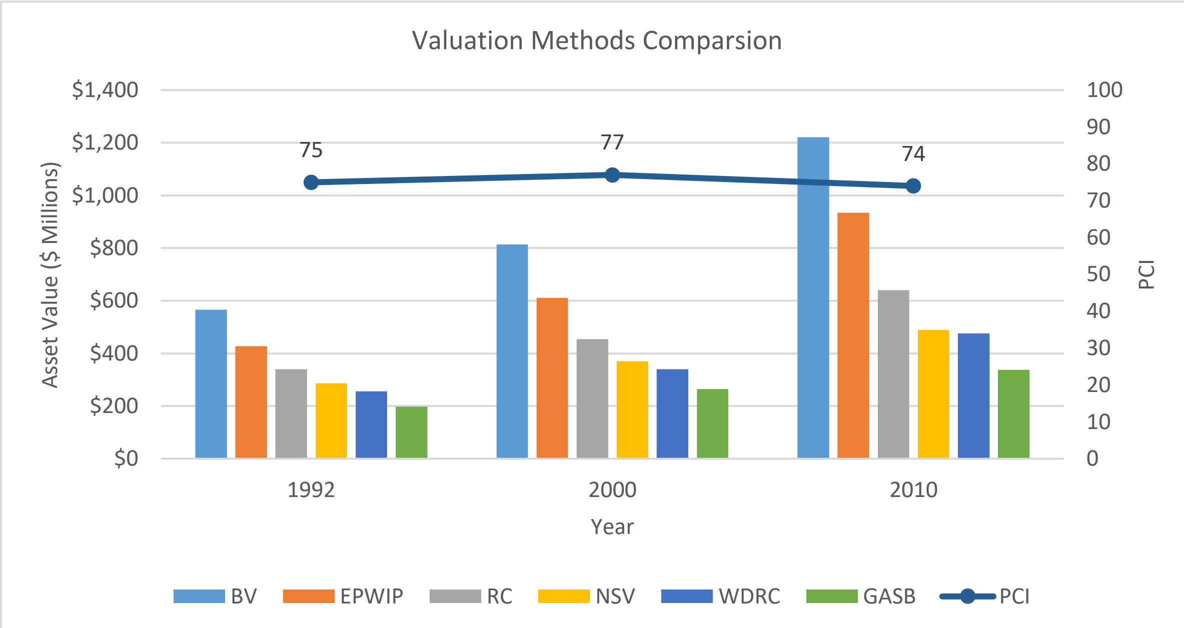


Figure 3.17 Network Total Asset Value Comparison

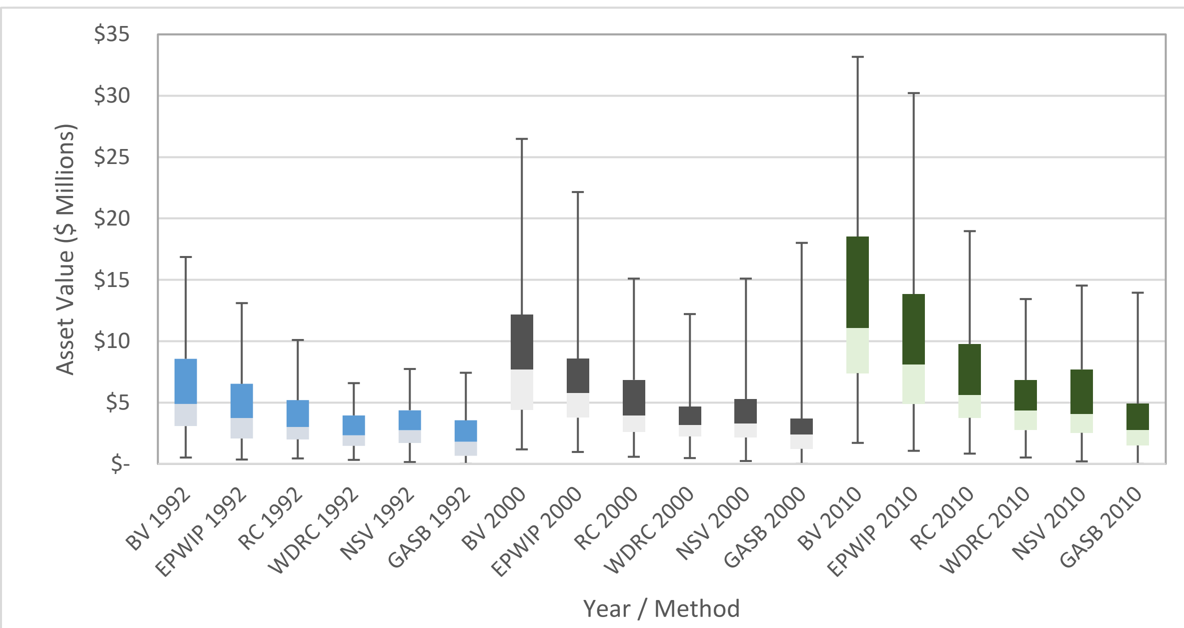


Figure 3.18 Network Asset Value Box Plot

The calculation of an asset value is primarily a function of the area of the asset for all given valuation methods. Therefore, some sections with similar characteristics, such as condition and age, may have higher or lower value solely based on area. Past-based methods such as the BV and EPWIP produced the highest value as they are a function of historical costs. On the other hand, GASB-34, WDRC and NSV methods produced the lowest values due to incorporating condition and age.

As shown in the previous section, some of the methods are a function of other methods; for example, the WDRC method is a function of RC. As such, the linear correlation is analyzed to evaluate the linearity between the methods. The linear correlation parameter ρ is a commonly used measure of how well two variables are linearly related. The correlation parameter lies within the interval [–1, 1]. The value $\rho = 0$ indicates that a linear relationship does not exist between two variables. The closer the ρ to the limits of the interval [-1, 1] indicates a strong linearity relationship. Table 3.4 and Table 3.5 summarize the ρ value between the various methods at different points along the analysis period. Where the ρ results are consistent over the analysis period, it is drawn that there is a strong linear relationship between the methods as highlighted in the tables.

As shown in Table 3.4 and Table 3.5, there is a positive linear relationship between the valuation methods. There is a strong linear relationship between RC and WDRC, and BV and EPWIP methods as they are explicitly used in the calculation. The GASB method has the lowest linear relationship to the remaining methods. This is due to the fact that GASB value can be zero when the asset reaches the calculation assumed asset useful life, 25 years.

On the other hand, the results presented in Figure 3.17, Figure 3.18 and Table 3.3 suggest that there are some similarity in the mean between the valuation methods. To validate this observation, Analysis of Variance (ANOVA) is conducted. ANOVA is a statistical method that tests if the means of several groups are equal or there are statistically significant differences between them. It is useful for comparing (testing) three or more means (groups or variables) for statistical significance.

Table 3.4 Asset Valuation Correlation Test Results

	Year	WDRC	BV	NSV	EPWIP	GASB
RC	1992	**0.920**	**0.899**	**0.802**	**0.826**	0.705
	1993	**0.895**	**0.900**	0.788	**0.805**	0.680
	1994	**0.902**	**0.900**	0.789	**0.802**	0.659
	1995	**0.908**	**0.900**	0.746	**0.808**	0.636
	1996	**0.887**	**0.900**	0.625	0.788	0.588
	1997	**0.882**	**0.899**	0.709	0.787	0.566
	1998	**0.883**	**0.899**	0.674	0.788	0.502
	1999	**0.912**	**0.909**	0.750	**0.850**	0.556
	2000	**0.913**	**0.917**	0.791	**0.840**	0.548
	2001	**0.909**	**0.924**	0.784	**0.832**	0.534
	2002	**0.904**	**0.921**	0.773	**0.825**	0.538
	2003	**0.905**	**0.920**	0.766	**0.827**	0.539
	2004	**0.889**	**0.922**	0.690	**0.813**	0.507
	2005	**0.886**	**0.922**	0.697	**0.812**	0.494
	2006	**0.889**	**0.923**	0.694	**0.808**	0.473
	2007	**0.893**	**0.923**	0.710	**0.827**	0.482
	2008	**0.888**	**0.931**	0.669	**0.825**	0.453
	2009	**0.870**	**0.931**	0.688	**0.805**	0.479
	2010	**0.865**	**0.931**	0.695	0.767	0.529

	Year	BV	NSV	EPWIP	GASB
WDRC	1992	**0.855**	**0.950**	**0.910**	**0.885**
	1993	**0.850**	**0.961**	**0.917**	**0.866**
	1994	**0.867**	**0.958**	**0.917**	**0.844**
	1995	**0.866**	**0.932**	**0.917**	**0.815**
	1996	**0.848**	**0.883**	**0.910**	**0.805**
	1997	**0.824**	**0.926**	**0.902**	0.789
	1998	**0.811**	**0.902**	**0.897**	0.746
	1999	**0.819**	**0.914**	**0.913**	0.797
	2000	**0.859**	**0.935**	**0.932**	0.792
	2001	**0.884**	**0.936**	**0.945**	0.792
	2002	**0.879**	**0.938**	**0.946**	**0.804**
	2003	**0.880**	**0.934**	**0.946**	0.798
	2004	**0.870**	**0.916**	**0.951**	0.789
	2005	**0.867**	**0.919**	**0.952**	0.770
	2006	**0.883**	**0.920**	**0.955**	0.748
	2007	**0.855**	**0.921**	**0.944**	0.752
	2008	**0.871**	**0.907**	**0.958**	0.734
	2009	**0.873**	**0.926**	**0.968**	0.791
	2010	**0.920**	**0.938**	**0.968**	**0.828**

Table 3.5 Asset Valuation Correlation Test Results (Continued)

	Year	NSV	EPWIP	GASB
BV	1992	0.781	**0.945**	0.672
	1993	0.774	**0.934**	0.666
	1994	0.789	**0.940**	0.664
	1995	0.748	**0.941**	0.645
	1996	0.679	**0.929**	0.592
	1997	0.721	**0.920**	0.511
	1998	0.671	**0.913**	0.462
	1999	0.719	**0.931**	0.476
	2000	0.787	**0.933**	0.526
	2001	**0.824**	**0.932**	0.547
	2002	**0.815**	**0.926**	0.554
	2003	**0.842**	**0.928**	0.548
	2004	0.744	**0.912**	0.540
	2005	0.746	**0.910**	0.522
	2006	0.749	**0.915**	0.512
	2007	0.726	**0.914**	0.463
	2008	0.716	**0.911**	0.462
	2009	0.756	**0.898**	0.514
	2010	0.799	**0.908**	0.681

	Year	EPWIP	GASB
NSV	1992	**0.884**	**0.859**
	1993	**0.890**	**0.836**
	1994	**0.892**	**0.826**
	1995	**0.873**	0.791
	1996	**0.853**	0.764
	1997	**0.875**	0.758
	1998	**0.849**	0.745
	1999	**0.870**	**0.814**
	2000	**0.897**	0.797
	2001	**0.923**	**0.812**
	2002	**0.928**	**0.821**
	2003	**0.948**	**0.817**
	2004	**0.914**	**0.816**
	2005	**0.913**	0.799
	2006	**0.910**	0.795
	2007	**0.899**	0.784
	2008	**0.907**	0.782
	2009	**0.931**	**0.800**
	2010	**0.929**	**0.811**

	Year	GASB
EPWIP	1992	**0.816**
	1993	**0.807**
	1994	0.795
	1995	0.777
	1996	0.753
	1997	0.684
	1998	0.663
	1999	0.699
	2000	0.734
	2001	0.754
	2002	0.771
	2003	0.760
	2004	0.772
	2005	0.748
	2006	0.730
	2007	0.692
	2008	0.703
	2009	0.780
	2010	**0.875**

The null hypothesis for this test is: $H_0 : \mu_1 = \mu_{1} = \mu_{2} = \ldots = \mu_k$; Where, μ is the mean for the valuation methods 1 through k. They null hypothesis is rejected if the $F_{stat} > F_{crtical}$. If the null hypothesis is rejected, then the alternate is true indicating that there is one or more groups that are significantly different.

Type I error, *p*-value is also observed and reported. The *p*-value is the smallest level of significance *α* that leads to rejection of the null hypothesis. In general, the larger the test statistic, the smaller the p-value the more evidence exists to reject the null hypothesis in favor of the alternative hypothesis

ANOVA analysis is conducted at a significant level of 5% (α =0.05); consequently, the level of confidence is 95%. Excel was used to conduct the ANOVA analysis for the analysis years 1992 to 2010. The results are summarized in Table 3.6. Complete test results are included in Appendix A.

Table 3.6 ANOVA Summary Results

Year	F (F critical = 2.2303)	P-value
1992	30.1352	4.14E-27
1993	31.874	1.48E-28
1994	34.8431	5.49E-31
1995	37.3717	5.06E-33
1996	39.4975	1.04E-34
1997	38.7429	4.11E-34
1998	43.4600	8.63E-38
1999	41.4314	3.2E-36
2000	39.8921	5.79E-35
2001	41.7326	1.86E-36
2002	43.8239	5.25E-38
2003	45.2615	4.23E-39
2004	48.6612	1E-41
2005	50.2224	7.01E-43
2006	52.1813	2.57E-44
2007	53.1250	5.29E-45
2008	55.5198	9.99E-47
2009	51.2365	1.26E-43
2010	45.3267	3.23E-39

As shown in Table 3.6, the null hypothesis was rejected in all years of analysis as the F_{stat} is higher than $F_{critcal}$ for all years. In addition, the *p*-value reported is very low giving strong evidence against the null hypothesis.

On the other hand, as shown in Figure 3.17 and Figure 3.18, it is observed that there is some similarity between some of the methods such as the NSV and WDRC. To further evaluate this observation, statistical t-test is conducted to evaluate the methods against each other. The t-test is considered appropriate due to the large number of the sample data and the assumed normal distribution. The normality of the sample data was validated using the Kolmogorov-Smirnov (K-S) method for each valuation method. The test is conducted at significant level 5% (α =0.05); as such the level of confidence is 95%. The hypotheses of the test are as follows:

Null hypothesis, H_0: $\mu_1 = \mu_2$, where μ_1 y μ_2 are the means of each group of evaluations

Alternative hypothesis, H_1: $\mu_1 \neq \mu_2$

The t-test was conducted to evaluate all the methods to each other at years 1992 to 2010 using minitab® statistical software. The null hypothesis is rejected if *p*-value is $< \alpha$. A summary of the test is presented in Table 3.7 and 3.8 (see Appendix A for complete test output). Two methods are said to be statistically similar if the null hypothesis failed to be rejected in all years analyzed.

As shown in Table 3.7 and

Table 3.8, the null hypothesis was failed to be rejected for the t-test between WDRC and NSV methods for all years of the analysis period. Therefore, based on the test results, the NSV and WDRC methods are statistically similar. Both methods take into account the asset condition; however, the NSV is dependent on the decision tree and the levels of treatments by thresholds. As such, this finding is applicable to this specific decision tree used in this case study. In other words, changes to the decision trees will result in changes to the NSV values and may result in violating aforementioned findings.

Table 3.7 Asset Valuation t-Test Summary Results

	Year	WDRC	BV	NSV	EPWIP	GASB
RC	1992	0.001	0.000	0.049	0.016	0.000
	1993	0.001	0.000	0.029	0.023	0.000
	1994	0.000	0.000	0.000	0.037	0.000
	1995	0.000	0.000	0.001	**0.078**	0.000
	1996	0.000	0.000	0.001	**0.091**	0.000
	1997	0.000	0.000	0.008	0.013	0.000
	1998	0.000	0.000	0.006	0.009	0.000
	1999	0.001	0.000	0.031	0.002	0.000
	2000	0.001	0.000	0.018	0.001	0.000
	2001	0.001	0.000	0.026	0.001	0.000
	2002	0.000	0.000	0.017	0.001	0.000
	2003	0.000	0.000	0.019	0.001	0.000
	2004	0.000	0.000	0.005	0.001	0.000
	2005	0.000	0.000	0.005	0.002	0.000
	2006	0.000	0.000	0.002	0.003	0.000
	2007	0.000	0.000	0.001	0.004	0.000
	2008	0.000	0.000	0.000	0.003	0.000
	2009	0.000	0.000	0.001	0.001	0.000
	2010	0.001	0.000	0.006	0.000	0.000

	Year	BV	NSV	EPWIP	GASB
WDRC	1992	0.000	**0.206**	0.000	0.011
	1993	0.000	**0.237**	0.000	0.003
	1994	0.000	**0.315**	0.000	0.001
	1995	0.000	**0.584**	0.000	0.000
	1996	0.000	**0.646**	0.000	0.000
	1997	0.000	**0.341**	0.000	0.001
	1998	0.000	**0.302**	0.000	0.000
	1999	0.000	**0.383**	0.000	0.001
	2000	0.000	**0.368**	0.000	0.005
	2001	0.000	**0.269**	0.000	0.003
	2002	0.000	**0.264**	0.000	0.003
	2003	0.000	**0.213**	0.000	0.002
	2004	0.000	**0.341**	0.000	0.001
	2005	0.000	**0.289**	0.000	0.000
	2006	0.000	**0.411**	0.000	0.000
	2007	0.000	**0.536**	0.000	0.000
	2008	0.000	**0.913**	0.000	0.000
	2009	0.000	**0.851**	0.000	0.000
	2010	0.000	**0.781**	0.000	0.002

Table 3.8 Asset Valuation t-Test Summary Results (Continued)

	Year	NSV	EPWIP	GASB
BV	1992	0.000	0.004	0.000
	1993	0.000	0.003	0.000
	1994	0.000	0.001	0.000
	1995	0.000	0.000	0.000
	1996	0.000	0.000	0.000
	1997	0.000	0.001	0.000
	1998	0.000	0.000	0.000
	1999	0.000	0.001	0.000
	2000	0.000	0.002	0.000
	2001	0.000	0.002	0.000
	2002	0.000	0.001	0.000
	2003	0.000	0.000	0.000
	2004	0.000	0.000	0.000
	2005	0.000	0.000	0.000
	2006	0.000	0.000	0.000
	2007	0.000	0.000	0.000
	2008	0.000	0.000	0.000
	2009	0.000	0.000	0.000
	2010	0.000	0.004	0.000

	Year	EPWIP	GASB
NSV	1992	0.000	0.000
	1993	0.000	0.000
	1994	0.000	0.000
	1995	0.000	0.000
	1996	0.000	0.000
	1997	0.000	0.000
	1998	0.000	0.000
	1999	0.000	0.000
	2000	0.000	0.001
	2001	0.000	0.000
	2002	0.000	0.000
	2003	0.000	0.000
	2004	0.000	0.000
	2005	0.000	0.000
	2006	0.000	0.000
	2007	0.000	0.000
	2008	0.000	0.000
	2009	0.000	0.000
	2010	0.000	0.002

	Year	GASB
EPWIP	1992	0.000
	1993	0.000
	1994	0.000
	1995	0.000
	1996	0.000
	1997	0.000
	1998	0.000
	1999	0.000
	2000	0.000
	2001	0.000
	2002	0.000
	2003	0.000
	2004	0.000
	2005	0.000
	2006	0.000
	2007	0.000
	2008	0.000
	2009	0.000
	2010	0.000

Moreover, based on the findings presented in Table 3.7 and

Table 3.8, the null hypothesis is rejected for the remainder of the tests; therefore, it can be stated that there are no significant statistical similarities between the various methods.

It is worth noting that the null hypothesis failed to be rejected at specific times between some of the valuation methods. For example, in year 1995 and 1996 valuation results, the RC and EPWIP were statistically similar. However, as this is only true to a specific year, and the null hypothesis was rejected for the remaining years, it can be concluded that the RC and EPWIP are statistically different.

3.5 Summary

In this Chapter, an overview of common asset valuation methods was presented and key observations in the context of asset management are presented. A sample case study based on data from the MTO's PMS2 was used to demonstrate and analyze the valuation methods presented. Historical performance were used, rather than the predicted one, which allowed to analyze the various asset valuation methods using actual condition performance and unit prices. The unit prices used are based on Ontario (TPI) with the base year of 1992. Asset value results and observations of each method were presented. In addition, statistical inferences were conducted to study the relationships between the valuation methods. Based on the ANOVA analysis and the t-test results, it can be concluded with 95% confidence interval that the methods are statistically significantly different except for the NSV and WDRC methods. However, this relationship cannot be concluded as the NSV is a function of the decision trees incorporated in the calculation of the NSV and changes to the decision tree will result in changes in the final results.

The analysis in the previous sections has led to identifying the following challenges in incorporating asset value in asset management decision making: 1) The asset valuation method selected should be readily and easily calculated. 2) The valuation method directly relates to the asset condition, reflecting the needs and returns on investments for assets' preservation. 3) The challenge of calculating value as measured by area. In other words, two identical sections with different areas have different values. 4) Addressing the challenges in predicting future asset values due to the instability of economic forces and the difficulty to predict future unit prices. In other words, because of the change in unit prices due to market forces, asset values may increase or decrease regardless of any asset management stewardship. The challenges identified in this chapter are addressed in the Chapter 4.

Chapter 4
Asset Value: An Integration Performance Measure

4.1 Introduction

Based on the analysis and the challenges identified in the Chapter 3, this Chapter presents a valuation methodology for integration in asset management state of the practice. In addition, this Chapter presents an integration methodology for the proposed valuation method in Life Cycle Cost Analysis (LCCA). Furthermore, a proposed framework for reporting TCA using the proposed valuation method is presented. Finally, this chapter introduces a methodology to develop value-based specifications for infrastructure assets management and reporting using the proposed method.

4.2 Asset Value Loss

In the context of asset management, it is paramount to establish a value of an asset and be able to manage it, maintain and enhance its value. Therefore, it is imperative to address the challenges identified above to provide a stable measure that can be used in asset management decision making.

To address the aforementioned challenges, the Asset Value Loss (AV_L) is introduced as a ratio of the depreciated asset value loss to that of a new value, expressed as follows:

$$\text{Asset Value Loss } (AV_L) = \frac{RC - WDRC}{RC} \qquad \text{Equation 4.1}$$

Where:

AV_L = Asset Value Loss ratio,

WDRC = Written Down Replacement Cost ($)

RC = Replacement Cost ($)

The RC and WDRC methods are straightforward methods and easily understood and communicated. Using the ratio eliminates the impact changes to unit prices and inflation or discount rate as the percentage loss will remain constant regardless of any changes to unit prices.

To illustrate, consider a pavement section with 15 years analysis period presented in Table 4.1. The section received rehabilitation at year 13. The section attributes, condition, replacement unit cost, and interest rate are provided in Table 4.1.

Table 4.1 Asset Value Loss Illustration Example

Pavement Section Information: **Pavement Type: AC, Area: 52250 m2, Replacement Unit Cost: $ 91.73, interest rate= 5%**					
Year	**PCI**	**RC** **(1)**	**WDRC** **(2)**	**Value Loss ($)** **(1-2)**	**VL Ratio (%)** **(1-2)/(1)**
1	97	$ 4,140,281	$ 4,006,964	$ 133,317	3%
2	96	$ 3,755,357	$ 3,617,160	$ 138,197	4%
3	95	$ 3,406,219	$ 3,236,930	$ 169,289	5%
4	94	$ 3,089,541	$ 2,901,388	$ 188,153	6%
5	88	$ 2,802,305	$ 2,463,506	$ 338,799	12%
6	87	$ 2,541,773	$ 2,200,921	$ 340,852	13%
7	86	$ 2,305,463	$ 1,974,168	$ 331,295	14%
8	80	$ 2,091,123	$ 1,664,743	$ 426,380	20%
9	79	$ 1,896,710	$ 1,499,919	$ 396,792	21%
10	76	$ 1,720,372	$ 1,313,676	$ 406,696	24%
11	73	$ 1,560,428	$ 1,135,524	$ 424,905	27%
12	69	$ 1,415,354	$ 975,179	$ 440,175	31%
13	92	$ 1,283,768	$ 1,181,067	$ 102,701	8%
14	90	$ 1,164,416	$ 1,047,974	$ 116,442	10%
15	87	$ 912,350	$ 793,745	$ 118,606	13%

The ratio indicates the total loss of asset replacement cost considering its current condition to that of a new asset. In other words, the ratio shows the loss of value due to the asset deterioration. If a preservation or rehabilitation is applied, the WDRC value increases as the condition improves, therefore reducing the loss ratio. The ratio allows for incorporating future values while addressing the challenges associated with economic fluctuations of unit costs. In addition, in the context of asset management decision making, the concept addresses the variation of value between sections due to the different area. Figure 4.1 graphically illustrates the value loss ratio over the analysis period. The proposed approach was applied to the same study from section 3.4 in the previous chapter. The network average PCI, the network total asset value loss ratio and box-plot are presented in Figure 4.2.

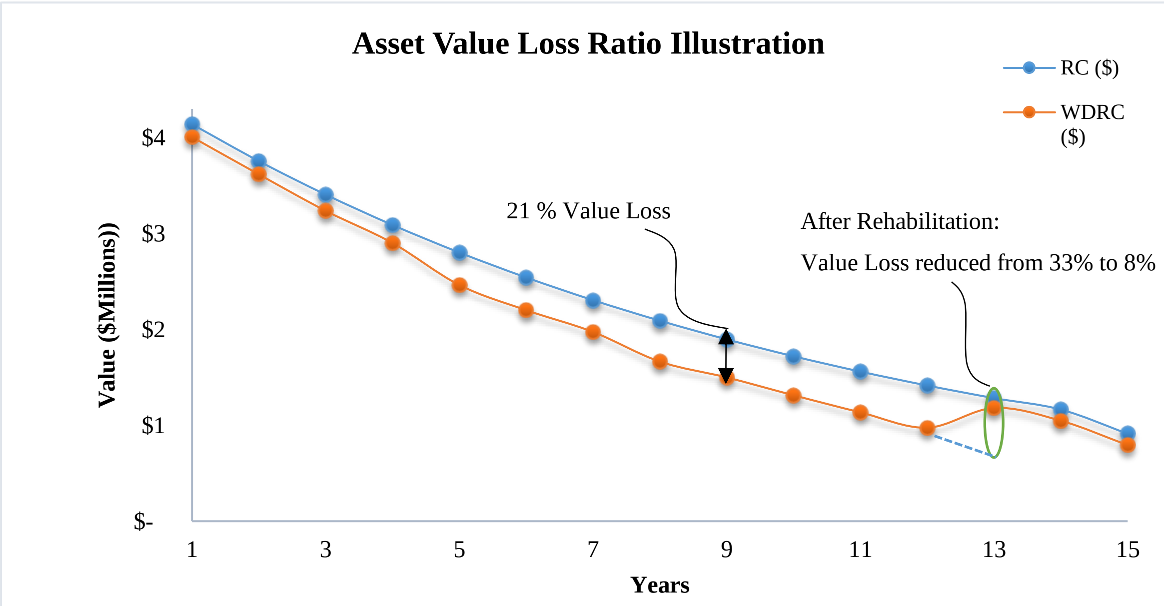


Figure 4.1 Graphical Representation of Value Loss Ratio over Analysis Period

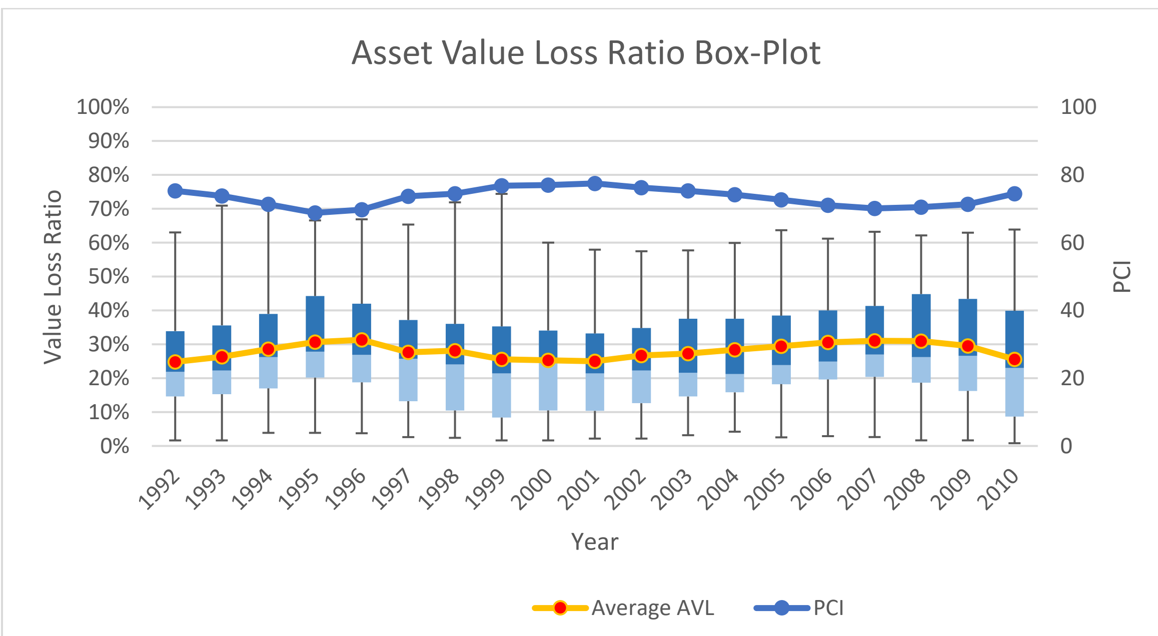


Figure 4.2 Network Asset Value Loss Ratio

As depicted in Figure 4.2, the value loss is measured and reported for the network while eliminating the variation due to changes in unit costs. On the other hand, the method reflects the network condition capturing the impact of good asset management practice. For example, between years 1992 and 1995, there was a decline in the network average condition, which was reflected in the increase of the asset total value loss.

4.3 Integrating Asset Value in Life-Cycle Cost Analysis

Life Cycle Cost Analysis (LCCA) refers to the direct financial costs associated with a project (TAC 2013). LCCA evaluates competing alternatives by evaluating costs incurred along the project life cycle including initial construction costs, maintenance and rehabilitation costs to maintain functional condition along the service life. This process is widely applied because it can evaluate differences between design options such as pavement type and various feasible design cross sections. Agencies of all levels have used LCCA to evaluate new technologies, develop alternatives, and to provide defensible decisions for alternative financing and procurement of projects (Smith and Fung 2006). LCCA is used by agencies to assist with long-term planning asset management plans and budget estimates.

In LCCA, it is important to account for the change of the time value of money (FHWA 2002b; Markow 2012; TAC 2013). In other words, costs at different times must be converted to their value at a common point in time using a discount rate. To evaluate competing alternatives, infrastructure investments are converted to a single variable, the Net Present Cost (NPC). The NPC allows for comparing the total costs of the alternatives in today's dollars. The NPW is calculated as follows:

$$\text{NPC} = IC + \sum_{j=1}^{k}(M\&R_j \ x \ (\frac{1}{1+i})^{n_j}) \qquad \text{Equation 4.2}$$

Where

NPC= Net Present Cost ($)

IC= Initial Cost ($)

K = Number of future maintenance, preservation and rehabilitation

$M\&R_j$= Cost of j[th] future maintenance, preservation and rehabilitation activity ($)

i= Discount rate

n_j= Number of years from the present to the j[th] future maintenance, preservation and rehabilitation treatment

As noted, the LCCA is used in asset management to evaluate different maintenance and rehabilitation strategies. In addition to maintenance and rehabilitation costs, agencies started to include other factors such as salvage value and user costs and environmental costs in the LCCA (Bryce et al. 2014; Mallela et al. 2011; Ozbay et al. 2004; Smith and Fung 2006; TAC 2013; Torres-Machí et al. 2015). However, to date, the impact of asset value on LCCA is not considered. Incorporating asset value in LCCA as a means of evaluating the return on investment is imperative. For example, the Transportation Research Board (TRB) issued a research needs statement with the objective to develop standard calculation methodologies to characterize the asset value of pavements for use in funding allocation, life cycle cost analysis and engineering evaluation.

The method proposed in the previous section can also be used in LCCA to evaluate different designs or the impact of different maintenance and rehabilitation strategies over the life cycle of the project on its value. The AV_L can be used to calculate the total loss of asset value over the analysis period and added as an incurred cost. Figure 4.3 shows an illustration of the proposed methods.

As shown in Figure 4.3, the AV_L up to the time maintenance or rehabilitation is applied and at the end of the analysis period is used to calculate the loss in value up to that point. Mathematically, the calculation shown in Equation 4.2 can be modified to include asset value loss as follows:

$$\text{NPC} = IC + \sum_{i=1}^{k}(M\&R_j \ x \ (\frac{1}{1+i})^{n_j}) + \sum_{t=1}^{T}(AV_{Lj} \ x \ RC) \qquad \text{Equation 4.3}$$

Where: AV_{Lj} is the Asset Value Loss ratio before the j[th] $R\&M_j$ treatment is applied, and at the end of the analysis period (Year T)

RC is the present Replacement Cost ($)

t = Year *t* of *T* years analysis period

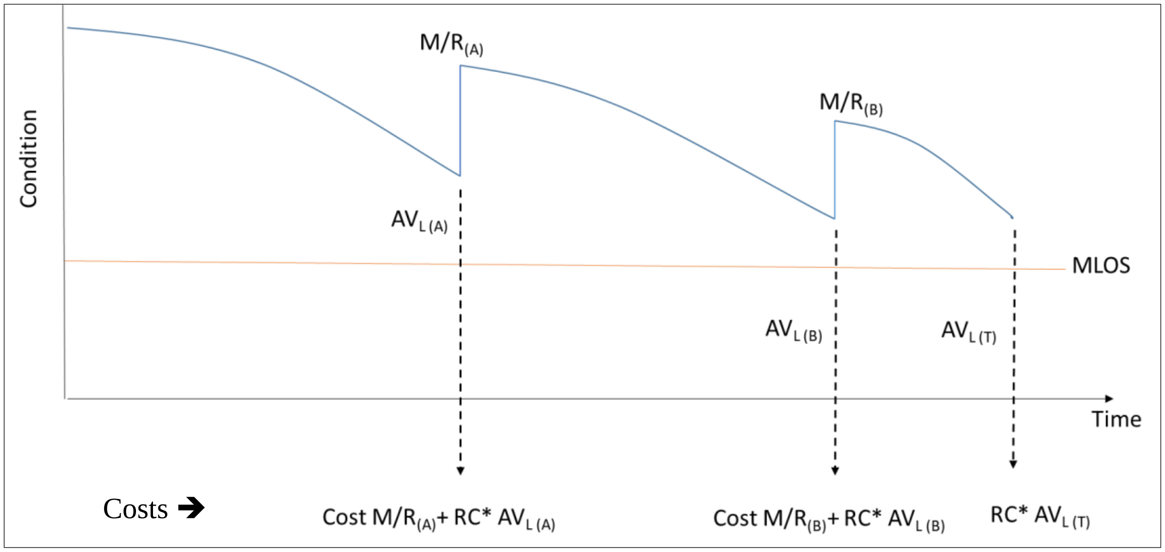


Figure 4.3 Incorporating Asset Value Loss in LCCA Illustration

Incorporating asset value loss allows for quantifying the opportunity loss in investment to preserve the asset and the impact of delay in maintaining assets. To further illustrate the proposed methodology, consider the pavement rehabilitation strategies example shown in Table 4.2. The pavement performance over the analysis period is illustrated in Figure 4.4.

Table 4.2 Pavement Rehabilitation Strategies Example

Area = 21,491 m^2, Replacement Unit Cost = $91.73, Rehabilitation Unit Costs: Hot Mix Overlay = $ 19.16 / m^2, Mill + Hot Mix Overlay = $19.5 / m^2 Analysis Year= 2010, Analysis Period = 20 Years, Discount Rate = 5%		
	Option A	Option B
Rehabilitation 1	Hot Mix Overlay , Year 9	Year 12: Hot Mix Overlay
Rehabilitation 2	Mill and Hot Mix Overlay, Year 18	Year 20: Mil + Hot Mix Overlay

Following Equation 4.3, the NPW of the alternatives are calculated as follows:

<u>Option A:</u> [($ 19.16 / m^2) * (21,491 m^2) * (1/1.05^9)] + [($ 19.5 / m^2)*(21,491 m^2)*(1/1.05^18)] + [(0.25+0.28+.012) * ($ 91.73 / m^2)*(21,491 m^2) = $ 1,508,257.53

Option B: [($ 19.16 / m^2) * (21,491 m^2) * (1/1.05^12)] + [($ 19.5 / m^2)*(21,491 m^2)*(1/1.05^20)] + [(0.3+0.26+0.1) * ($ 91.73 / m^2)*(21,491 m^2) = $ 1,688,525.61

Based on the calculation above, option A is preferred. It is worth noting that without taking asset value loss into consideration, option B is more preferred as the NPW is $387,421 while the NPW for option A is $ 439,775. Therefore, by taking into account the asset value loss due to the delay in maintaining the asset allows for a justifiable and quantifiable need for funding and opportunity loss in investment.

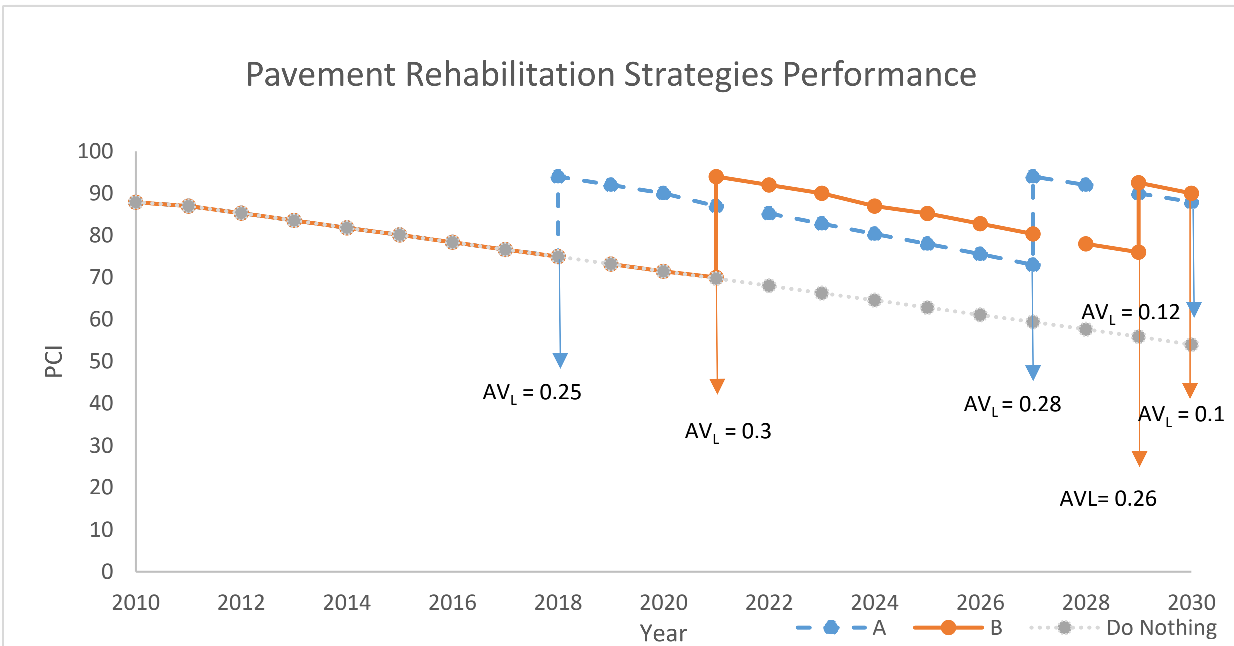


Figure 4.4 Value Based Life Cycle Cost Analysis Example for Rehabilitation Strategies

4.4 Reporting Tangible Capital Assets Framework

As indicated earlier, several government regulatory bodies mandate agencies to report their TCA values within their annual statement (for example, PSAB in Canada, the GASB in the United States and the NZ IFRS in New Zealand). Asset valuation is an important method to demonstrate proper management of public assets and effective utilization of tax payers' money. In addition, it allows agencies to demonstrate justifications of funds needed to preserve its assets (Lugg 2005). The AV_L is introduced to provide a stable measure that can be used in asset management decision making. Figure 4.5 presents a systematic framework to establish the current and future AV_L for infrastructure assets.

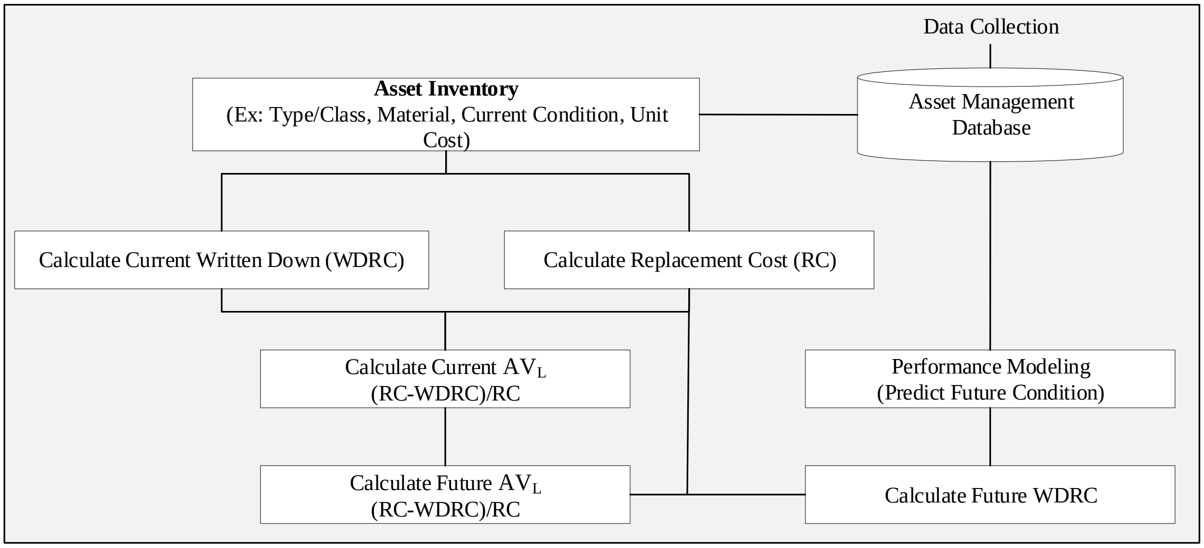


Figure 4.5 Asset Value Loss Framework

As discussed earlier, one of the key challenges in reporting asset value using the current methods is predicting future asset values due to the instability of economic forces and the difficulty to predict future unit prices. Therefore, it is recommended that the AV_L is used to report the value as a percentage of the replacement cost (fixed to the analysis year unit cost) over the analysis period. The ratio can be presented to convey an increase of value loss due to lack of proper funding and asset management stewardship or vice versa. As presented earlier, the RC and WDRC methods are straightforward methods and easily understood and communicated. Using the ratio eliminates the impact changes to unit prices and inflation or discount rate as the percentage loss will remain constant regardless of any changes to unit prices.

4.5 Value-Based Specifications

Asset management decision making is guided by its performance measures and the associated targets or thresholds. Therefore, it is important that the required performance measures and the associated LOS to be achieved are properly identified.

Using asset value as a performance measure in asset management, and in performance based specifications, such as Performance Based Maintenance Contracts (PBMC) or PPP, it is imperative to carefully establish value thresholds or LOS for the purpose of measurement and tracking.

The proposed AV_L is a function of the WDRC valuation methods, which incorporate asset condition to write down the replacement cost. To establish the LOS for AV_L, equation 4.1 is rearranged and the $AV_{L,LOS}$ is calculated as follows:

$$AV_{L,LOS} = 1 - \frac{Asset\ Condition\ LOS}{Asset\ Condition\ (New)} \qquad \text{Equation 4.4}$$

Where,

$AV_{L,LOS}$: The maximum Asset Value Loss acceptable for the specified LOS

Asset Condition LOS: Established LOS or threshold in place for asset condition

Asset Condition (New): The asset condition if newly constructed

For example, a Freeway pavement LOS threshold is a PCI of 75. As such, using equation 4.4, the $AV_{L,LOS}$ is 0.25.

4.6 Summary

In the context of asset management, it is paramount to establish a value of an asset and be able to manage it, maintain and enhance its value. Based on the analysis of the various valuation methods, challenges in applying the valuation methods in the context of asset management decision making are identified and addressed by the proposed asset value loss concept. A methodology to integrate the proposed asset value loss ratio in LCCA is presented. In addition, this chapter presents a proposed framework for reporting infrastructure TCA using the proposed method. A methodology to develop value-based specifications for infrastructure assets based on the proposed AV_L is introduced. The following chapter presents a methodology to incorporate the proposed AV_L in asset management decision making.

Chapter 5

Value Based Asset Management Methodology

5.1 Introduction

The objective of this research is to develop a methodology that integrates asset value as a performance measure in asset management decision making. This Chapter introduces an asset management methodology that aims to arrive to an optimum value-based asset management plan of maintaining infrastructure assets taking into account budgetary and performance constraints. To achieve this objective, an Asset Value Index (AVI) that integrates asset value and value-driver performance measures and associated thresholds and LOS requirements is proposed. The Multi-Attribute Utility Theory (MAUT) is used to develop the proposed AVI. The information and analysis summarized in previous chapters are used to develop the proposed methodology. The proposed framework and the various components are discussed. Version of the proposed methodology in this chapter has been submitted and presented at the Canadian Society of Civil Engineers conference.

5.2 Incorporating Asset Value in Asset Management

Agencies (public or private) who are managing infrastructure assets rely on external funding from the stakeholders, such as goverments and taxpayers. Given the challenge of reduced budgets and available funding, it is becoming increasingly important that the agencies implement efficient and effective asset management systems that justify investement needs and implications on their assets and system as a whole.

Asset valuation is an essential component of effective asset management (TAC 2013). It is an important method to demonstrate proper management of public assets and effective utilization of tax payers' money. In addition, it allows agencies to demonstrate justifications of funds needed to preserve its assets (Lugg 2005). Asset valuation is used in standard reporting, depreciation schedules, auditor requirements and condition assessments (Byrne 1994). In other words, valuation methods are accounting methods; the methods do not really reflect the value of an asset to an agency, user and the society at large. Also, it is often challenging to explicitly reflect the impact of asset management practices on the asset values. Therefore, a value-based asset management decision-making approach is imperative to manage assets to meet the required LOS cost effectively while maintaining or enhancing the value of these assets to the various stakeholders.

Using the current asset valuation methods as a basis of decision making in asset management poses a few challenges. First, as shown in Chapter 3, different valuation methods yield different values. In addition, valuation methods consider different parameters to determine asset value. For example, the WDRC considers condition (value from the user perspective), while GASB considers service life of the asset (value from the agency's perspective). However, it is imperative that value reflects both perspectives. Furthermore, the current valuation methods do not account for the change of unit prices, probabilistic behaviour of assets' deterioration and the sectioning of assets; i.e. sections area.

To address the challenges inherited in the current valuation methods, the AV_L method is proposed in Chapter 4. However, as indicated earlier, other key factors impact the value from the perspective of the various stakeholders. For example, the asset capacity and utilization, asset function in the network, location, and safety, to name a few.

The objective is to develop a decision making support system to aid agencies to develop an optimum value-based asset management plan of maintaining infrastructure assets. To meet this objective, an Asset Value Index (AVI) that integrates asset value and key factors as performance measures is proposed.

Integrating asset value as a performance measure in asset management decision making introduces the need to deploy a Multi-Criteria-Decision Making (MCDM) method that incorporates various performance measures such as condition, asset value and utilization. The performance measures are of different measurement units; for example, Pavement Condition Index (PCI) and Annual Average Daily Traffic (AADT). As such, the Multi-Attribute-Utility-Theory (MAUT) is an effective candidate that can unify the units through the use of utility functions (Keeney and Raiffa 1976; Labi 2014). Utility theory is used to capture the asset value considering various performance measures (attributes) to allow decision makers to objectively develop a value driven asset management plan.

An overview of the proposed framework that utilizes the MAUT method to develop the proposed AVI is presented in Figure 5.1. The framework is generic in nature and can be used for different asset classes. The framework is complementary to the generic asset management framework presented in Chapter 2, Figure 2.1.

The main components of the proposed framework are presented in Figure 5.1: Strategic Planning, AVI development, and Planning and Programming. The Strategic Planning phase includes the input information required which identifies the agency's goals and objectives, translating that into performance measures, weights and associated targets or LOS, budget constraints, and the agency's asset management database.

The AVI development component of the framework involves three main steps: Development of performance prediction models for the performance measures, development of utility functions, and amalgamation to calculate the AVI.

Assets management is performed over a time horizon to develop optimized multi-year plans for maintenance and rehabilitation utilizing the available funds. Therefore, it is important not only to understand the current network AVI, but also to evaluate the network AVI over the analysis period. The AVI is a function of various performance measures that can be predicted over time with some level of certainty (such as condition, traffic, etc.) and therefore the AVI can also be forecasted over the planning horizon. On the other hand, some key factors or performance measures are constant or subjective, such as asset class, which may remain constant over the analysis period.

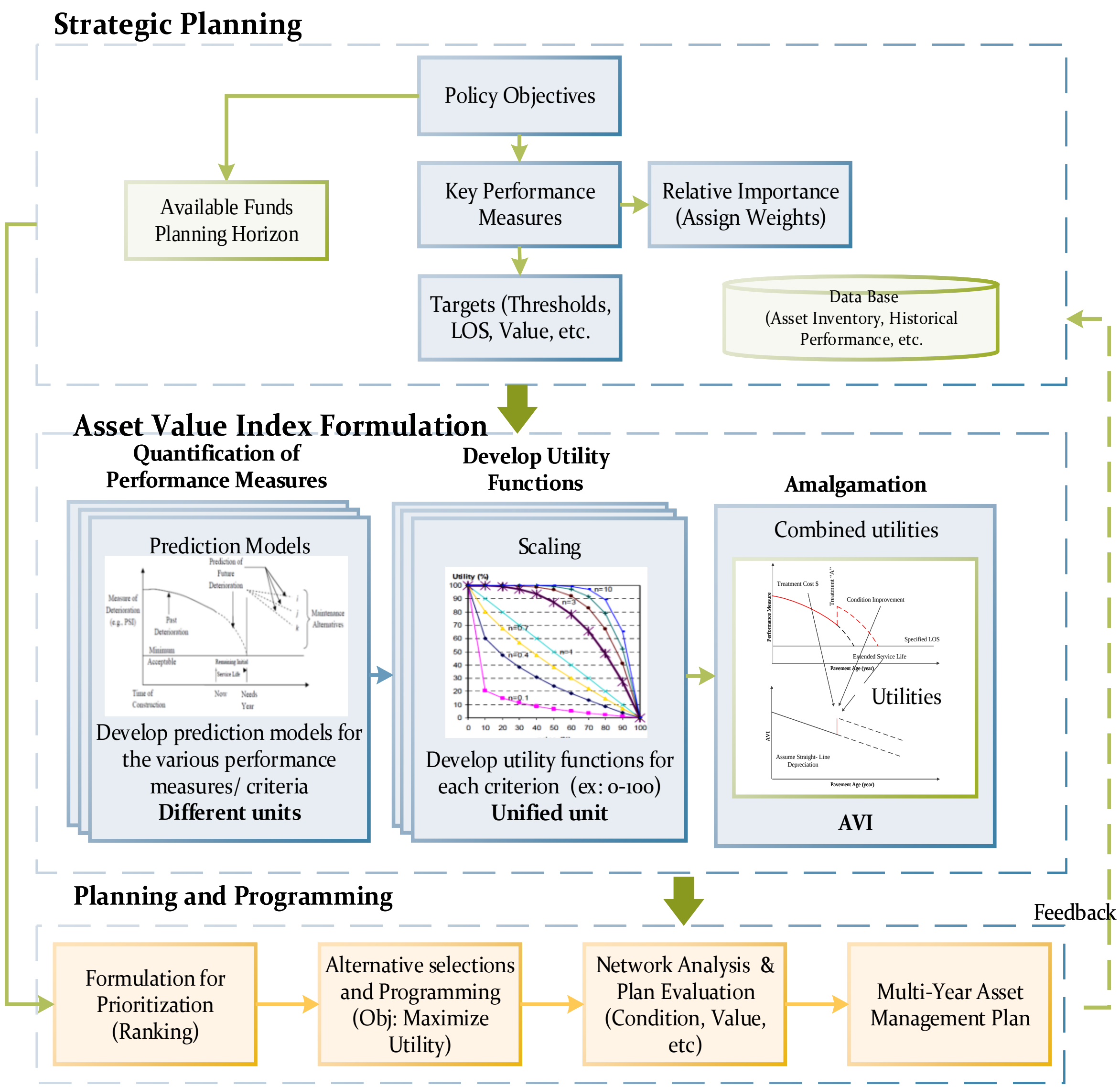


Figure 5.1 Value-Based Asset Management Methodology

The planning and programming phase of the framework is the development of the asset management plan using the AVI of the asset network and prioritizing the maintenance and rehabilitation plans to maximize the network overall value. In other words, the AVI final score for each asset is used for ranking (lowest to highest) and prioritizing the assets for maintenance and rehabilitation in order to maximize the overall value of the network. Further details of the various components are presented in the following sections. A case study to illustrate the methodology is presented in Chapter 6.

5.3 Performance Measures

Performance measurement represents a very important underpinning of the successful application of asset management (Cambridge Systematics et al. 2006). Effective asset management requires performance measures that are objectively based, consistent, quantifiable and sensitive to changes in technology or policy. Moreover, they should incorporate institutional, economic, environmental, safety, technical and functional considerations, as well as user expectations (TAC 2013). Asset management decision making is guided by its performance measures and the associated targets or thresholds. Therefore, it is important that the required performance measures and the associated LOS are properly identified.

"Value does not exist in the abstract and must be addressed within the context of time, place, potential owners and potential users" (Smith and Parr 1989). Therefore, it is imperative when establishing the value of an asset to address the question , "to whom?" (Kadlec and McNeil 2001; McNeil et al. 2000). Value can be viewed from different perspectives: agency, user, and society as a whole (Cowe Falls et al. 2004a; Dewan and Smith 2005). Figure 5.2 shows a Venn diagram of asset value.

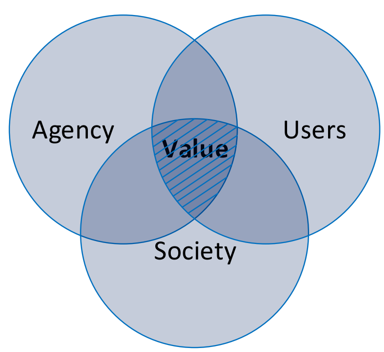


Figure 5.2 Infrastructure Asset Value Venn Diagram

For an agency, the value can be based on the cost associated with constructing and maintaining the asset (Dewan and Smith 2005), the condition of the asset, function and utilization of the asset. For a user, asset value can be in reference to accessibility, convenience, safety and satisfaction (Cowe Falls 2004). Moreover, the value to the user can be based on user cost, including: vehicle operating cost, user delay, accident, emission, and other costs (Arditi and Messiha 1999). For society, the value of an asset can be categorized based on the following (Forkenbrock et al. 2001):

- Social effects: enhancing accessibility to family, friends, and community resources, need for relocation, and changes in choice of travel modes
- Economic effects: such as land and property value, competitiveness of businesses, and linkage between jobs and employees.
- Environmental: such as air quality, wet lands and pollution.
- Aesthetic effects: such as visual quality, noise and vibration

In the proposed value based approach, the asset category performance measures that impact value (to the agency, user and society at large) are to be identified. The flexibility of the framework allows for tailoring the performance measures and associated LOS and targets based on the agencies' goals and objectives and asset category.

5.4 Relative Importance

The weight assigned (from 100%) to each performance measure represents the importance of said performance measure to the decision maker. There are various methods that can be implemented to establish the weights for the performance measures, from direct weighting to more complex methods such as the Analytical Hierarchy Process (AHP). It is worth noting regardless of the method used, the weights assigned and any changes to the weights can dramatically change the outcome of the decision (Bai et al. 2008; Labi 2014). Therefore, it is imperative to review the agencies' policies and objectives to establish the weights. Sensitivity analysis of the assigned weights is a key to evaluating the impact on the outcome of the MCDM (Labi 2014). Some of the methods are presented in the following subsections.

5.4.1 Equal Weights

In this method, the performance measures are assigned equal weights, and the sum of weights is equal to 1 (Bai et al. 2008) . For example, consider a performance measure set *n*, the weight for each performance measure is:

$$w_i = \frac{1}{n} \quad \text{and ,} \quad \sum_{i=1}^{n} w_i = 1 \qquad \text{Equation 5.1}$$

The equal weights method is straightforward and requires no analysis or surveys with the decision makers and subject matter experts. However, the method does not represent the importance of the various performance measures to the decision maker. This method can be used as a starting point or a comparison method of the decision outcome using different weights.

5.4.2 Direct Weighting

In this method, the decision maker assigns the weights to the performance measures directly. There are three types of direct weighting: Point Allocation, Categorization, Ranking (Labi 2014):

Point Allocation allocates points (out of 100%) to the performance measures representing the respective importance. In Categorization, the performance measures are grouped in a category that represent their importance relative to other performance measures in a different category. Ranking assigns a rank to each performance measure in order of importance (r_1, r_2, $...r_n$), the performance measure with the highest importance receives a rank of 1 and so on. Then the weights can be calculated as follows:

$$W_i = \frac{n - r_i + 1}{\sum_{i=1}^{n}(n - r_i + 1)} \quad \text{and} \quad \sum_{i=1}^{n} w_i = 1 \qquad \text{Equation 5.2}$$

5.4.3 Direct Rating

In the direct rating methods, performance measures are rated on a point-scale (say 1-5, 1-10, etc.); there is no restriction on the rate scale, and then the rating is transformed into weights (Bai et al. 2008). For example, for performance measures set *n*, and a point scale 10 point, the rating is a_1, a_2, …a_n, then the weights are calculated as follows:

$$w_i = \frac{a_i}{\sum_{i=1}^{n} a_i} \qquad \text{And ,} \sum_{i=1}^{n} w_i = 1 \qquad \text{Equation 5.3}$$

5.4.4 The Analytical Hierarchy Process (AHP)

The AHP determines the weights for the criteria indirectly by pairwise comparison assigning relative importance scores between the criteria (Labi 2014). The final weighting is then normalized by the maximum eigenvalue for the matrix to minimize the impact of inconsistencies in the ratios (Saaty 1980). The method is illustrated in the following steps.The process is further illustrated in the case study presented herein.

Let C = {C_1, C_2, C_3, …,C_n} be the (*n*) Selection Criteria identified to be assigned weights

Let A = (a_{ij}) be a square matrix where a_{ij} presents the relative importance between pairs (C_i,C_j) as follow:

$$A = \begin{bmatrix} a_{11} a_{12} \dots & a_{1n} \\ a_{21} a_{22} \dots & a_{2n} \\ a_{n1} a_{n2} \dots & a_{nn} \end{bmatrix} \qquad \text{Equation 5.4}$$

Where, $a_{ij} = \frac{\mathbf{1}}{\boldsymbol{aji}}$, $\forall \; i,j = 1,2,3,\dots\, n$ Equation 5.5

a_{ij} assumes a value of relative importance between C_i and C_j in a scale from 1-9 as shown in Table 5.1.

Let w = {w_1, w_2, w_3…w_n}=1 be the weight vector for the *n* criteria. The weight for each criterion can be obtained as follow:

$$w_i = \frac{1}{n} \sum_{j=1}^{n} \frac{aij}{(\sum_{j=1}^{n} aij)} \qquad \forall \; i, j = 1,2,\dots.n \qquad \text{Equation 5.6}$$

Table 5.1 Comparison Scale (Adapted from Saaty 1980)

Intensity of importance	Definition
1	Equal Importance
3	Moderate more important
5	Strongly More Important
7	Very Strongly More Important
9	Extremely More Important
2,4,6,8	Intermediate values between adjacent scale values

The AHP method allows to check the consistency of the decision maker in the pair-wise comparison to establish the weights. To check the consistency, the following is computed:

Consistency Index (C.I.) = (λ max – n) / (n-1) Equation 5.7

Consistency Ratio (C.R.) = C.I. / Random Index (R.I) Equation 5.8

Where,

λ max is the eigenvalue obtained as the sum of the resultant vector of (A*w/w) divided by number of selection criteria (*n*).

Random Index (R.I.) is a constant that depends on the number of criteria (*n*), Table 5.2. A consistency ratio lower than 0.1 is considered consistent.

Table 5.2 Random Index (Adapted from Saaty 1980)

n = 1, R.I. = 0	n = 6, R.I. = 1.24
n = 2, R.I. = 0	n = 7, R.I. = 1.32
n = 3, R.I. = 0.59	n = 8, R.I. = 1.41
n = 4, R.I. = 0.9	n = 9, R.I. = 1.45
n = 5, R.I. = 1.12	n = 10, R.I. = 1.49

5.4.5 The Delphi Method

The Delphi Method (Dalkey and Helmer 1963) is a method that can be used to refine the weighting established by various stakeholders. The respondents of a survey are shown the results of the surveys and given a chance to review and modify their responses. This process is repeated until agreement is reached and there is no variance in two successive surveys.

5.5 Utility Functions

Performance measures are of different units (EX. PCI, Dollars, AADT). Scaling provides a common scale of measurement (say 0-1, or 0-100) that converts the performance measure values to a unified scale called utility. Utility functions capture the decision-makers ‘preferences regarding the levels of each decision criterion (Keeney and Raiffa 1976; Labi 2014). To reduce dimensionality, scaling (normalizing) of all possible outcomes for each performance measure is performed separately (Labi 2014).

Scaling techniques can be classified as non-preference-based methods, and preference-based methods (Labi 2014). Non-preference-based methods include rudimentary techniques, linear scaling, and monetization, while preference-based methods include the direct rating method (Labi 2014). Non-preference based methods are considered subjective as they are developed based on survey questionnaires of expert groups (Bai et al. 2008; Porras-Alvarado et al. 2015).

The various utility values as a result of scaling form the final utility functions. Utility functions are used to represent the preference level the decision maker associates with given performance measures value or outcome, where the least preferred outcome is given a utility value of zero and most preferred is one (Keeney and Raiffa 1976). In addition, the utility functions capture the decision maker attitude towards risk classified as risk-taker, risk-adverse and risk-neutral, as depicted in Figure 5.3 (Keeney and Raiffa 1976; Labi 2014).

Typically, utility functions take monotonically-increasing, monotonically-decreasing, concave and convex, or non-monotonic shapes (Labi 2014). The consistency of the utility function must hold for all values of the performance measure. For example, in an increasing utility where an increase in the performance measure is preferable, the utility function should be selected such that if $x_1 < x_2 \ldots < x_n$ the $U(x_1) < U(x_2) \ldots < U(x_n)$. The functional form of the utility function represents the rate at which the utility changes in reference to performance measure values.

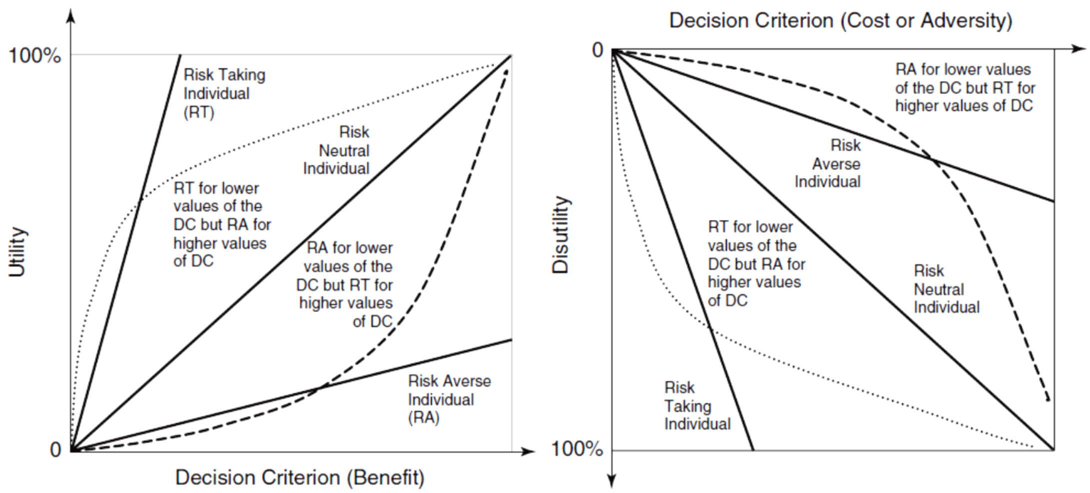


Figure 5.3 Utility Functions Reflection of Decision Maker Attitude towards Risk (Adopted from Labi 2014)

Various research has established utility functions forms for various performance measures in civil infrastructur as summarized by Bai et. al. (Bai et al. 2008; Porras-Alvarado et al. 2015). Typical utility equations forms include:

Exponential Increasing:	$u(x) = k\, e^{-ax}$	Equation 5.9
Exponential Decreasing	$u(x) = k\,(1 - e^{-ax})$	Equation 5.10
Sigmoidal (S-Shape) Increasing	$u(x) = k\, e^{-ax^2}$	Equation 5.11
Sigmoidal (S-Shape) Decreasing	$u(x) = k\,(1 - e^{-ax^2})$	Equation 5.12

Where: (a) and (k) are calibration coefficients and $k > 0$, $a > 0$

Utility functions are established by previous research in the equation forms presented above and the factors a and k are calibrated to align with the agencies' policy objectives and translated to their performance measures and associated LOS or targets. In other cases where utility functions are not available, utility functions and associated coefficients can be developed using the Direct Questioning approach or Certainty Equivalent approach (Keeney and Raiffa 1976). The approaches use a five point assessment that can be used to obtain desired utility values at five points of the performance measure. Then the coefficients are calibrated to fit the curve to one of the utility function forms presented in Equations 5.9 through 5.12 (Porras-Alvarado et al. 2015)

The development of the utility function is an important step of the development of the AVI. Therefore, it is imperative that the performance measures and thresholds are carefully reviewed to establish the utility function, shape, and utility extremities, zero and one.

5.6 Amalgamation

The utility values for a given section are calculated in reference to each criterion and then amalgamated to calculate the total utility, AVI, for that section. Amalgamation is the combination of the different utility values of the multi-criteria for a given section using mathematical equations to yield the total utility value (Bai et al. 2008; Labi 2014), the AVI for that section, considering the weights established for the performance measures. Two methods can be used for amalgamation, the weighted sum method (WSM), commonly used by decision makers (Bai et al. 2008), and the multiplicative utility function (Labi 2014).

The final AVI value for a given section can be calculated using the WSM as follows (Bai et al. 2008; Triantaphyllou 2000):

$$AVI_{ij} = \sum_{j=1}^{n} W_i \, U_{ij} \,, \quad j = 1, 2, 3, \ldots, m \qquad \text{Equation 5.13}$$

Where;

W_i = weight for *i*th performance measure, $\sum_{i=1}^{n} w_i = 1$

U_{ij} = utility value for *i*th performance measure for asset section j , i, $0 \leq U_{ij} \leq 1$

On the other hand, the WPM is calculated as follows:

$$AVI_{ij}=\frac{1}{k}*(\prod_{i=1}^{n}[1+kw_i\ U_{ij}\ (x_i)]-1)$$

Where;

k = Scaling factor that is calculated by solving $\prod_{i=1}^{n}(1+kw_i) = 1+k$

The WSM is used in the case where the performance measures are utility independent and preference independent. Utility independence is achieved when the performance measures' utility functions do not depend on the value of the other performance measure level. Preference independence assumes that trade-off between performance measures does not depend on the level of other performance measures. Premise of using the multiplicative form is when all performance measures are mutually utility independent. If $X_1,X_2,\ldots,X_n$ are the *n* performance measure, we say criterion X_i is utility independent if X_i 's utility function does not depend on the levels of other performance measure. Also $X_1,X_2,\ldots,X_n$ are mutually utility independent if every subset of $\{X_1,X_2,\ldots,X_n\}$ is utility independent of its complement (Keeney and Raiffa 1976).

5.7 Priority Programming

In asset management, budget constraints dictate establishing priority programming of various maintenance and rehabilitation activities for the network to maintain the performance LOS. In other words, with the available budget, managers and engineers determine how much work can be carried out to maximize the objective of achieving the specified performance LOS. Different methods were established to develop priority programs as discussed earlier in section 2.5 of this thesis.

In the proposed method, the objective of the priority programming is to maximize the network AVI, subject to the available annual budget, and performance targets constrain over an analysis period. The AVI incorporates the various performance measures in accordance with their utility and preference to the decision maker, reflected in the weights assigned. The priority framework proposed using the AVI is presented in Figure 5.4.

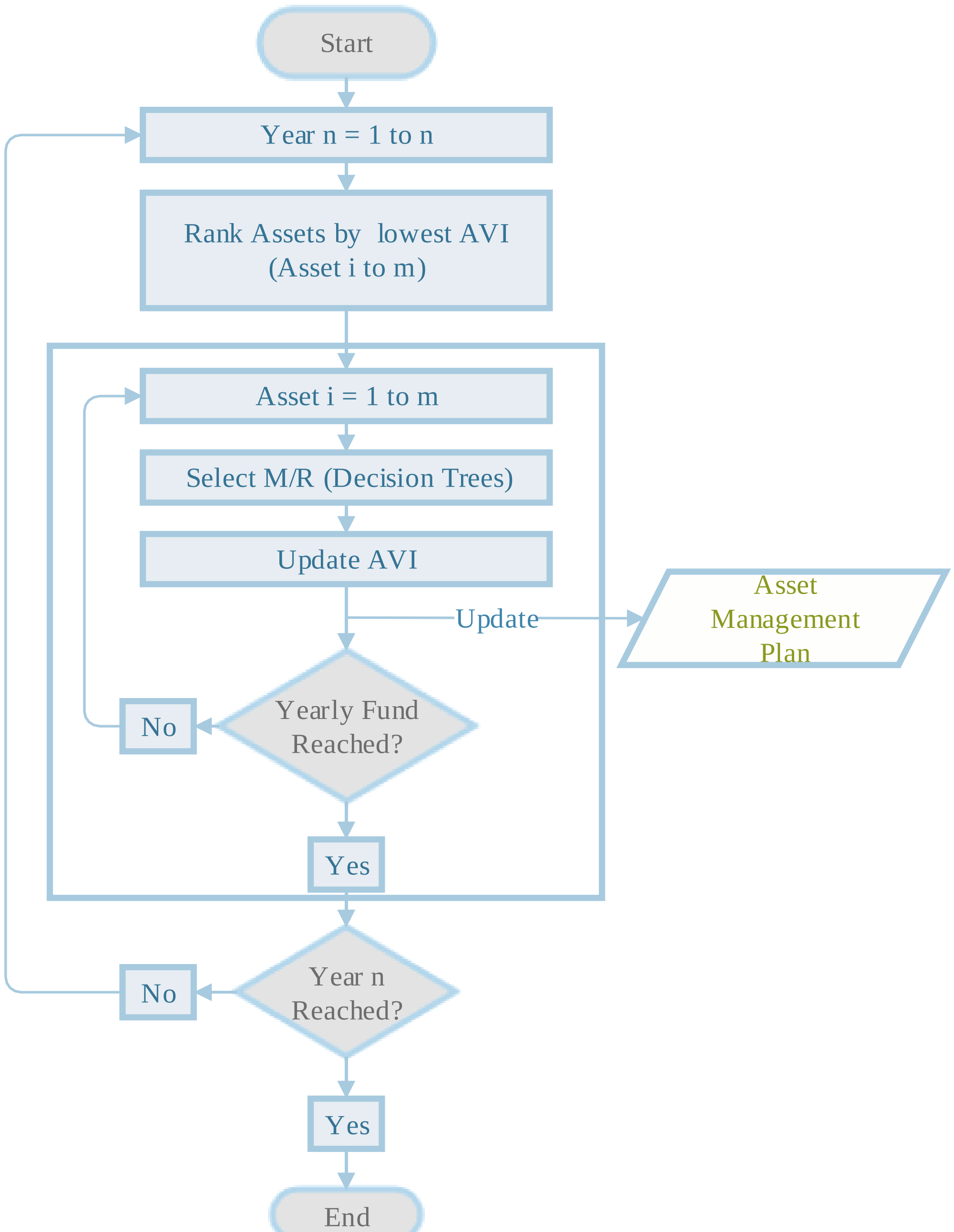


Figure 5.4 Proposed Network Prioritization Flowchart

As depicted in Figure 5.4, for each year, a ranking of the assets based on the lowest AVI is established and nominated for treatment using the appropriate decision trees (project level). The sections are selected from worst to best AVI until the available budget for the given year is exhausted. For each year, the performance of the selected projects is updated to reflect the section overall improvements and the updated AVI. The processes are then repeated for the following year and so forth until the end of the analysis period and the asset management plan is developed.

5.8 Summary

Agencies rely on external funding from stakeholders, such as goverments and taxpayers. Given the challenge of reduced budgets and available funding, it is becoming increasingly important that the agencies implement efficient and effective asset management systems that justify investement needs and implications on their assets and system as a whole.

In this chapter, a conceptual asset management methodology that integrate asset value as a performance measure is proposed. The objective is to develop a decision making support system that arrives to an optimum value-based asset management plan of maintaining infrastructure assets taking into account budgetary and performance constraints. The methodology aims to provide agencies with tools to develop a value driven, structured and justifiable asset management plans. To meet this objective, an Asset Value Index (AVI) that integrates asset value as a performance measure is proposed. The MAUT is proposed as a tool to develop the AVI. The framework is generic in nature and can be used for different asset classes. The framework is complementary to the generic asset management framework. In addition, key components of the proposed methodology are discussed, with a focus on the utility functions and the weighting methods. Various methods to develop the utility functions are discussed in detail. The development of the utility function is an important step of the development of the AVI. Therefore, it is important that the performance measures and thresholds are carefully reviewed to establish the utility function, shape, and utility extremities, zero and one. Furthermore, various methods to establish the weights are discussed, from simple methods such as direct weighting to a more complex methods such as the AHP. It is worth noting that regardless of the method used, the weights established can dramatically change the outcome of the decision. Therefore, it is imperative to review the agencies' policies and objectives to establish the weights. Sensitivity analysis of the assigned weights is a key to evaluating the impact on the outcome of the decision. The proposed methodology and the key components are demonstrated through a case study in Chapter 6.

Chapter 6

Value-Based Asset Management Application: Pavement Assets Case Study

6.1 Introduction

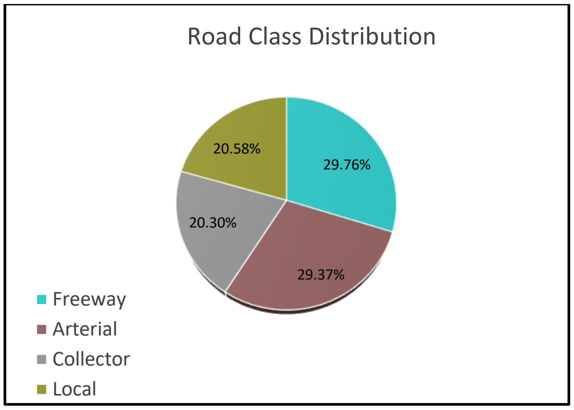
To demonstrate the proposed methodology presented in the Chapter 5, a case study from the Ministry of Transportation of Ontario (MTO) second generation Pavement Management System (PMS2) is presented in this chapter. An overview of MTO network is presented and analyzed. In addition, the various components of the proposed methodology are demonstrated through the case study. Furthermore, the outcome of the implementation of the proposed AVI is compared to optimization output, Do-Nothing output as well as needs assessment output. Version of the implementation case study presented in this chapter has been submitted and presented at the CSCE. In addition, part of the analysis to develop the performance models has been submitted and published at the Transportation Research Record (TRR).

6.2 Pavement Assets: Ministry of Transportation of Ontario (MTO)

Ontario network contains over 18,000 km of roadways. The road classification in Ontario include Freeways, Arterials, Collectors and Local roads, Figure 6.1. The pavement type in Ontario is mostly asphalt pavement. Other pavement surface types include Portland Cement Concrete (PCC), Composite (concrete with asphalt layers), surface treated, and gravel, Figure 6.1. This study will focus on asphalt pavements as it forms the majority of the pavement in Ontario.

The MTO's PMS2 obtained for this study contains data collected from 1990 to 2010. The data base includes 870 sections with data classified as historical data and survey data. The historical data include: Climatic Zone (Northern and Southern), Equivalent Thickness, Subgrade Soil Type, Pavement Type as well as the maintenance and rehabilitation activities applied throughout pavement life cycle. On the other hand, survey data include: Annual Average Daily Traffic (AADT), Truck Percentage, Equivalent

Single Axel Load (ESALs), Roughness (IRI m/km), Rutting (cm), Pavement Condition Index (PCI), and Distress Manifestation Index (DMI) (Alyami and Tighe 2013). Table 6.1 shows a sample of the PMS2 data used in this study.



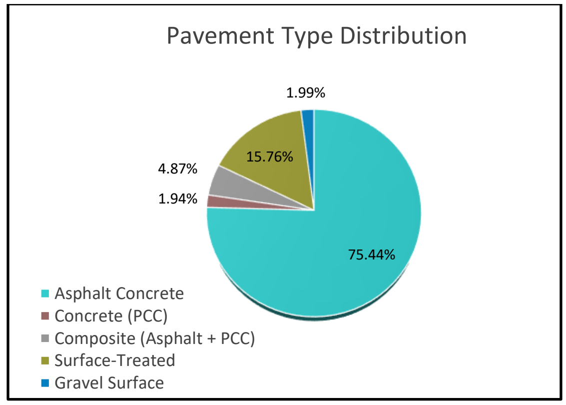


Figure 6.1 Pavement Network Overview

Table 6.1 PMS2 Sample Data

Fun_Class	Sec	Mile	Mile	Year	PCI	IRI	DMI	AADT	Type	Sur_Thick	ESAL	SubGrade	Env
FWY	1	0.23	4.658	2010	67.81	1.36	7.14	20442	AC	101.8	317097	Sandy si	SO
FWY	1	0.23	4.658	2009	69.12	1.48	7.38	20442	AC	101.8	378283	Sandy si	SO
FWY	1	0.23	4.658	2008	68.9	1.51	7.38	20442	AC	101.8	317097	Sandy si	SO
FWY	1	0.23	4.658	2007	72.77	1.3	7.64	20442	AC	101.8	317097	Sandy si	SO
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FWY	1	0.23	4.658	1997	96.78	0.93	10	20442	AC	101.8	317097	Sandy si	SO
FWY	1	0.23	4.658	1996	54.04	0	5.94	20442	AC	101.8	317097	Sandy si	SO
FWY	9	56.669	72.946	2010	65.08	1.22	6.72	90318	AC	307.6	1065447	Sandy si	SO
FWY	9	56.669	72.946	2009	69.86	1.14	7.18	90318	AC	307.6	1065447	Sandy si	SO

Note: func_class= Function Class, Sec =Section Number, year= year of data collection, Type= Pavement Type, surf_thick= Surface Thickness, ESAL= Equivalent Single Axel Load Env= Environmental Zone,

The key performance indicators used in MTO's PMS include International Roughness Index (IRI), Distress Manifestation Index (DMI), and Pavement Condition Index (PCI) (Li et al. 2014).

Roughness is defined as "Distortion of the pavement surface that contributes to an undesirable or uncomfortable ride" (Hudson 1978). Roughness measurements can be used to measure the serviceability of the pavement and directly relate to the vehicle operating cost (TAC 1997). The quality indicator generally used for ride quality is the IRI. Roughness is the direct interaction between pavement, vehicle and user and therefore a very important performance measure.

Pavement Condition Index (PCI), is a mathematical equation of which the inputs are values of different performance or distress measures such as cracking and rutting. The PCI is calculated using IRI and surface distresses. The surface distresses and its assigned weights calculated based on the PCI values are presented in Table 6.2 (MTO 1990). The PCI is calculated on a scale from 0 to 100, where a value of 100 is excellent and zero is failure (MTO 1990; MTO 1989). However, it is worth noting that a PCI of zero is impractical and a PCI value of 30 will be assigned as the value of failure in this study. This would be based on the fact that a road with a PCI below 30 would be impossible and unsafe for vehicles.

Table 6.2 Pavement Distress and Relevant Weights (MTO 1990)

Distresses	Weight
Ravelling and Coarse Aggregate Loss	3.0
Long Wheel Track –Alligator	3.0
Wheel Track Rutting	3.0
Transverses- Single/Multiple	3.0
Distortion	3.0
Centerline- Alligator	2.0
Rippling and Shoving	1.0
Long Wheel Track- Single/Multiple	1.0
Pavement Edge- Alligator	1.0
Transverse- Alligator	1.0
Centerline- Single/Multiple	0.5
Flushing	0.5
Pavement Edge- Single Multiple	0.5
Long Meander Mid-lane Map	0.5

6.3 Cost Data

The cost of Maintenance, preservation and rehabilitation alternatives are required for Life Cycle Cost Analysis (LCCA), prioritization and optimization, planning as well as asset valuation. The costs of applying a given treatment of a pavement section is a function of the length of section, width, material used, thickness, etc. The unit costs used in this research are obtained from MTO's PMS2, in 2010 dollars.

6.3.1 Discount Rate

In LCCA and prioritization and optimization, it is important to account for the change of the time value of money (FHWA 2002b; Markow 2012; TAC 2013). In other words, costs at different times must be converted to their value at a common point in time using a discount rate. Typically, discount rates range from 3 to 5 percent (FHWA 2002b). In this case study, a discount rate of 5 %.

A number of techniques based on the concept of discounting are available. The FHWA recommends the present value (PV), also known as present worth, approach (FHWA 2002b); this approach is adopted in this study. The formula to discount future constant value costs to present value is as follows:

$$\text{Net Present Value (NPV)} = \text{Future Value} * \frac{1}{(1+r)^n} \qquad \text{Equation 6.1}$$

Where,

r = real discount rate

n = number of years in the future when the cost will be incurred

6.4 Pavement Network Overview

The PMS2 data were analyzed in terms of the performance of the network over the analysis period, 1990-2010. Figure 6.2, to 6.5 present the overall condition box plots for Freeway, Arterial, Collector, and Local roads in Ontario, respectively.

The network condition for each road class over the analysis period is presented as box plots showing the median, the 25th and the 75th percentiles. The whisker lines on the box plots extend to the largest and smallest observed data at the 95th and 5th percentile.

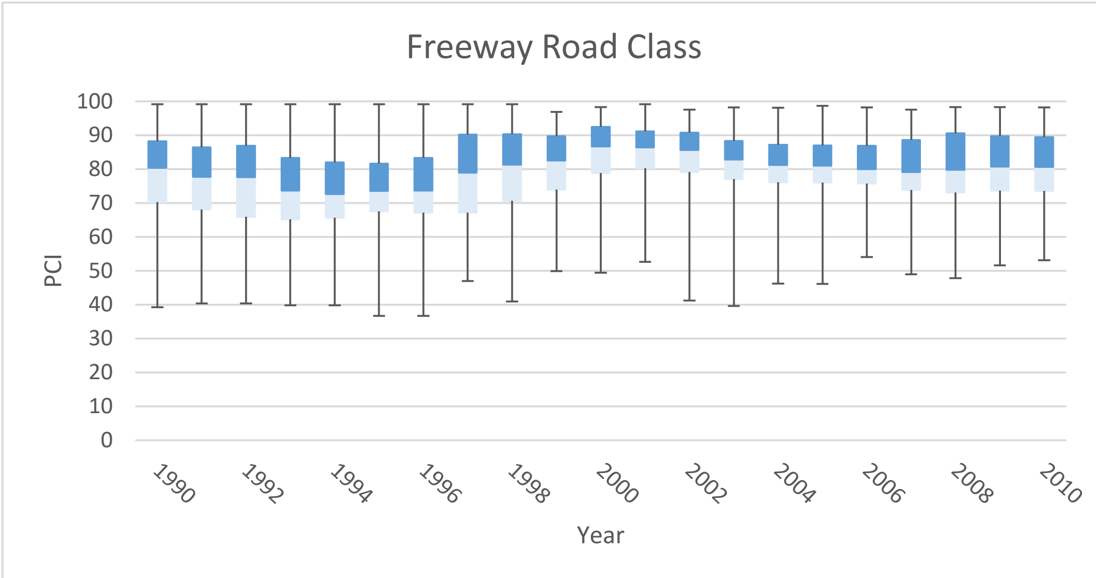


Figure 6.2 Box Plot- Freeway Road Performance

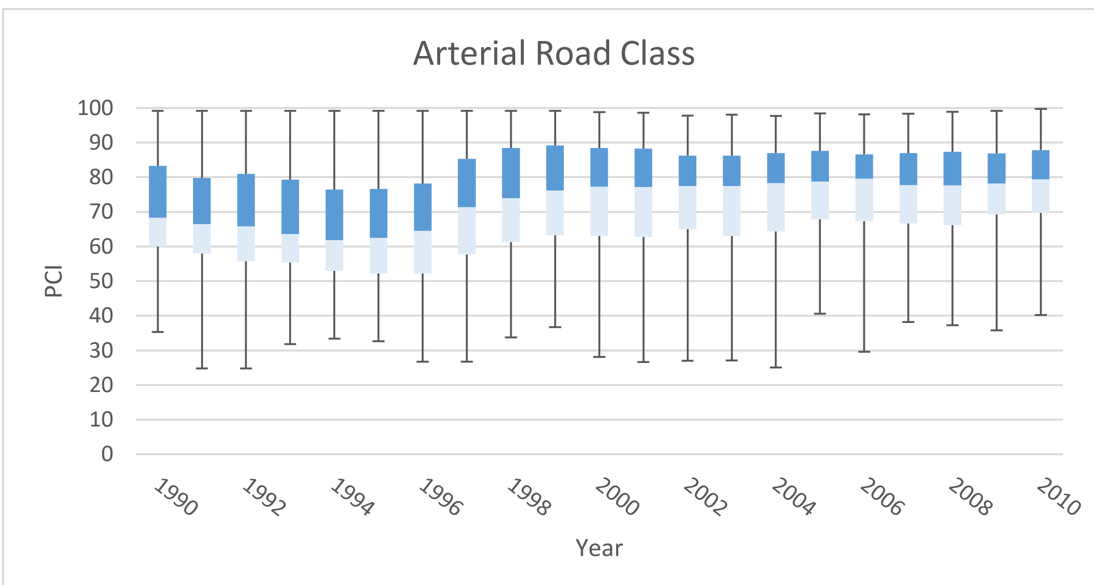


Figure 6.3 Box Plot- Arterial Roads Performance

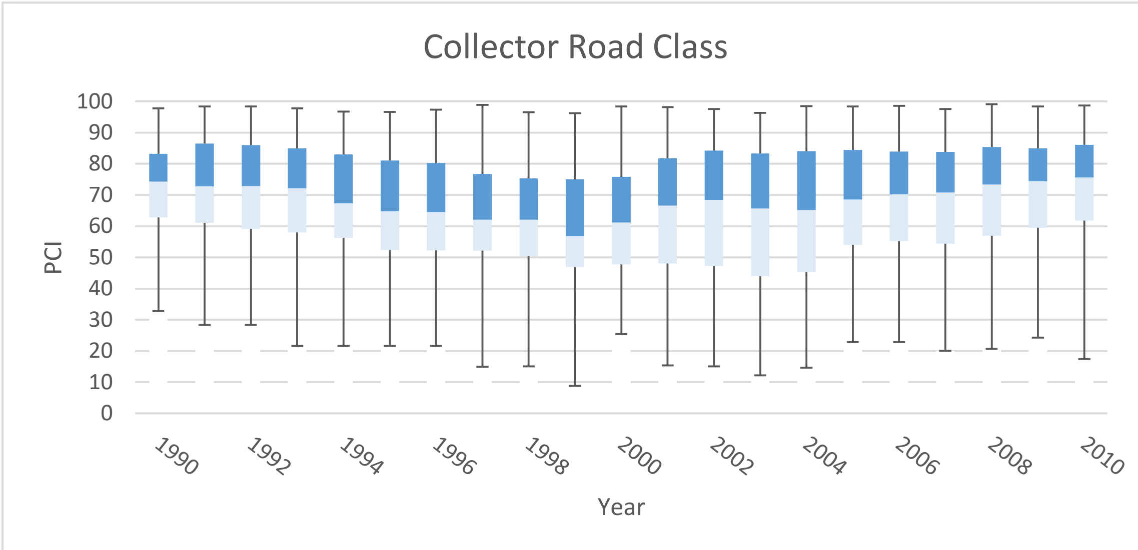


Figure 6.4 Box Plot- Collector Roads Performance

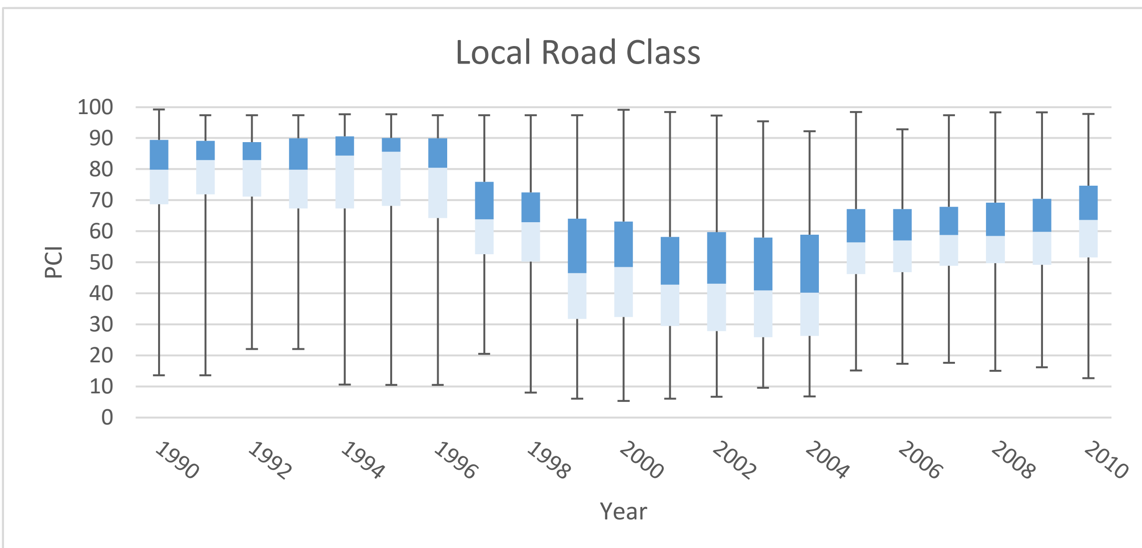


Figure 6.5 Box Plot- Local Roads Performance

Figure 6.2 shows that most of the Freeway road class network is well maintained as illustrated in the box range, 25th, 50th, and 75th percentile over the analysis period. The whiskers on the other hand, specifically the lower tail, suggests that some lower PCI data were observed as low as 40. The network condition analysis of Arterial road class network, Figure 6.3, shows that the network is also well maintained, however with a higher range shown in the 25th and 75th percentile of the network. It is also noted that the last ten years, more improvement is shown for both the Freeway and Arterial road classes. In addition, it is noted in Figure 6.4 that the network condition for the collector road class has a wider condition range suggesting that less maintenance and more deterioration is observed, in particular, more apparent between the years 2000- 2005. In addition, the local road network, Figure 6.5, has observed more deterioration in condition over the last fifteen years, more so between years 1999 to 2004. This can be attributed to the handover of local network to local municipalities. The decline of the network condition in collector and local road class is offset by improvement in the network condition for the Arterial and Freeway network.

Comparing the box plots for the four road classes illustrates a shift in the network overall condition with higher values and improved overall condition towards Freeways and Arterials, while the opposite is true for Collectors and Local road classes.

6.5 Performance Measures

The Canadian economy is dependent on good pavement infrastructure. About 90 percent of goods are transported via trucks (Transport Canada 2004); in Ontario, 60 percent of goods are transported on roads to the United States (TAC 2013). Therefore, one key performance indicator when considering value of pavement asset within MTO asset management framework is utilization. For example, two identical pavement sections with the same condition may be of the same asset value to the decision maker from an accounting prospective while one has a higher Annual Average Daily Traffic (AADT) and or Truck Traffic. Therefore, the value of an asset is in the economic and social value it provides to the stakeholders whether it is in transport of goods or people's commute and movement. Consequently, the asset function and utilization are included as performance measures in the development of the AVI. This allows the decision maker to incorporate the impact of an asset condition and return of investment to the users within the network.

Furthermore, in order to capture the return on investment of applying a maintenance or a rehabilitation treatment, it is imperative to measure the value-add realized over time, in addition to the immediate condition improvement realized. This allows for evaluation and trade-off between alternative maintenance and rehabilitation treatments. For example, for a pavement section, some treatments may result in similar immediate improvements in pavement condition; however, the deterioration rate over time may differ. Therefore, the Remaining Service Life (RSL) is considered as a performance measure to evaluate the trade-off in investments between maintenance and rehabilitation alternatives and the impact overtime on the network preservation. The RSL is defined as the time remaining until the asset reach the minimum acceptable LOS.

The performance measures hierarchy considered in developing the proposed AVI for pavement assets in Ontario is shown in Figure 6.6.

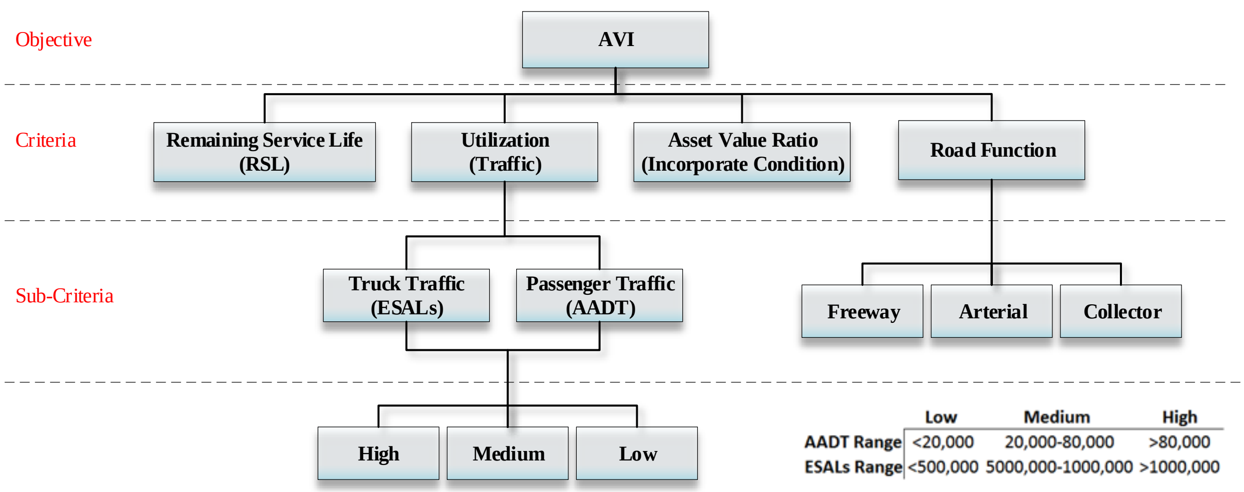


Figure 6.6 AVI Performance Measures for MTO Pavement Network

6.6 Performance Prediction Models

As indicated earlier, performance modeling is very crucial in terms of establishing the appropriate intervention alternative, and the appropriate time of application to maintain the specified level of services for different performance measures (Alyami and Tighe 2013).

As discussed earlier, performance models are classified as deterministic or probabilistic. Probabilistic models predict the performance of a pavement by giving the probability with which the pavement would fall into a particular condition state (Durango 2002). Probabilistic models are developed to characterize the uncertain behavior of pavement deterioration processes (Li 2005; Panthi 2009). The Markov model has proven to be an effective performance modeling tool among various researchers (Haas, Hudson, and Zaniewski 1994; Li 1997; Butt et al. 1987; Madanat et al. 1995; Tighe 1997). The Markov model is commonly used due to its ability to capture the probabilistic behavior of pavement and the time dependent uncertainty deterioration process for different maintenance, preservation and rehabilitation activities (Panthi 2009). The model is based on the change of a pavement from a given state to another over a period of time. As such, Markov models are developed using a Transition Probability Matrix (TPM). In order to develop the Markov models, the following steps are followed:

- Data screening and evaluation
- Identifying homogenous pavement section groups
- Developing TPM

6.6.1.1 Data Analysis

The pavement deterioration process is affected by many factors such as environment, loading, material type and thickness. To construct accurate deterioration models for maintenance, preservation and rehabilitation activities, homogeneous pavement sections should be identified. The PMS2 data obtained for this study are analyzed to develop performance prediction models for various rehabilitation alternatives common to Ontario network. The PMS2 data were evaluated to identify influence factors and develop homogeneous sections for the purpose of developing deterioration models of various intervention alternatives. The influence factors and the corresponding levels are presented in Table 6.3.

As noted in Table 6.3, the majority of the network data are for Asphalt Concrete (AC) pavement, which is a result of the fact that about 75% of Ontario network is asphalt pavement, Figure 6.1. In addition, most of the pavement section have thin equivalent total thickness and a Sandy Silt subgrade.

Table 6.3 Pavement Deterioration Influence Factors and Corresponding Levels

Influence Factors	Corresponding Levels	Total Sections
Pavement Type	Asphalt (AC)	651
	Portland Cement (PC)	6
	Composite (CO)	26
	Surface Treatment (ST)	187
Equivalent Total Thickness	Thin (TH) (<500 mm)	846
	Moderate (M) (<=500-750mm)	19
	Thick (TK) (>=750 mm)	5
ESAL	Class 1 (< 500,000)	423
	Class 2 (500,000 – 1,000,000)	339
	Class 3 (> 500,000)	108
Subgrade Type	Sandy Silt (SM)	645
	Granular Material (GM)	114
	Lacustrine Clay (LC)	93
	Varved Clay (VC)	18
Subgrade Strength M_R	Category 1 ($M_R < 30$)	351
	Category 2 ($30<M_R<50$)	504
	Category 2 ($M_R > 50$)	15
Climate Zone	Southern	496
	Northern	374

In total, 85 percent of the data is used to develop the deterioration models and the remaining fifteen percent are used for validation. In addition, outliers are identified and eliminated from the database used in this study. The main data elimination is based on the following:

- Pavement section with 0 values for PCI are considered errors in data entry
- Pavement section with high condition (Ex. PCI= 95) while at an older age (Ex. 10 years) is considered misentries

- Pavement with unsupported changes to the PCI during its lifecycle is considered a misentery. For example, a pavement PCI at 85 at a given year and 90 the following year, then 82 the year after that.
- Pavement sections with missing attributes such as soil type, weather, traffic and rehabilitation type.

The network sections are analyzed to identify maintenance and rehabilitation life cycles, i.e. identify sections for each maintenance and rehabilitation activity until the next intervention for each homogenous section. An example for a pavement section life cycle is shown in Figure 6.7. Based on the data analysis, 51 treatments were identified for performance modeling, Table 6.4.

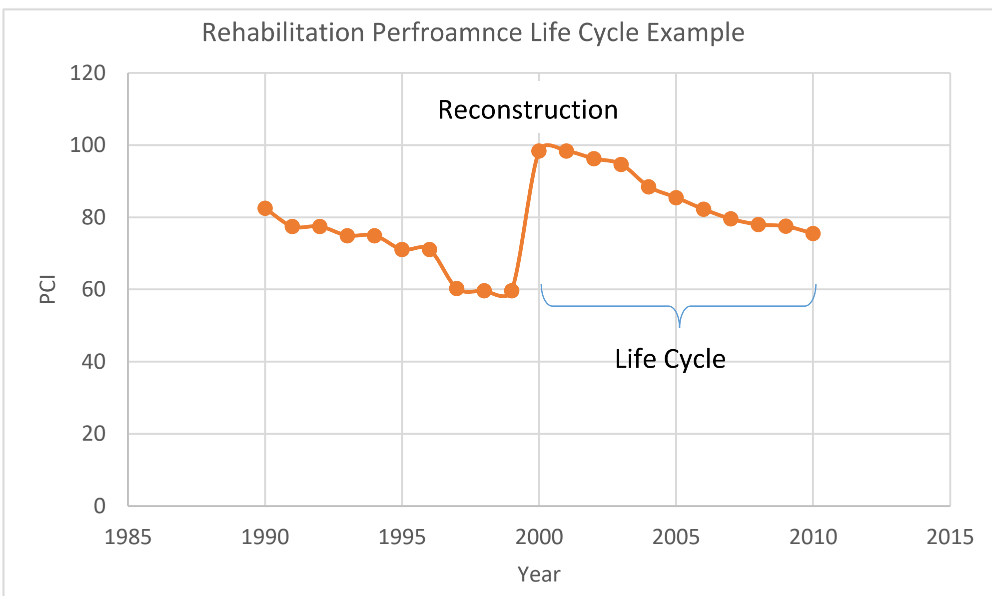


Figure 6.7 Pavement Performance Cycle of Asphalt Concrete Reconstruction

Table 6.4 Treatments Identified For Performance Modeling

Environment	subgrade	subgrade Category	traffic class	CIR + HM Overlay1	CIR + HM Overlay2	FDR+HM Overlay2	FDR+HM Overlay3	HM Overlay1	HM Overlay2	Mill+HM Overlay1	Mill+HM Overlay1 Fwy	Mill+HM Overlay2	Mill+HM Overlay2 Fwy	Recon To AC Fwy	Recon to AC3	Recon to AC5 Fwy
SO	Sandy Silt	1	1			33		50	44	42		105			173	
SO	Sandy Silt	1	3					42		49	47	41	231	113		186
SO	Sandy Silt	2	1	59		43	106	116	230	371		397	54		710	
SO	Sandy Silt	2	2						52			151			74	
SO	Sandy Silt	3	3										32			
SO	Lacus	1	1						118			32			154	
NO	Sandy Silt	1	1			184	73	44				50				
NO	Sandy Silt	2	1		59	344	119	118	110	65		104			87	
NO	Sandy Silt	3	1	47		62	105	47		49	72				45	
NO	Gran	3	1			78	42									
NO	Lacus	2	1			48										

Note: CIR=Cold in Place, FDR= Full Depth Reclamation, HM= Hot Mix, Recon= Reconstruction

6.6.1.2 Developing The Transition Probability Matrix (TPM)

The TPM is used to present the probability of pavement condition transitioning from one state to the other. It is assumed that the pavement will transition by only one state condition each year (Butt et al. 1987). In other words, the pavement will either stay in its current state in the following year, or it will move to the following state. The condition states used to develop the performance models are presented in Table 6.5. The lowest state for PCI is 30 as it is impractical for pavement to go beyond this state and considered safe.

Table 6.5 State Condition Change Classification

State	**1**	**2**	**3**	**4**	**5**	**6**	**7**
PCI (Scale 100-30, or 10-3))	100-95	95-90	90-85	85-80	80-75	75-70	70-65
	8	**9**	**10**	**11**	**12**	**13**	**14**
	65-60	60-55	55 -50	50-45	45-40	40-35	<30

The TPM is presented in the form of a matrix of order *(n x n)* where (*n)* is the number of condition states identified. The TPM is therefore in the following form:

Condition State at year t+1

Condition state at year t

P1	1-P1	0	0	0
0	P2	1-P2	0	0
.	.	.	.	.
.	.	.	.	.
0	0	0	Pi	1-Pi
0	0	0	0	1

P_i is the probability of staying in the same state, while $1\text{-}P_i$ is the probability of transitioning to the following state in one year. The unity at the last row of the matrix indicates a holding state where the pavement does not transition any further (Butt et al. 1987). To determine probabilities, the proportion method is used (Jiang et al. 1988; Ortiz-García et al. 2006). In this method, the probability is found as follows:

$$P_{ij} = \frac{n_{ij}}{n} \qquad \text{Equation 6.2}$$

Where,

P_{ij} = the probability of a pavement section to transition from state i to state j

n_{ij} = number of pavement section transitioned from state i to state j in one year

n = Total number of section in state i

The state vector of pavement section at any given year t $[\widehat{Pt}]$ can be found by multiplying the initial state vector $[\widehat{P0}]$ by TPM to the power of t. (Butt et al. 1987). Thus:

$$[\widehat{Pt}] = [\widehat{P0}] \times [TPM]^t \qquad \text{Equation 6.3}$$

Where the initial state vector is the state vector at year t=0 and is assumed that the pavement will be in best state, Thus:

$$[\widehat{P0}] = [1 \;\; 0 \;\; 0 \;\; \ldots \;\; 0] \qquad \text{Equation 6.4}$$

Once the state vector at any year t is determined, the Future State (FS) value can be determined by multiplying the state vector at year t by the state index vector [S], i.e. the state condition established in Table6.5. Thus,

$$FS_t = [\widehat{P0}] * [TPM]_t * [S] \qquad \text{Equation 6.5}$$

For each treatment in a homogeneous section group, the procedure described above is used to establish the TPMs for PCI performance. The TPMs are then used to predict future conditions of pavement due to applying each intervention alternative.

An example of a developed TPM for a hot mix and two-overlay treatment, on homogenous sections in southern Ontario (SO), with Silty Sand (SS) subgrade, subgrade strength category 1, and a traffic class 1, (SO-SS-1-1) is presented in Table 6.6.

Table 6.6 TPM- Mill and Hot Mix Overlay2 (SO-SS-1-1)

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	0.417	0.583												
2		0.579	0.421											
3			0.222	0.778										
4				0.333	0.667									
5					0.333	0.667								
6						0.333	0.667							
7							0.833	0.167						
8								0.667	0.333					
9									0.800	0.200				
10										0.500	0.500			
11											0.750	0.250	0.000	
12												0.800	0.200	
13													0.500	0.500
14														1

RMSE= 6.09

The root-mean-square error (RMSE), also called root-mean-square deviation (RMSD), is used to validate the performance models. The RMSD is a statistical measure of the difference between the data predicted using the prediction model and observed data, which provides an indication of the model accuracy, Equation 6.6. The fifteen percent of data retained are used for validation of the performance models. The developed performance models and the validation results are presented in Appendix B.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(x_i - y_i)^2}{n}} \qquad \text{Equation 6.6}$$

Where; x_i = Model Predicted PCI

y_i = Actual PCI (retained data)

n= number of retained data

6.7 Utility Functions

The procedure followed in developing the utility functions for the proposed AVI is to incorporate the thresholds or minimum LOS to evaluate the utility of the section for corresponding performance measure. For example, MTO performance targets (Table 6.7) were utilized to develop the utility functions corresponding to pavement condition and value. For instance, a Freeway pavement section with a PCI lower than 75, is considered to have a RSL of zero and therefore is given an RSL utility value of zero.

Table 6.7 MTO PCI Performance Targets (MTO 2013)

	Good		Fair		Poor	
Road Function	%	PCI	%	PCI	%	PCI
Freeway	70	75	30	74-66	0	65
Arterial	65	75	30	64-56	5	55
Collector	65	70	30	64-51	5	50

The utility functions used in this case study are based on infrastructure utility functions summarized by Bai et.al. (Bai et al. 2008). The utility functions' coefficients (*a* and *k*) are calibrated to incorporate the LOS for this case study. The utility functions for the performance measures used in this case study are presented in Table 6.8. The utility values for a given section are calculated in reference to each criterion and then amalgamated to calculate the total utility, AVI, for each section.

Table 6.8 Utility Function for MTO Pavement Management

Performance Measure	Utility Function
Asset Value Loss Ratio	U AVL = 6.132823*(1-EXP(-0.1607864*(AV_L ^ $^{2.2}$))
Remaining Service Life	U RSL = 1-EXP(-0.04272*RSL$^{\wedge 2.3}$)
Annual Average Daily Traffic	U AADT = 0.0882 * AADT ^$^{0.2}$
Equivalent Single Axel Load (ESALs)	U ESALs = 0.041 * ESALs ^$^{0.2}$
Road Function	FWY = 0.68, ART = 0.78, COL = 0.84

6.8 Weights – AHP Survey Results

The AHP method was deployed to establish the weights for the performance measures hierarchy presented in Figure 6.6. The AHP method is a theory of relative measurements of intangible criteria (Saaty 1980). The AHP determines the weights for the criteria indirectly by pairwise comparison assigning relative importance scores between the criteria (Labi 2014). The final weighting is then normalized by the maximum eigenvalue for the matrix to minimize the impact of inconsistencies in the ratios (Saaty 1980). A survey was distributed to academics, public and private agencies for pairwise comparison scores for the performance measures hierarchies presented in this study, see Appendix C for a sample of the survey. In total, 21 responses were received (55% of total survey requests) and analyzed as summarized in Table 6.9.

Table 6.9 AVI Performance Measures Weights

Criteria	Sub-Criteria	Mean	SD
Asset Value		30%	18%
Remaining Service Life		27%	14%
Utilization		23%	14%
	Truck Traffic (ESALs)	73%	18%
	Passenger Traffic (AADT)	27%	18%
Road Function		20%	15%
	Freeways	62%	14%
	Arterials	22%	6%
	Collector	16%	13%

6.9 Case Study

The random sample network is drawn for this study. The sample consists of 100 pavement sections, of which 29% are Freeway, 42% Arterial and 29% Collectors. Local roads are not included due to the lack of sufficient data recorded as they are managed by local municipalities. The purpose of the case study is to develop an asset management plan using the proposed methodology. The database is based on 2010 data, as such a 20 year analysis period is set from 2010-2030. Following MTO condition thresholds (Table 6.10), the current condition of the sample network is shown in Figure 6.8. The sample network age histogram is presented in Figure 6.9.

Table 6.10 MTO Pavement Condition Thresholds (Adopted from (MTO 2013)**)**

	PCI		
Road Function	Good	Fair	Poor
Freeway	75	74-66	65
Arterial	75	64-56	55
Collector	70	64-51	50

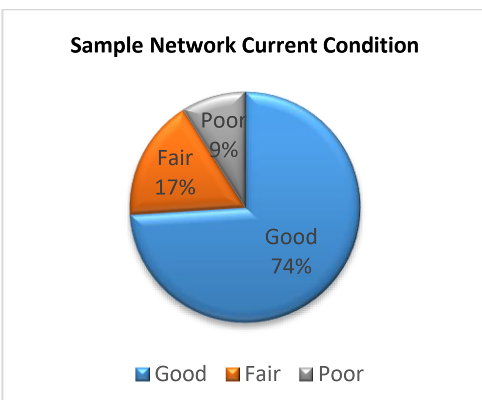


Figure 6.8 Sample Network Condition

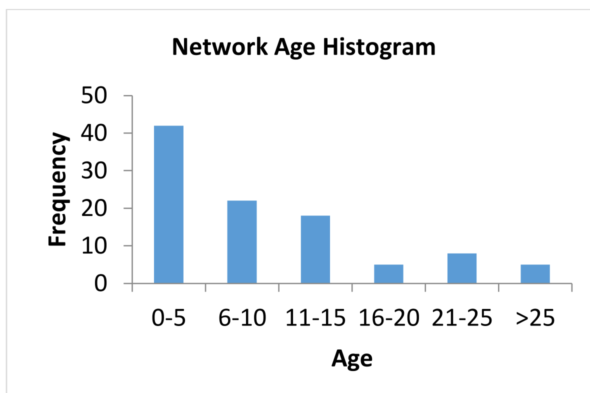


Figure 6.9 Sample Network Age Distribution

As shown in Figure 6.8, about 75 percent of the network is in good condition, while seventeen percent in fair cobdition and nine percent is in poor condition. In addition, as shown in Figure 6.9, the majority of the network age falls below 15 years, which indicates that a major intervension is applied within 15-year life cycle of the pavememt. However, some sections are beyond 15 years of age indicating a backlog of pavement sections that are not maintained, which is reflected in the fair and poor conditions pavements in the network.

6.9.1 Do-Nothing Analysis

To better evaluate the network, a Do-Nothing option is conducted to evaluate the impact on the network condition due to lack of maintenance and rehabilitation. The network condition box-plot, AVI and AV_L are presented in Figure 6.10.

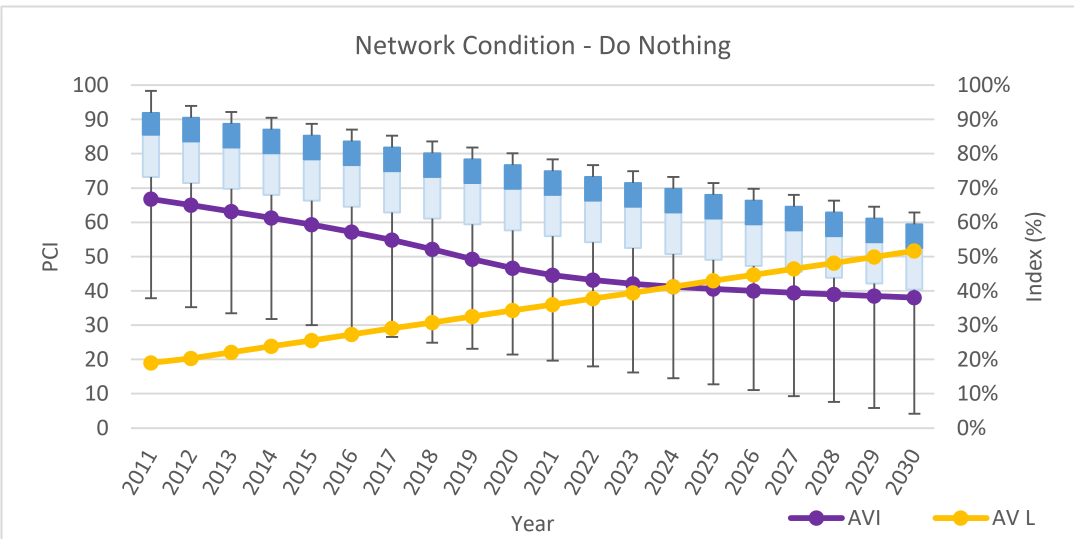


Figure 6.10 Network Performance- Do-Nothing Option

As depicted in Figure 6.10, the overall average pavement PCI deteriorates over the analysis period to an average PCI of 50. In addition, as shown in the whisker tails, some pavement sections fall below a PCI of 30 starting year 2017, which is considered unsafe to use. On the other hand, the average AV_L of the network reaches 50 at the end of the analysis period. That is, 50 percent of the asset RC value is lost due to the lack of maintenance and rehabilitation. In addition, the network average AVI deteriorates over the analysis period to below 40.

6.9.2 Needs Assessment

In order to establish the budget for the analysis, a needs assessment is conducted. That is, the network is rehabilitated to maintain the MTO target levels with no budget constraints. Figure 6.11 presents the yearly budget required to maintain the MTO level of service in 2010 dollars ($2010). In total, the minimum budget required for the 20-year analysis period to maintain the LOS is $533,333,159. The network performance box-plot, AVI and AV_L are presented in Figure 6.12.

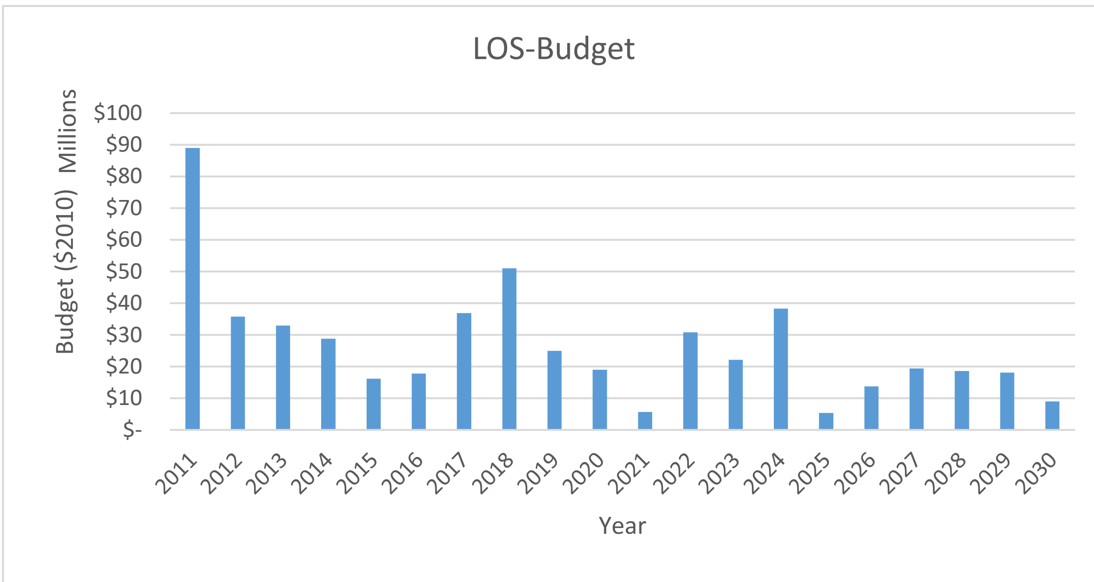


Figure 6.11 Yearly Budget to Maintain LOS

As depicted in Figure 6.12, the network is maintained to MTO's performance LOS over the analysis period. The AV_L is maintained at 10 percent in average and an AVI at 80 percent.

The total budget obtained from the needs assessment is used to establish a yearly budget for the analysis. Based on the needs assessment, a yearly budget of $26,666,657.98 ($2010) is required. However, to mimic the challenge agencies face in maintaining their network, the yearly budget is set to $15,000,000 ($2010).

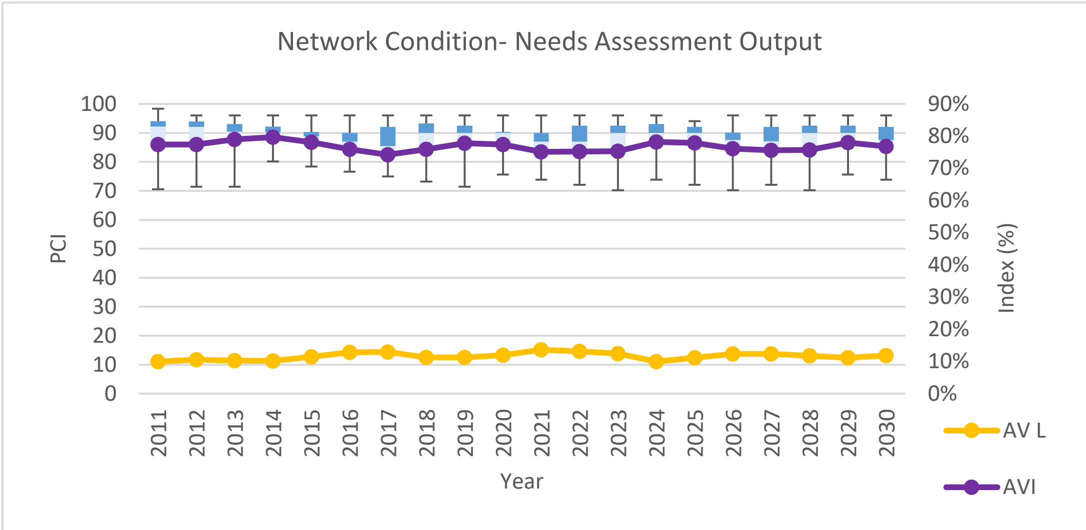


Figure 6.12 Network Condition - Needs Assessment Budget Output

6.9.3 Optimization Model

To evaluate the effectiveness of the proposed methodology, an optimization model is developed and the results are used as bases of comparison to the output of the proposed methodology. The objective of the optimization model is to maximize the total network PCI subject to the available budget (Equation 6.8) and to the LOS constraints (Equation 6.9). The mathematical model is as follows:

$$\text{Maximize } Z = \frac{(\sum_{j=1}^{M} \sum_{k=1}^{T} PCI_{jk})}{T*M} \quad \text{Equation 6.7}$$

Subject to:

(1) $$\sum_{i=1}^{N} \sum_{j=1}^{M} \sum_{k=1}^{T} c_{ijk} \leq B_k \quad \forall \ k \in \{1,T\} \quad \text{Equation 6.8}$$

(2) $$PCI_{jk} \geq PCI_{min,j}; \quad \forall \ k \in \{1,T\} \text{ and } \forall \ j \in \{1,M\} \quad \text{Equation 6.9}$$

Where,

Z = Total network average PCI

c_{ijk} = Present worth cost of rehabilitation *i* applied to section *j* at year *k*

PCI_{jk} = PCI of section *j* at year *k*

$PCI_{min,j}$ = PCI threshold for section *j*

i = Rehabilitation $i \in \{0, N\}$, where $i = 0$ indicate no rehabilitation

j = Section number $j \in \{1, M\}$

k = Year k of T years analysis period

To assist with the optimization process for the case study, Evolver software is utilized. Evolver is a genetic algorithm optimization add-in for Microsoft Excel (see palisade.com/Evolver).The optimization model inputs and calculations are formulated in the Excel cells. An illustrative screenshot of the developed excel worksheet and the use of Evolver ® is depicted in Figure 6.13.

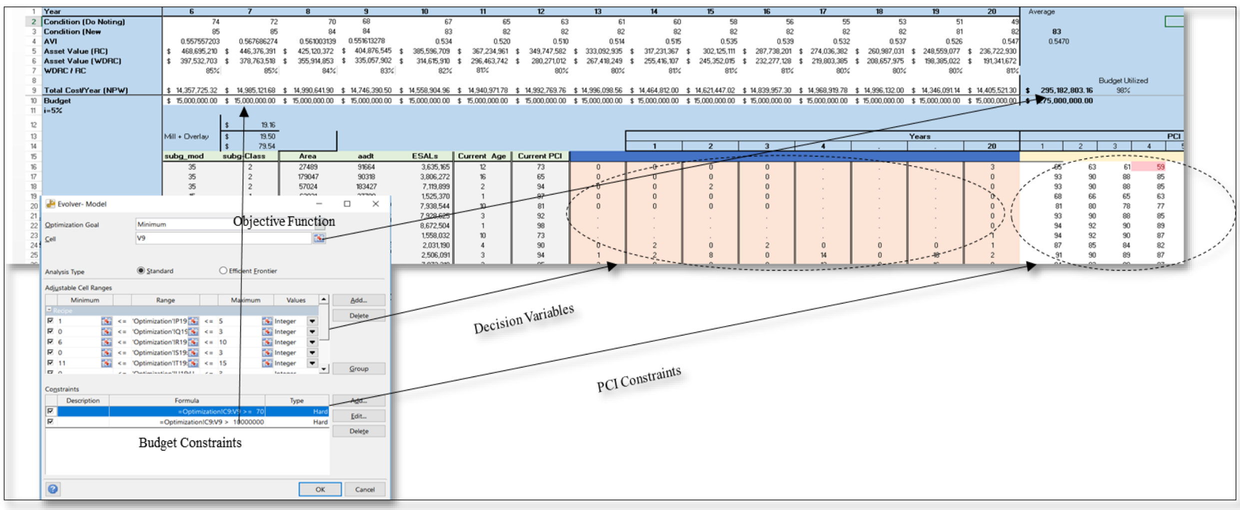


Figure 6.13 Network Optimization Model Snapshot

As shown in Figure 6.13, the model definition box shown on the left corner allows for identifying the variables and the constraints to reach the objective function. The objective function shown in the figure is to maximize the total network average condition while maintaining the performance LOS and budget constraints. To ensure the optimum (or near optimum) plan developed, the optimization model was run several times until no improvements to the final plan observed.

The results of optimization of the network PCI presented in Figure 6.14 show a good overall performance of the network. However, from the box-plot it can be noted from the whiskers' lower tail that some sections were not maintained and therefore do not meet the minimum LOS. That can be attributed to the nature of the optimization objective to maximize the overall PCI average for the network. For example, a section in very poor condition may be neglected in favor of selecting sections that are in fair condition to maximize the overall performance of the network. In addition, the network average AV_L is maintained around 20% over the analysis period. The AVI shows a decline after year 2020 due to the backlog of sections with poor condition as shown in the lower whisker values.

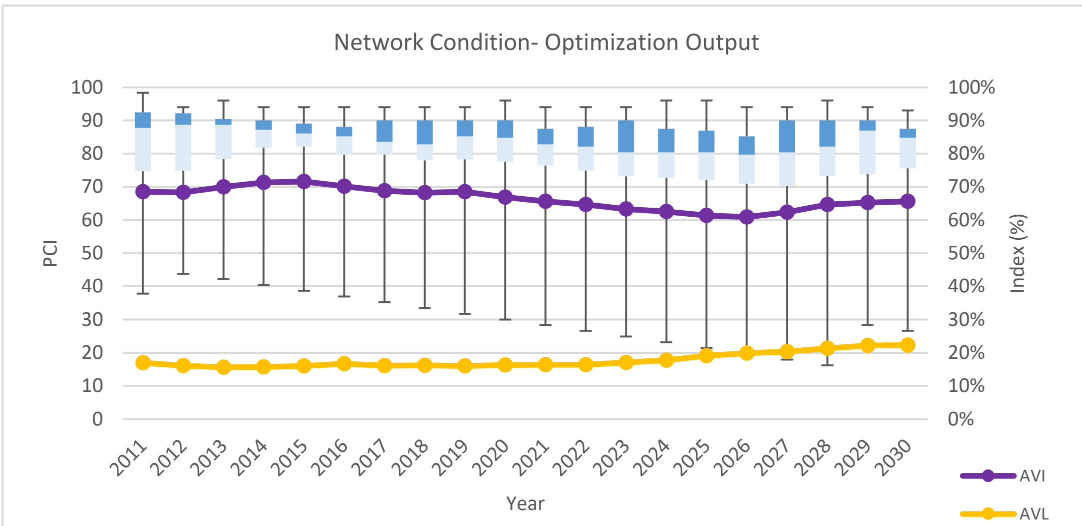


Figure 6.14 Network Condition- Optimization Output

6.9.4 Proposed Value-Based Priority Programming

Although it is desirable to maintain all pavements in good condition, the challenge of available funds dictates that a prioritization of maintenance and rehabilitation is required. Figure 6.15 shows typical treatments as a function of pavement condition and suggested timing of treatments (Ningyuan and Kazmierowski 2007; TAC 2013). As such, the decision tree presented in Chapter 3, Figure 3.12 is used as basis for the priority programming at the project level.

The objective of the priority programming is to maximize the network AVI, subject to the available annual budget, and performance targets constraints over an analysis period. The AVI incorporates the various performance measures in accordance with their utility and preference to the decision maker, reflected in the weights assigned.

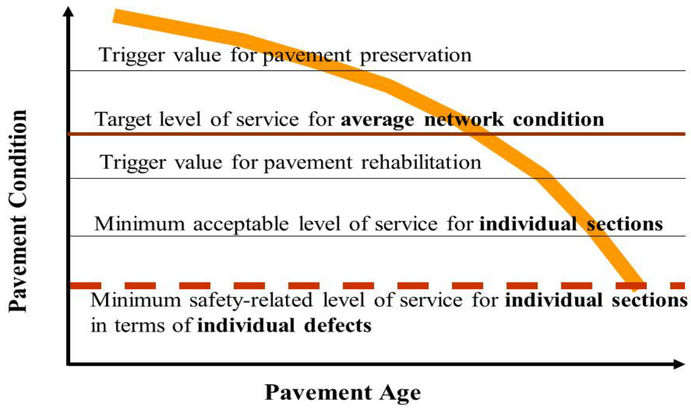


Figure 6.15 Types of Service Levels and Trigger Levels for Pavements (TAC 2013)

To demonstrate the proposed AVI implementation in asset management decision making through the case study presented herein, a priority programming model is developed with the aid of Excel. All inputs and calculations are formulated in the Excel cells. An illustrative screenshot of the developed worksheet and the various components are shown in Figure 6.16.

The prioritization flow chart presented in Chapter 5, Figure 5.4, is implemented in this case study. As presented in Figure 6.16, the model uses pavement attribute information and deterioration models to obtain all the performance measures' values, shown in *part A* of Figure 6.16. The performance values are then converted to utility values using the utility functions for each criterion and the total AVI for each section is calculated over the analysis period, *part B*. For each year, a ranking of the assets based on the lowest AVI is established and nominated for treatment using the appropriate decision trees (project level). The sections are selected from worst to best until the available budget for the given year is exhausted, *part C*. For each year, the performance of the selected projects is updated to reflect the section overall improvements. The processes are then repeated for the following year and so forth until the end of the analysis period and the asset management plan is developed, *part D*. The network output of the prioritization is presented in Figure 6.17.

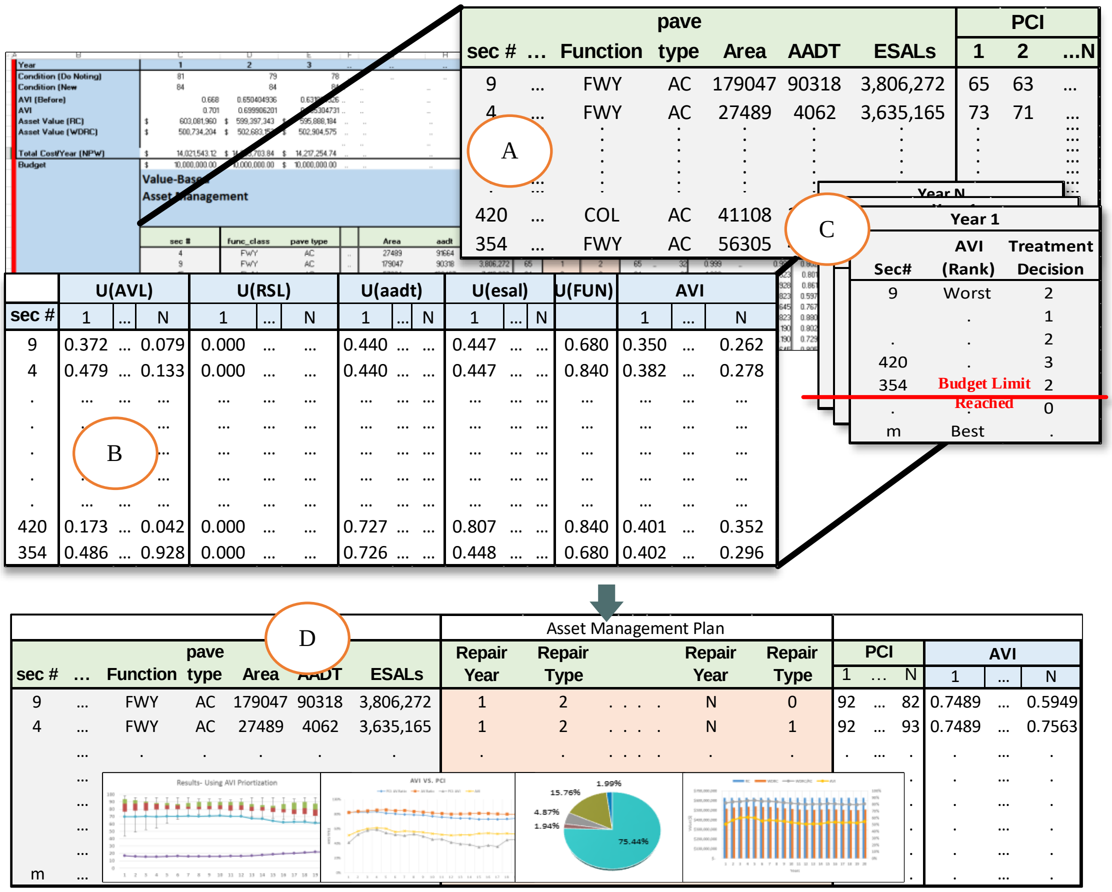


Figure 6.16 Case Study Priority Programing Illustration

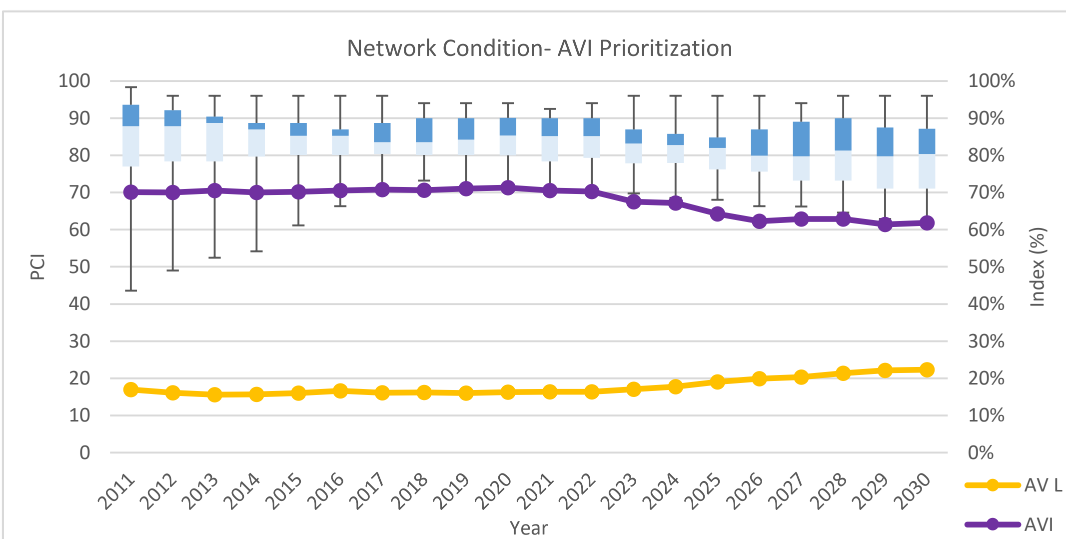


Figure 6.17 Network Condition - AVI Prioritization Output

As depicted in Figure 6.17, the network condition is maintained at the required LOS. The prioritization, using the AVI, selected sections based on a holistic value-based approach that allowed to prioritize the sections by taking into account condition, traffic utilization, road function, and RSL. The average AVI is maintained at 70%, while the AV_L ratio is maintained below 20%. In other words, the network is maintained at 80% of its RC value.

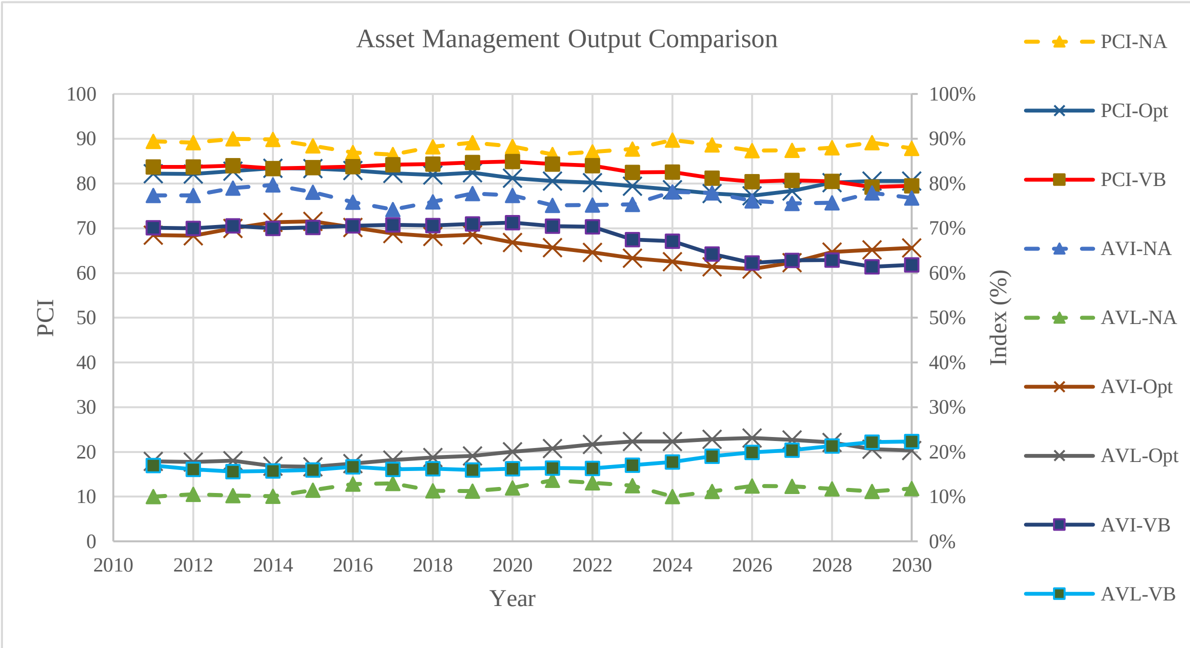
In order to evaluate the effectiveness of the proposed AVI, a comparison with the Do-Nothing option, Needs Assessment, and an Optimization outputs is conducted as summarized in Table 6.11 and Figure 6.18.

Table 6.11 Asset Management Output Comparison

	Do Nothing	Needs Assessment	AVI	Optimization
Number of Interventions	0	360	161	222
Overall Average PCI	65	88	83	81
Overall Average AVI	49%	77%	68%	66%
Overall Average AV_L	35%	12%	18%	20%
%Overall Budget Utilized	N/A	N/A	96%	94%

As shown in Table 6.11 and Figure 6.18, the prioritization using the AVI and the optimization model produced comparable results. However, the AVI model produced higher overall performance of the network, while efficiently utilizing the available budget compared to the optimization model. In addition, the AVI method resulted in a similar performance trend to that obtained from the needs assessment.

As can be noted, the proposed method produced comparable overall results to that obtained from optimization. However, the proposed method provides an efficient fund allocation that is transparent and justifiable with a structured decision-making strategy, as opposed to the outcome of the optimization model. The AVI model prioritizes the sections by considering multiple performance measures that affect the value of the assets and allocate the funds accordingly.



Note: NA= Needs Assessment, Opt= Optimization, VB = Value Based

Figure 6.18 Asset Management Output Comparison

6.10 Sensitivity Analysis

In this section, a sensitivity analysis is conducted to evaluate the asset management plan output due to variability in budget and the impact of the change in the importance weights of the performance measures used to develop the AVI.

6.10.1 Budget Gap Analysis

Budget constraints are a major challenge to agencies managing infrastructure assets. Gap analysis is used to evaluate the impact of an increase or decrease of budget on the network performance. In this case study, ± 10 percent changes of the budget scenarios are used to evaluate the network overall performance. The procedure presented in the previous sections is used for the budget scenarios and the final results are compared to the base case obtained in the section 6.9.4. The outputs from the scenarios are compared in terms of AVL, AVI and average PCI as summarized in Figure 6.19. The overall conditions as a result of the budget scenarios are presented in Figure 6.20 and Figure 6.21.

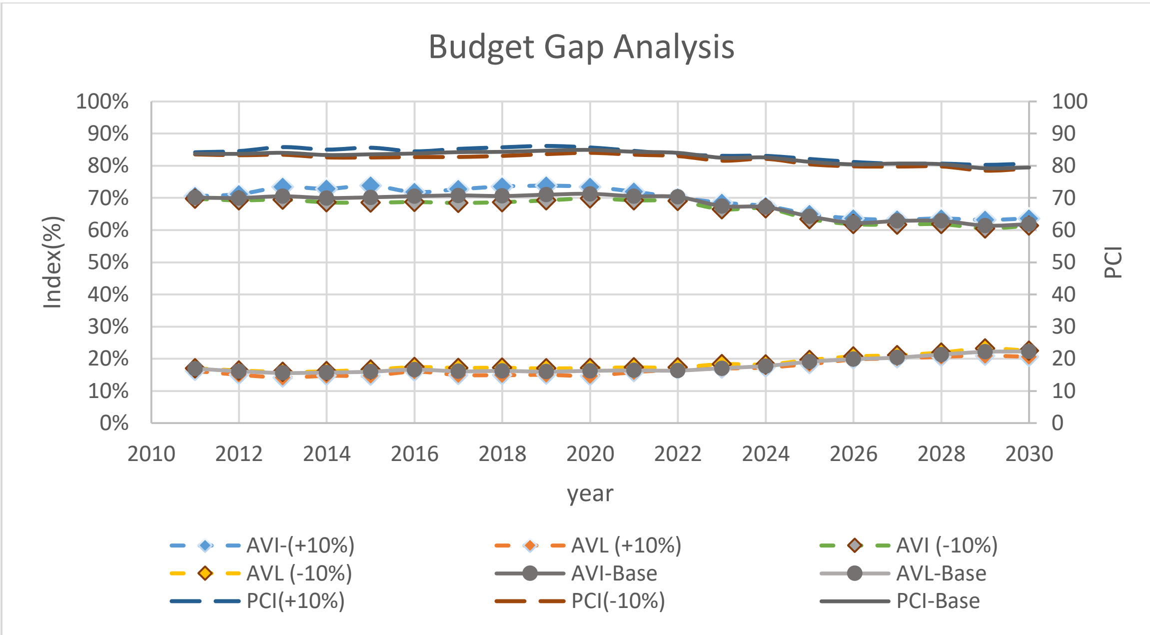


Figure 6.19 Budget Gap Analysis Results Comparison

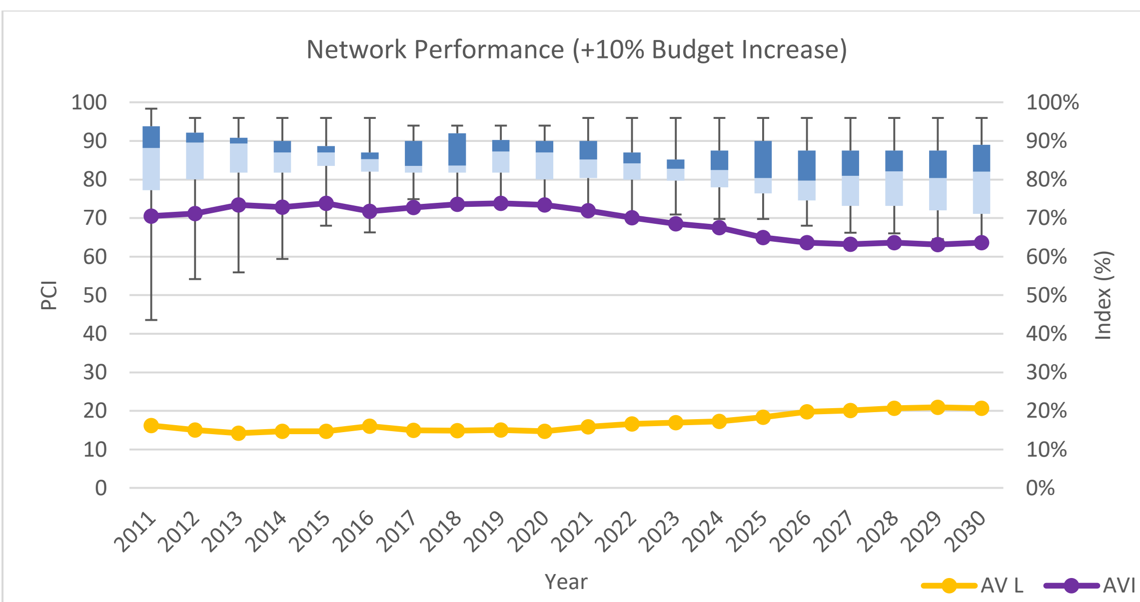


Figure 6.20 Pavement Overall Performance – 10 % Budget Increase

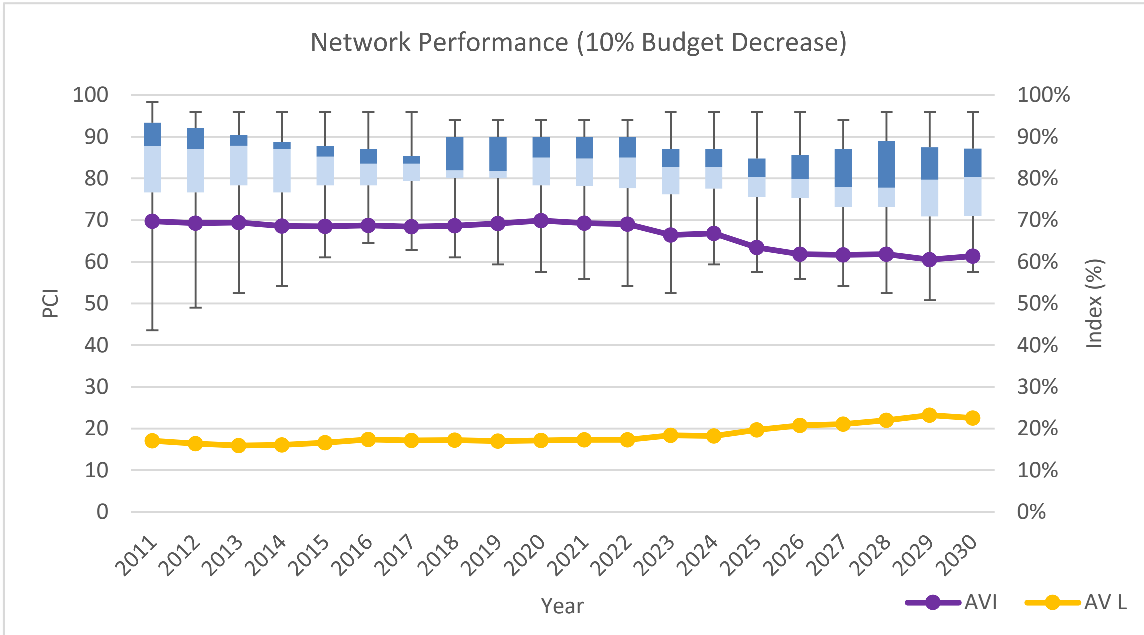


Figure 6.21 Pavement Overall Performance – 10% Budget Decrease

As shown in Figure 6.19, the budget changes result in a change of the overall network performance. An increase of 10 percent in the budget resulted in an overall decrease of one percent in AV_L on average and two percent increase of AVI over the analysis period. In addition, the increase in budget by 10 percent resulted in an improvement of overall PCI average from 83 to 84.

On the other hand, a decrease in the budget by 10 percent resulted in an increase of one percent in AV_L and one percent decrease of the AVI of the network on average over the analysis period. Furthermore, a reduction in the budget results in a decrease of the overall PCI average of the network from 83 to 82. As shown in Figure 6.20 of the whiskers' lower tail, an increase in the budget has resulted in more sections selected for rehabilitation improving the overall network. On the other hand, as shown in Figure 6.21, a decrease of the budget results in some sections not being selected for rehabilitation falling below the required LOS.

As indicated, gap analysis provide means of evaluating the budget impact on the network condition. It is also used in this research to evaluate the impact on the asset value.

6.10.2 Importance Weights

As indicated earlier, the weights assigned to the performance criteria can change the outcome of the prioritization decision. Therefore, sensitivity analysis of the assigned weights is key to evaluating the impact on the outcome of the proposed index. Using the survey results, mean and standard deviation, a Monte Carlo simulation was conducted to produce different importance level scenarios. Three cases were developed as summarized in Table 6.12.

Table 6.12 Monte Carlo Simulated Weights

				Weights		
Criteria	**Sub-Criteria**	**Mean**	**SD**	**Case 1**	**Case 2**	**Case 3**
Asset Value		30%	18%	53%	28%	29%
Remaining Service Life		27%	14%	19%	34%	19%
Utilization		23%	14%	13%	1%	27%
	Truck Traffic (ESALs)	73%	18%	66%	27%	81%
	Passenger Traffic (AADT)	27%	18%	34%	23%	19%
Road Function		20%	15%	15%	37%	25%
	Freeways	62%	14%	79%	37%	57%
	Arterials	22%	6%	19%	19%	26%
	Collector	16%	13%	3%	44%	17%

Following the procedure presented in Chapter 5, the three scenarios were used to develop an asset management plan for the network. The results of the three cases are presented in Figure 6.22, Figure 6.23, and Figure 6.24.

As shown in Table 6.12, in the first case, the weight is heavily assigned to value loss ratio (i.e. condition), Truck traffic, and Road function. As such, in this case, the selection was prioritized based on those factors more than others. The results in Figure 6.22 show a higher performance where more sections are selected on the basis of condition and traffic. However, this has created a backlog and an evident decline in the overall performance of the network.

The second case however placed lower weight to the asset utilization and assigned more to the road function class, RSL and AV_L. The outcome presented in Figure 6.23 shows a good average performance of the network; however, as this decision case ignores the traffic factor, more sections in the Freeway class were prioritized and resulted in a decline of the assets' overall performance over the analysis period on the other classes. The third case weights resemble those obtained from the survey (See Table 6.9). It can be noted that the outcome of the prioritization is comparable to those obtained from the base case study, Figure 6.24.

The three cases resulted in different asset management programs due to the change in importance weights assigned to the AVI factors. Therefore, it is imperative that the key factors considered in developing the AVI are carefully reviewed and a sensitivity analysis is conducted to ensure that the assigned weights and the decision outcome align with the agencies' goals and objectives.

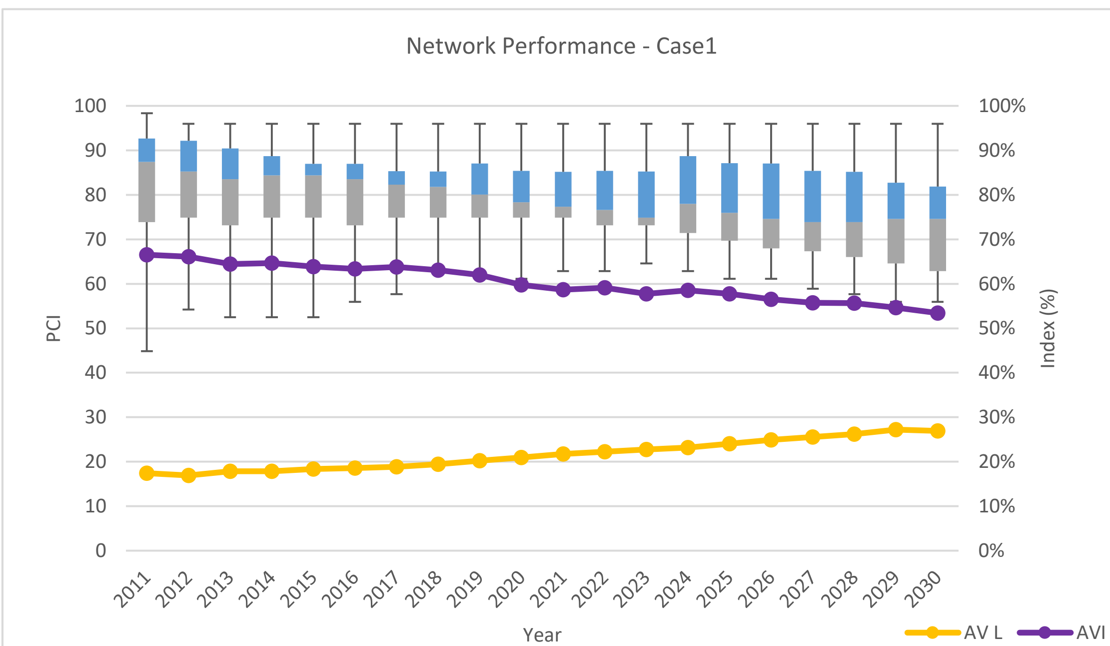


Figure 6.22 Network Performance Condition - Sensitivity Analysis Case 1

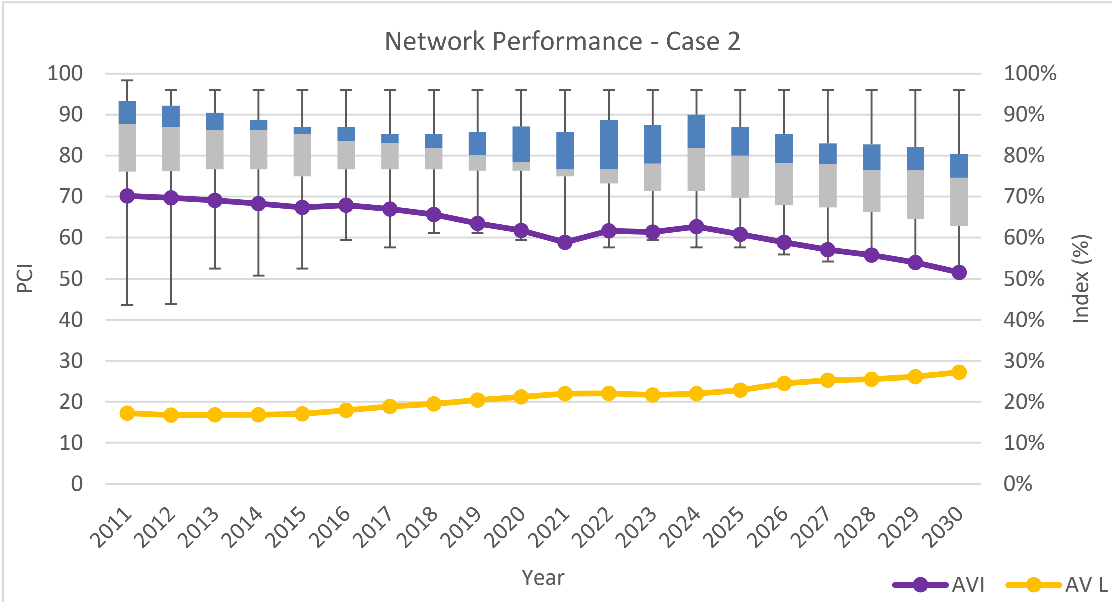


Figure 6.23 Network Performance Condition - Sensitivity Analysis Case 2

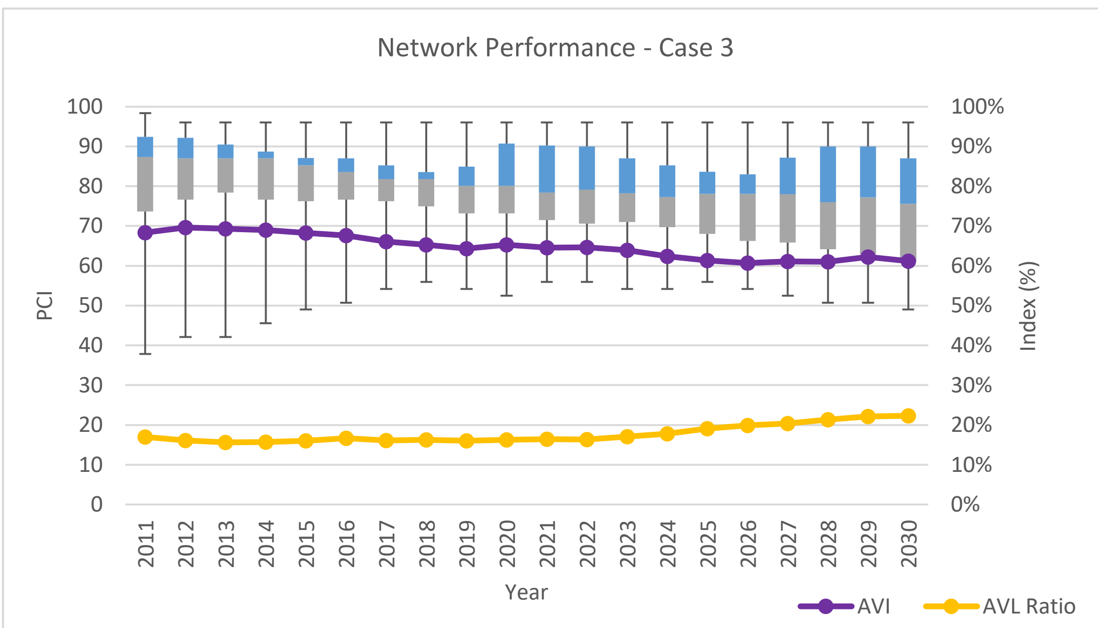


Figure 6.24 Network Performance Condition - Sensitivity Analysis Case 3

6.11 Summary

This chapter presented a case study utilizing MTO's PMS2 data to illustrate the proposed value-based asset management methodology. In order to develop the AVI for the network, value performance measures were identified including: utilization, road function, RSL, and conditions as a function of AV_L. The importance weights for the identified measures were established using the AHP via a survey distributed to expert subject matters from academic, public and private agencies.

The proposed AVI implementation in asset management decision making was demonstrated through the case study presented and a priority programming model is developed with the aid of Excel.

In order to evaluate the effectiveness of the proposed AVI, a comparison with the Do-Nothing option, Needs Assessment, and an Optimization outputs was conducted and analyzed. The prioritization using the AVI produced superior results to that of the optimization model. The AVI model produced higher overall performance of the network by efficiently utilizing the available budget compared to the optimization model. Finally, a sensitivity analysis of the importance weights of performance measures was conducted. The sensitivity analysis demonstrates the impact of the weights on the performance measures used for AVI development. Therefore, it is recommended that a similar approach is conducted using this methodology.

Chapter 7

Value-Based Cross Asset Management: Mixed Assets Case Study

7.1 Introduction

Building on the proposed methodology presented in Chapter 5 of this thesis, this chapter introduces a value-based cross asset management methodology. A case study of pavements and bridges based on data obtained from the 7th International Conference of Managing Pavement Assets (ICMPA 7) is used to illustrate the proposed methodology.

7.2 Value-Based Cross Asset Management Framework

Agencies have traditionally made investment decisions for individual assets separately. Independent management systems have traditionally been developed to manage assets, in particular pavements and bridges, the two main transportation assets (TAC 2013). The lack of integration between management systems may be due to restrictions associated with funding and/or limitations to the agency's ability to compare data objectively across asset types (Proctor and Zimmerman 2015). Deciding how to best allocate limited resources across these various asset classes to provide acceptable performance poses a persistent and difficult challenge for agencies. Asset value holds a great promise to be incorporated in asset management as a performance measure that translates infrastructure condition in monetary terms that can be easily communicated and understood by the stakeholders (agency, policy makers, users, etc.).

The methodology to develop AVI for infrastructure assets as presented in Chapter 4 of this thesis can be used as a common performance measure for the integration mechanism between competing asset management systems. The proposed framework is presented in Figure 7.1.

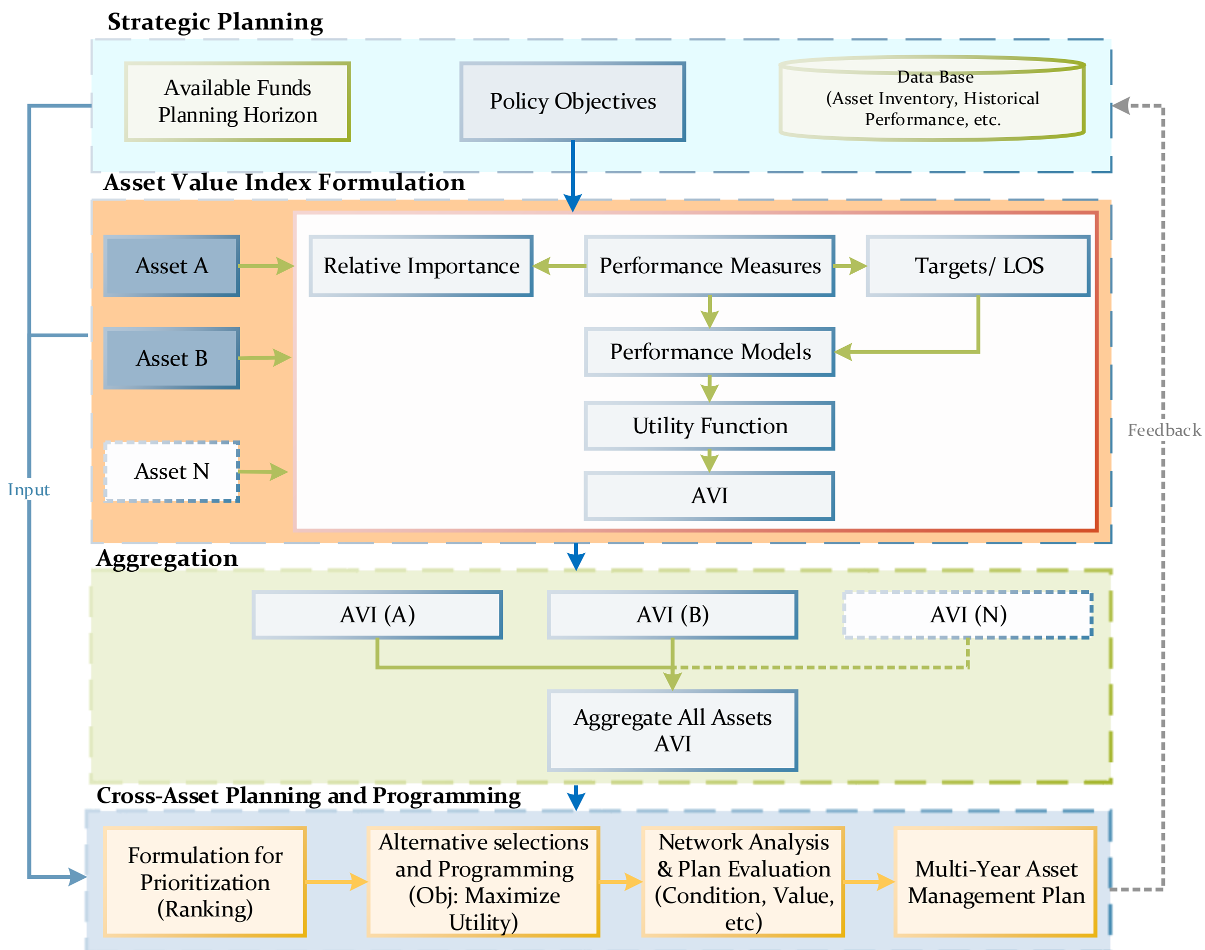


Figure 7.1 Value-Based Cross Asset Management Framework

As shown in Figure 7.1, the AVI is developed for each asset class following the proposed methodology that is presented in Chapter 5 of this thesis. The AVI of all assets are then aggregated and the projects are prioritized to maximize the total network utility.

It is worth noting that different assets have different value performance measures that can be used in the development of the AVI of said asset. The agency's goals and objectives should be carefully reviewed to establish the appropriate AVI. It is recommended that the analysis is conducted for each asset class separately and aggregated for investment trade-off.

7.3 Mixed Assets Case Study: ICMPA Challenge

Mixed asset network data are obtained from the 7th International Conference of Managing Pavement Assets (ICMPA 7) (Haas 2008) for the purpose of demonstrating the application of the proposed methodology for cross asset management. The Challenge was initiated with a worldwide call for expression with the aim to identify, encourage, and disseminate good practice in pavement management, to encourage innovation and to provide a forum and documentation illustrating state-of-the-art asset management systems. The database provided in the Challenge is based on data from Alberta Transportation (AT) and incorporate a variety of assets within the right-of-way in addition to pavements. The challenge is included in Appendix D.

The objective of this study is to develop an asset management plan to maintain the level of service for the mixed assets network. An analysis period of 10 years is assumed, and an interest rate of 5 % is used in the analysis. All costs are based on 2007 dollars ($2007) as provided by the challenge.

The network of assets used in this study is composed of pavements and bridges. The pavement network is comprised of a total of 1293 road sections spanning 3240 km, covering two road classes Rural (R) and Inter-urban (I). The road data include: length, width, number of lanes, traffic, surface age, material, and last treatment. In addition, condition, extent of distresses and predicted trigger or needs year are specified for all sections. A sample of data is presented in Table 7.1.

Table 7.1 Sample Road Data (Haas 2008)

							PAVEMENT							TRAFFIC		CONDITION				DISTRESS			
							Base			Last Activity													
Hwy ID	Hwy Dir	Hwy Type	From (km)	To (km)	Width (m)	Soil Type	Type	Year	mm	Type	Year	Surf (mm)	Seal Coat	AADT	ESAL/Day	PQI	IRI	SDI	SAI	TRc %Ar	LWPc %Le	OtherC %Ar	RUT (mm)
3A	C	R	0.0	4.4	12.6	CL	ACB	1976		OL	1991	280	###	####	688	7.5	2	9	5	0	0	0	5
3A	C	R	4.4	5.5	12.6	CL	ACB	1976		OL	2003	380		####	688	7.4	1			0	0	0	5
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3A	L	R	6.49	7.06	6.6	CL	ACB	1976		OL	2006	330		####	688	6.4	2		9	0	0	0	

3A	L	R	7.3	7.6	7.4	CL	ACB	1973		OL	2006	380	###	####	688	6.3	2			0	0	0	5

The bridge component is comprised of 161 bridges. Bridges are one of two basic types, standard bridges which are built according to standard drawings and major bridges which do not fit the standard bridge plans (due to length, height, or site conditions). Bridge attributes are provided in the data and include: length, number of spans, maximum span length, span type, clear roadway width, usage, and first year in service. In addition, a condition rating, and replacement cost are provided. A sample of the bridge network are presented in Table 7.2.

Table 7.2 Bridge Sample Data (Haas 2008)

Structure ID	Bridge Cat	Hwy ID	Hwy Dir	KM	Usage Code	Replacement Cost ($)	First Year In Service	Unique Span Type	Max Span Ln (m)	No of Spans	Nominal Bridge Ln (m)	Total Clear Roadway (m)	Cond Rat	Insp Date
B1	STD	135A	C	14.82	RV	89000	1978	VS	6.1	1	6.1	13.7	55	20-8-2006
B2	MAJ	231B	C	23.77	RV	3426000	1977	VF	36.6	4	146.4	8.5	61	8-1-2008
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
B11	MAJ	138C	C	32.83		334000	1999	SCC	14	1	14	13.4	83	14-1-2007
B12	MAJ	102C	C	10.52	RV	5840000	1980	WG	56.4	4	204.2	11	66	1-12-2006

The pavement deterioration is expressed in terms of IRI as shown in Table 7.3 for Interurban and Rural pavements as a function of AADT. In addition, the alternative treatments and costs are provided in Table 7.4. In addition, improvements of pavement condition as a result of the provided treatments for Interurban and Rural pavements is provided in terms of IRI, Figure 7.2 and Figure 7.3.

Table 7.3 Pavement Deterioration Rate

Road Class	AADT	Rate of Increase in IRI (m/km/yr)
Interurban	> 8000	0.069
	< 8000	0.077
Rural	> 1500	0.091
	< 1500	0.101

Table 7.4 Pavement Treatments Unit Costs

Maintenance	Cost/unit
40 mm Overlay	$ 7.00
Cold Mill & 40 mm overlay	$ 9.00
75 mm Overlay	$ 15.00
100 mm Overlay	$ 16.00

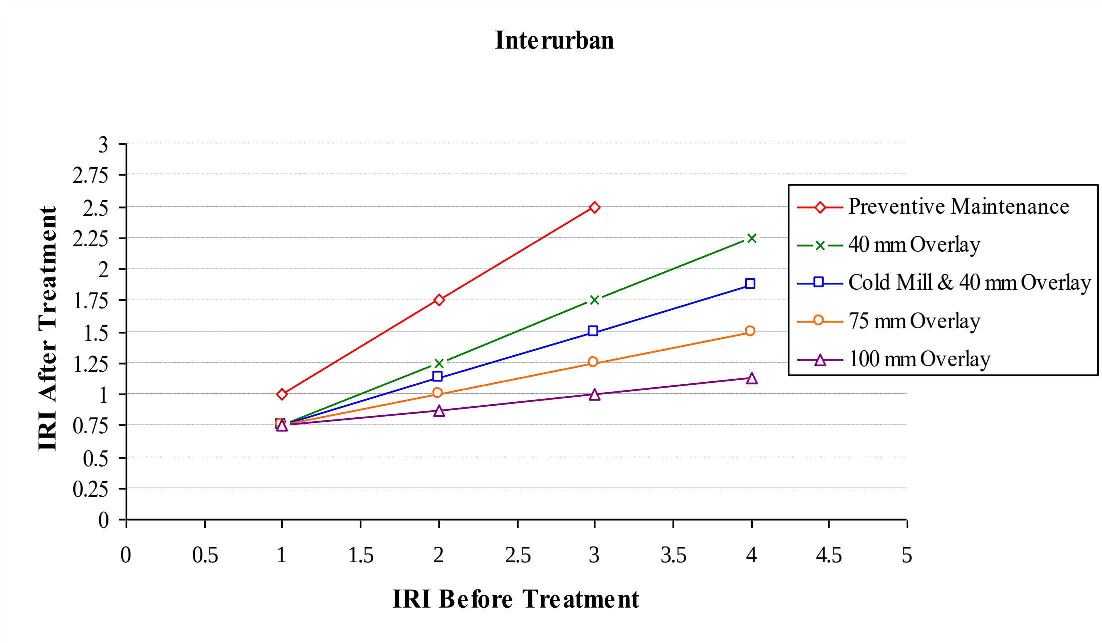

Figure 7.2 Interurban Pavement Roughness Improvement (IRI Before and After)

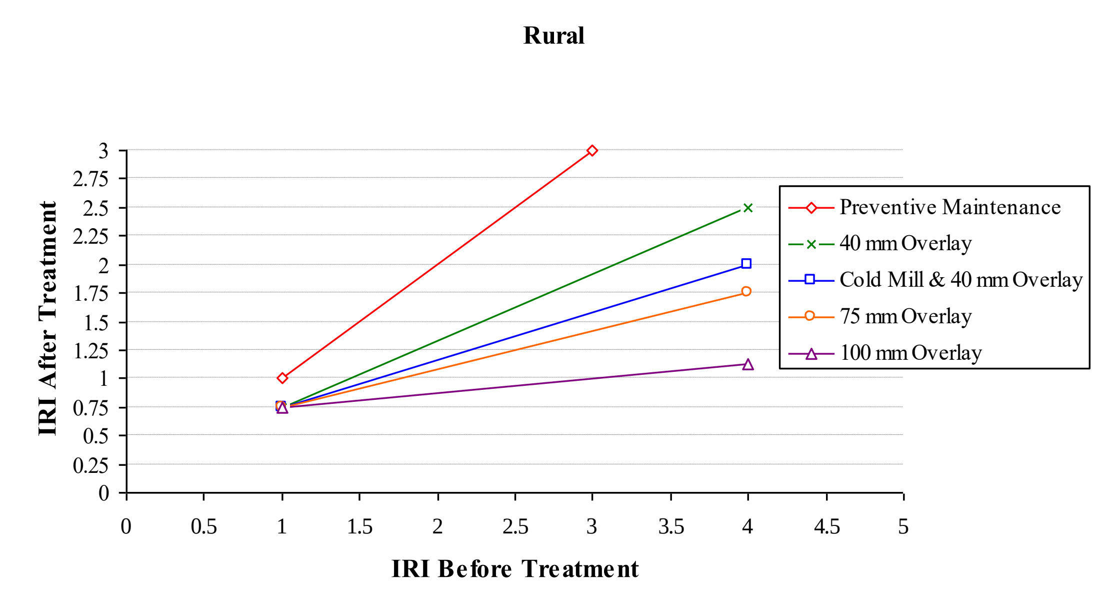

Figure 7.3 Rural Pavement Roughness Improvement (IRI Before and After)

The bridge network current condition is provided; however, no historical performance is provided to establish deterioration models. Using the expected service life provided for the various bridges, a linear deterioration rate is assumed for the purpose of this study and expressed as follows:

$$\text{Deterioration Rate} = \frac{100}{Expected\ Service\ Life} \qquad \text{Equation 7.1}$$

The expected service life of a bridge is a function of the bridge type as presented in the challenge, see Appendix D. Full replacement of a given bridge is provided in the data set as the only alternative treatment for the bridge network. As such, for the purpose of this study, a major rehabilitation is assumed to be 50 percent of the full replacement cost and improves the bridge to a condition equivalent to that at 50 percent of the bridge's expected service life and established using equation 7.1.

The condition rating for the pavement network is provided by the challenge based on IRI as shown in Table 7.5. The condition rating for the bridge network is not provided in the challenge. However, as the data are based on Alberta Transportation (AT) asset management system, the condition rating for AT is assumed in this case study, Table 7.6.

Table 7.5 Pavement IRI Condition Rating

Condition	IRI (m/km)
Good	IRI < 1.5
Fair	1.5≤IRI<2.0
Poor	IRI>= 2.0

As shown in Table 7.6, medium priority bridge repair is required at condition rating of three while a full replacement is triggered at condition rating of one. Minor or major rehabilitations are not included in the challenge.

Table 7.6 Bridge Condition Rating (Alberta Infrastucture and Transportation 2008)

Rating		Commentary	Maintenance Priority
9	Very Good	New condition.	No repairs in foreseeable future.
8		Almost new condition.	No repairs in foreseeable future.
7	Good	Could be upgraded to new condition with very little effort	No repairs necessary at this time.
6		Generally good condition. Functioning as designed with no signs of distress or deterioration.	No repairs necessary at this time.
5	Adequate	Acceptable condition and functioning as intended.	No repairs necessary at this time.
4		Below minimum acceptable condition.	Low priority for repairs.
3	Poor	Presence of distress or deterioration. Not functioning as intended.	Medium priority for replacement, repair, and/or signing
2		Hazardous condition or severe distress or deterioration.	High priority for replacement, repair, and/or signing.
1	Immediate Action	Danger of collapse and/or danger to users.	Bridge closure, replacement, repair, and/or signing required as soon as possible.

7.4 Asset Value Index Development

Following the methodology outlined in Chapter 5 of this thesis, the AVI is developed for the bridge and pavement assets. First, performance measures that impact the value are identified for each asset components and assigned importance weights. The utility functions are then established for the performance measures based on established utility functions in the literature calibrated for the network (Bai et al. 2008). A summary of the AVI components for the pavement and bridge networks are presented in Table 7.7 and Table 7.8, respectively.

Table 7.7 Pavement AVI Performance Measures

Performance Measure	Weight	Utility Function
Asset Value Loss	30%	U_{AVL} = 1-(5.1328230*(1-EXP(-0.21818*AV_L^0.8))
Remaining Service Life	30%	U_{RSL} = 1-EXP(-0.0327195*RSL^2.5)
Utilization	20%	
- AADT	70%	U_{AADT} = 1-(0.0394*AADT^0.3)
- ESALs	30%	U_{ESALs} =1-(0.0139*ESALs^0.3)
Function	20%	Interurban= 0.7, Rural= 0.9

Table 7.8 Bridge AVI Performance Measures

Performance Measure	Weight	Utility Function
Asset Value Loss	30%	U_{AVL} =1-(1.67*(1-EXP(-0.83272*AVL^0.8))
Remaining Service Life	30%	U_{RSL} = 1-EXP(-0.00535195*RSL^1.6)
Utilization	20%	
- AADT	50%	U_{AADT} = 1-(0.0394*AADT^0.3)
- ESALs	50%	U_{ESALs} =1-(0.0139*ESALs^0.3)
Function	20%	Interurban= 0.7, Rural= 0.9

7.5 Do-Nothing Analysis

Using the deterioration rates, the condition rating for the network, a Do-Nothing option analysis is conducted to evaluate the network condition if no treatment is applied over the analysis period. The network is assumed to have no maintenance or rehabilitation over the analysis period. The pavement condition distribution, condition box-plot, AV_L and AVI over the analysis period are presented in

Figure 7.4 and Figure 7.5, respectively. The bridge condition distribution, condition box-plot, AV_L and AVI over the analysis period are presented in Figure 7.6 and Figure 7.7, respectively.

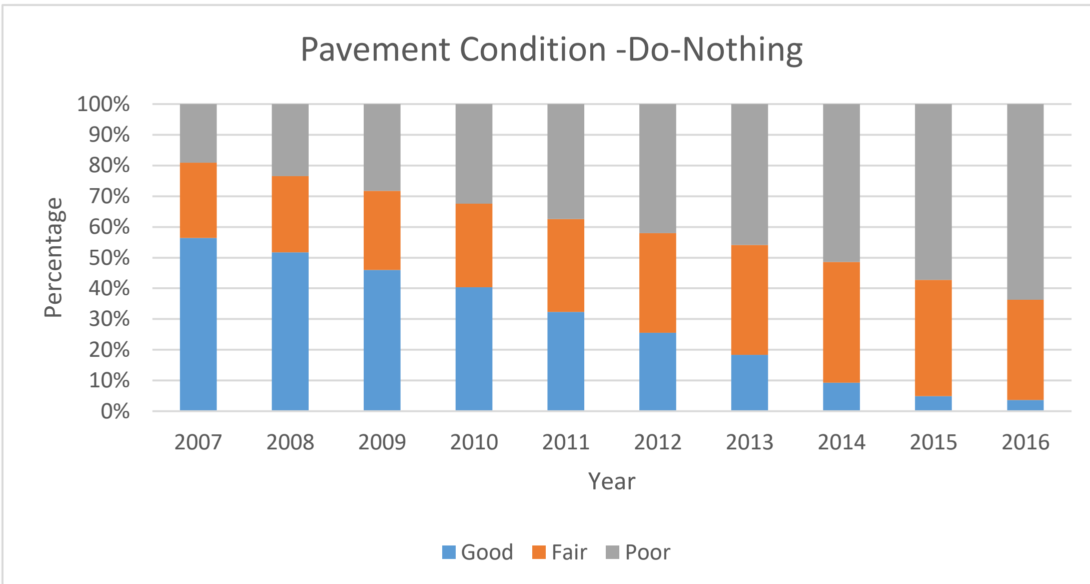

Figure 7.4 Do-Nothing Pavement Condition Distribution

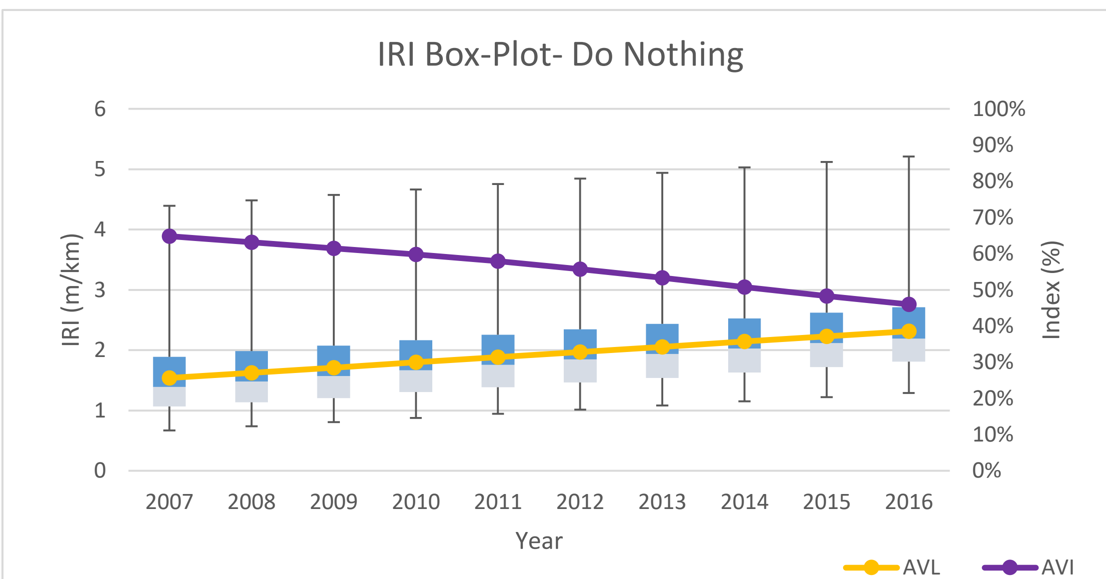

Figure 7.5 Do-Nothing Pavement IRI Box-Plot, AV_L and AVI

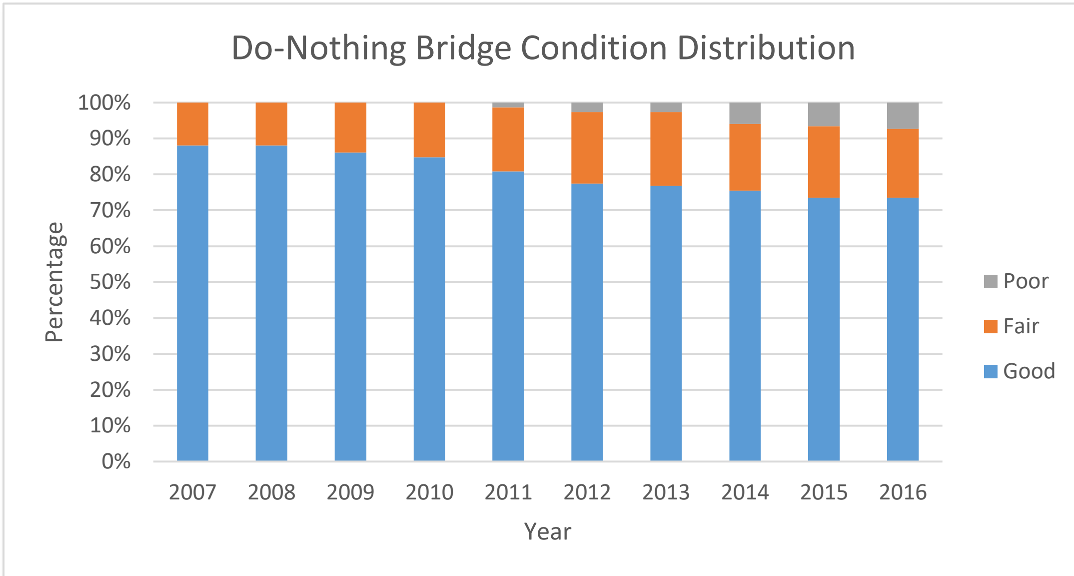

Figure 7.6 Do-Nothing Bridge Network Condition Distribution

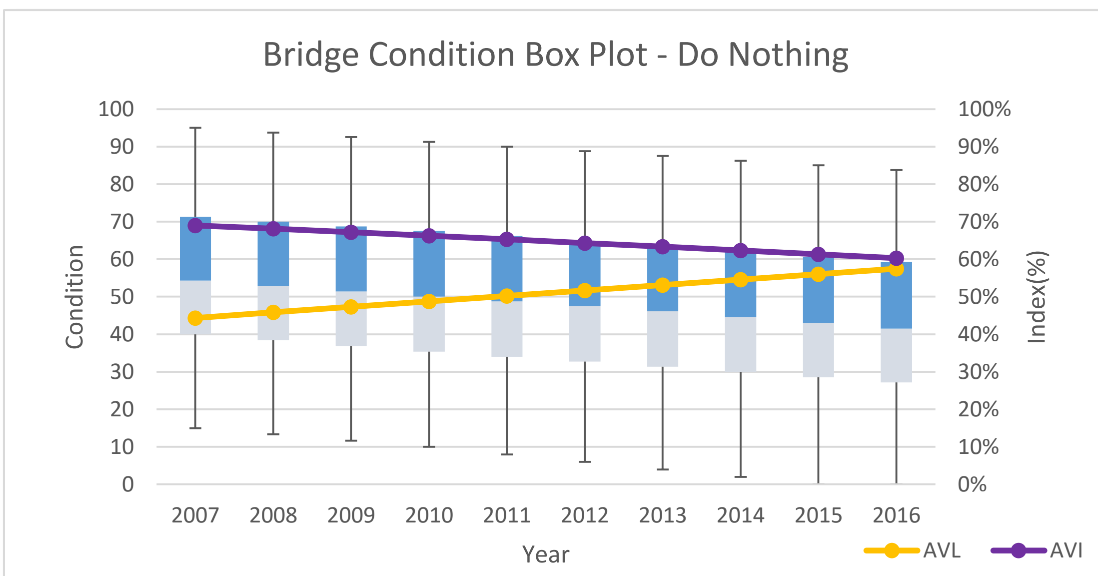

Figure 7.7 Do-Noting Bridge Condition Box-Plot, AV_L and AVI

As shown in Figure 7.4, the pavement overall condition at the beginning of the analysis period contained 56 percent of the pavement in good condition, 25 percent in fair, and 19 percent in poor condition. Over the analysis period, the pavement network deteriorates resulting in over 64 percent of the pavement in poor condition, 33 percent in fair condition, and only 4 percent in good condition. That is also reflected in the network IRI box-plot in Figure 7.5.

Furthermore, as shown in Figure 7.5, the pavement asset value loss ratio increases over the analysis period from 25 percent to over 45 percent value loss of the network replacement cost value. In addition the pavement AVI of the network decreases from 70 percent to below 50 percent over the analysis period.

On the other hand, as shown in Figure 7.6, the bridge network at the beginning of the analysis period shows 88 percent of the bridges in good condition and 12 percent in fair condition. Due to the lack of maintenance and rehabilitation assumed during the analysis period, the bridge network deteriorates resulting in 74 percent in good condition, 19 percent in fair, and 7 percent in poor condition. In addition, the whisker lower tail presented in Figure 7.7 shows some bridges to deteriorate to a condition of zero at the end of the analysis period deeming the bridge inaccessible. Furthermore, the bridge value loss ratio increases over the analysis period to 60 percent of the network replacement cost value.

7.6 Needs Assessment Analysis

In this analysis, the pavement and the bridge networks are maintained to the specified LOS with no budget constraints assumed. This is to establish the minimum budget required to maintain the network to the required LOS. The pavement network maintained at an IRI level below 2 m/km while the bridge network is maintained at a condition rating above 30. Based on the analysis, the total yearly budget ($2007) is presented in in Figure 7.8.

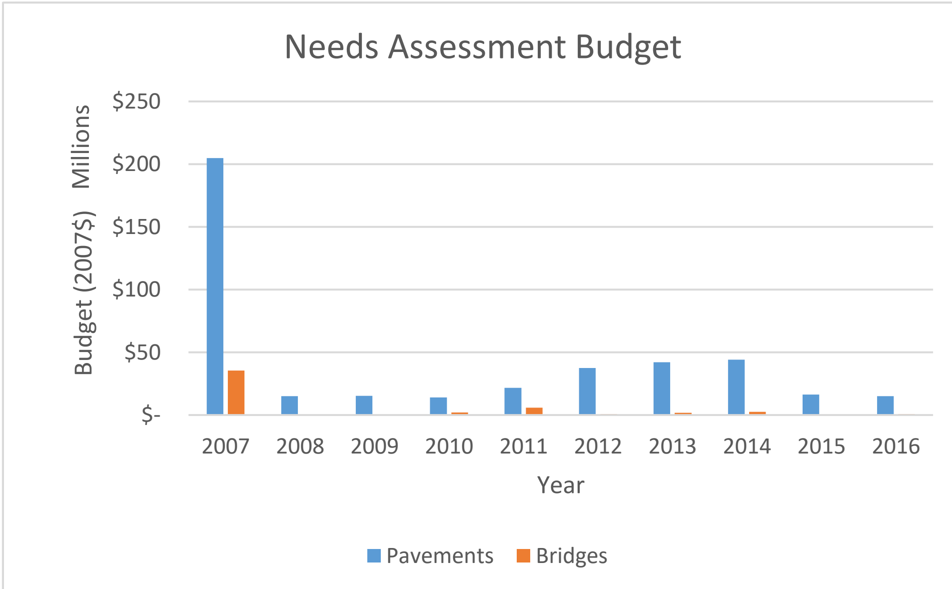

Figure 7.8 Pavement and Bridge Needs Assessment Yearly Budget

Total budget to maintain the network LOS is $477,792,495 ($2007) equivalent to 47 Million a year. To simulate budget constraints for the analysis, a 35 Million ($2007) is used. The pavement and bridge network condition are presented in Figure 7.9 and Figure 7.10; respectively.

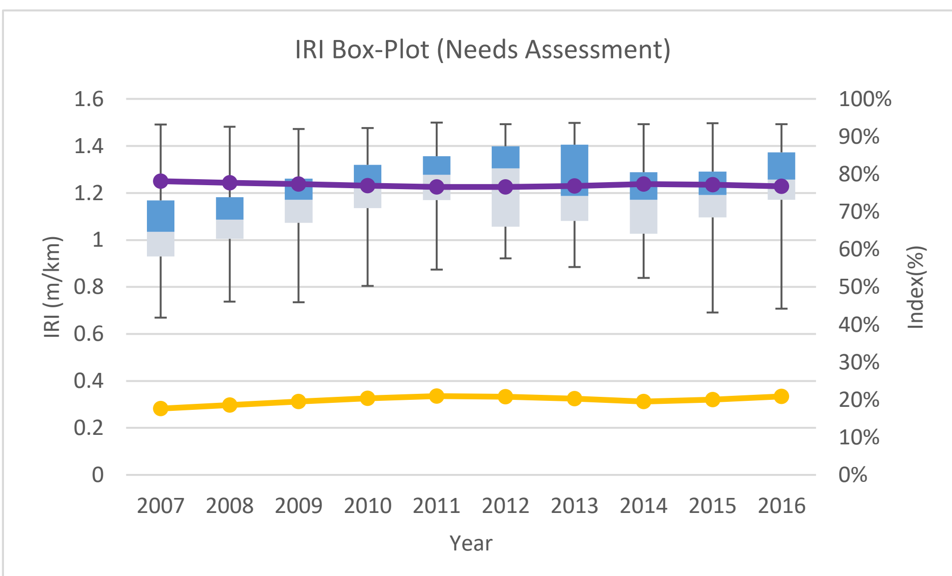

Figure 7.9 Needs Assessment Output – Pavement IRI Box-Plot, AV_L, AVI

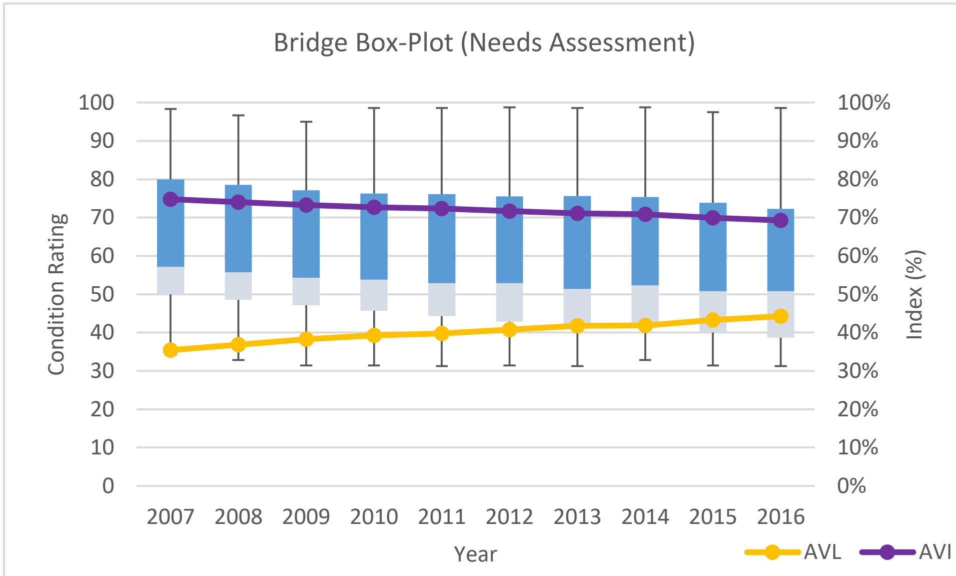

Figure 7.10 Needs Assessment Output – Bridge Condition Box-Plot, AV_L, AVI

As shown in Figure 7.9, the pavement IRI is maintained in good condition over the analysis period. In addition, the network AV_L is maintained around 25% and AVI at 80% over the analysis period. Figure 7.10 shows that the bridge network is maintained in good condition over the analysis period. In addition, the AV_L of the network is maintained at 40% and AVI above 70%. It is worth noting that the bridge network AV_L is at a higher rate due to the low threshold for bridge repair at condition rating of 30.

7.7 Value-Based Cross-Asset Prioritization

To demonstrate the proposed AVI implementation in cross asset management decision making through the case study presented, a priority programming model is developed with the aid of Excel following the framework presented in Figure 7.1. All inputs and calculations are formulated in the Excel cells. The objective is to maximize the overall network AVI subject to the available funds and LOS constraints. An illustrative screenshot of the developed worksheet and the various components is shown in Figure 7.11.

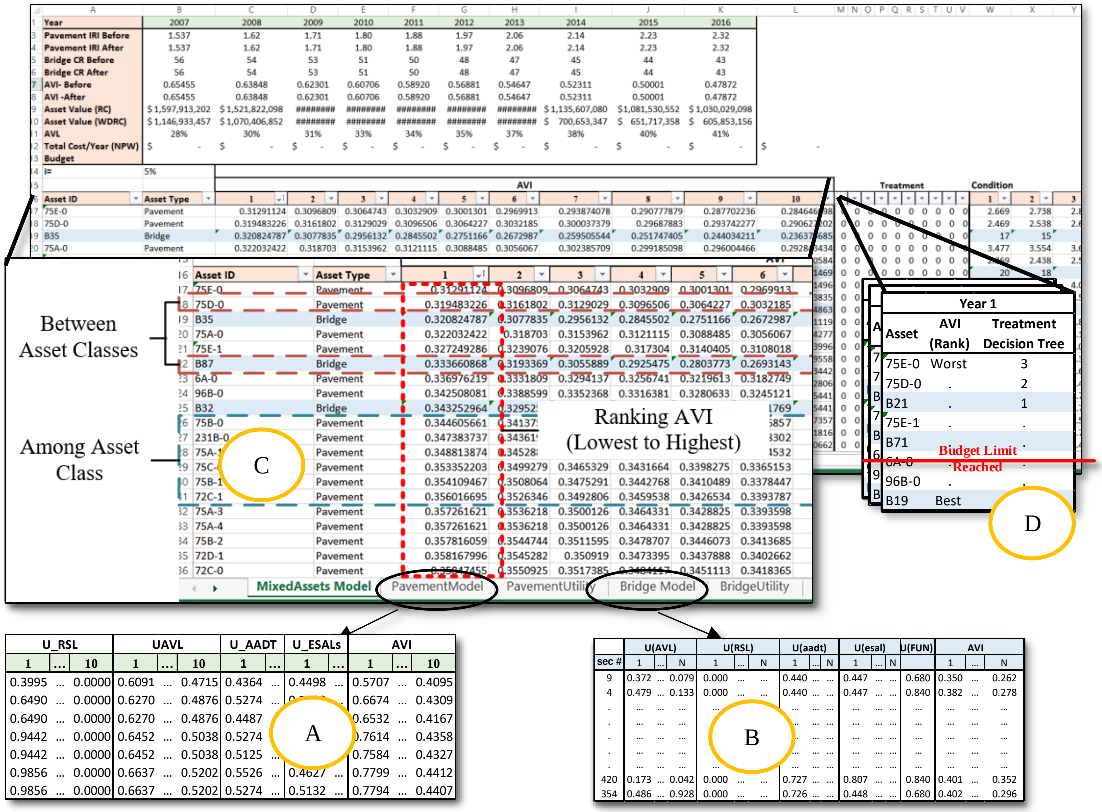

Figure 7.11 Value-Based Cross Asset Management Programming Snapshot

As shown in Figure 7.11 *Part A and B*, the AVI is developed for each asset class based on performance measures, importance weights, prediction models, and utility functions. The AVI development process is similar to that presented in Chapter 5 and Chapter 6. The AVI of the asset groups are then combined for the priority programming for the asset management plan, Figure 7.11 *Part C*. The prioritization decision making scheme presented in Chapter 4 of this thesis, Figure 5.4, is utilized to develop the asset management plan. As shown in Figure 7.11, *Part C*, the assets are ranked based on AVI for selection each year; this process allows for prioritization between asset classes as well as within each asset class. For each year, a ranking of the assets based on the lowest AVI is established and nominated for treatment using the appropriate decision trees for each asset class (project level). The sections are selected from worst to best until the available budget for the given year is exhausted, *part D*. For each year, the performance of the selected projects is updated to reflect the section overall improvements. The processes are then repeated for the following year and so forth until the end of the analysis period and the asset management plan is developed. Figure 7.12 and Figure 7.13 present the pavement and the bridge network overall condition as a result of the proposed model implementation as outlined in this section.

As depicted in Figure 7.12, the pavement network Average IRI is maintained at a good and fair condition. However, as shown in the whisker upper tail, some sections were not maintained and are in poor condition. Those sections have very low AADT traffic and have trigger IRI value of 3.0 m/km, see Appendix D. In addition, the pavement AV_L is maintained below 30 percent and AVI average of 70 percent over the analysis period. The results are comparable to the needs assessment output presented in the previous section.

Furthermore, the bridge network is maintained in a good condition over the analysis period as depicted in Figure 7.13. The Bridge AV_L is maintained at 35 percent on average and AVI at 72 percent over the analysis period. As noted earlier, the high AV_L value is a reflection of the low condition threshold for repair. The results obtained are comparable to that of the needs assessment output.

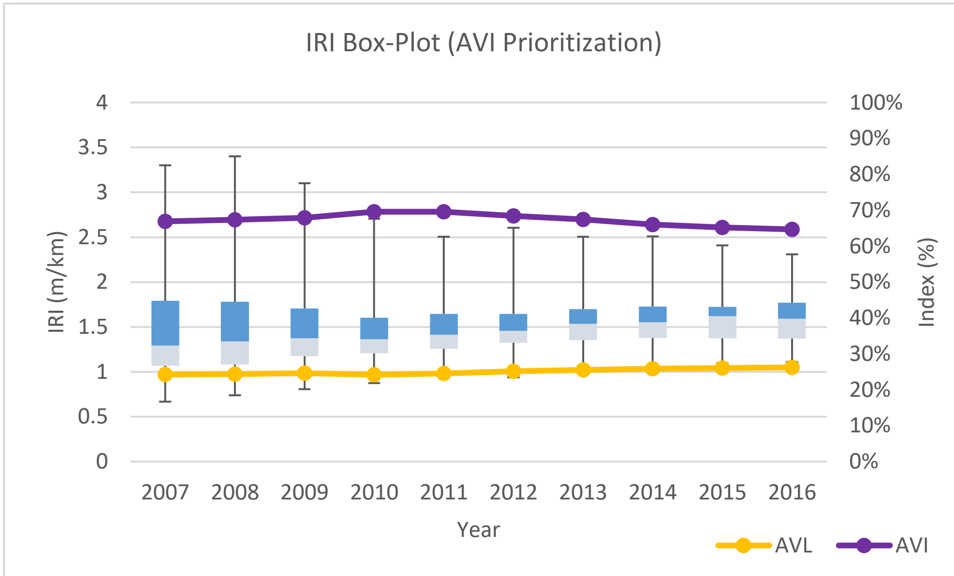

Figure 7.12 Pavement Network Condition -AVI Prioritization Output

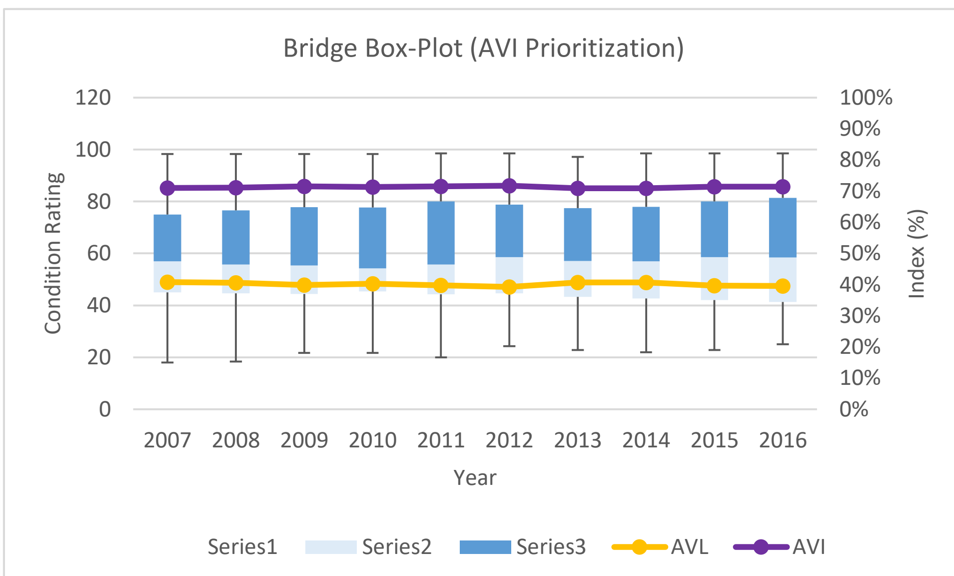

Figure 7.13 Bridge Network Condition -AVI Prioritization Output

7.8 Summary

This chapter presented a methodology to develop AVI for infrastructure assets, based on the methodology presented in Chapter 4 of this thesis, as a common performance measure for cross asset management mechanism between competing asset management systems.

The proposed methodology was demonstrated through a mixed assets case study comprising of 1293 pavement sections and 161 bridges. Performance measures to develop the AVI for each asset class were identified and include: asset value loss, asset utilization, asset function, and remaining service life. The performance measures were based on the available data and considered for both assets. To better evaluate the network, a do-nothing case was conducted and analyzed. In addition, a needs assessment was implemented for both asset networks to identify the budget needs to maintain the required LOS for the network. The output of the needs assessment was used to establish a budget for the implementation of the proposed cross asset management framework. The value-based asset management prioritization framework was implemented for the mixed asset network and an asset management plan was developed. The output of the implementation arrived at an asset management plan that meets the LOS requirements of the assets and comparable results to that of the needs assessment output. In other words, the proposed methodology provides a value-based, structured, justifiable and efficient cross asset management fund allocation mechanism using the proposed AVI.

Chapter 8
Conclusions and Recommendations

8.1 Summary and Conclusions

Agencies (public or private) that are managing infrastructure assets rely on external funding from the stakeholders, such as goverments and taxpayers. Given the challenge of reduced budgets and available funding, it is becoming increasingly important that the agencies implement efficient and effective asset management systems that justify investement needs and implications on their assets and system as a whole. Therefore, a value-based asset management decision making approach is imperative to manage assets in the most optimized cost-effective ways while maintaining or enhancing the value of these assets to the various stakeholders. This research endeavors to integrate asset value as a performance measure in asset management state-of-the- practice. Integrating asset value is imperative to manage assets in the most optimized cost-effective ways while maintaining or enhancing the value of these assets. To meet this objective, Asset Value Index (AVI) that integrate asset value and key factors as performance measures is proposed.

As part of the development of the AVI, a comprehensive review of asset valuation methods was conducted to gain more understanding of the valuation methods in the context of asset management. Analysis was conducted to evaluate the valuation methods and select suitable methods for the proposed integration methodology. Based on the statistical inferences between the various valuation methods, it was concluded that there is no significant statistical similarity between the methods. However, the t-test showed that the NSV and WDRC methods result in similar values. Both methods take into account the asset condition; however, the NSV is dependent on the decision trees and the levels of treatments by thresholds. Therefore, it was concluded that this relationship is specific to the decision tree developed in this case study and changes to the decision trees will result in changes to the values.

All the valuation methods are accounting methods; the methods do not really reflect the value of an asset to an agency, users and the society at large. Also, it is often challenging to explicitly reflect the impact of asset management practices on the asset values. Using the current asset valuation methods as a basis of decision making in asset management poses a few challenges. First, different valuation methods yield different values. In addition, valuation methods consider different parameters to determine asset value. For example, the WDRC considers condition, value from the users' perspective, while GASB considers the service life of the asset, value from the agency's perspective. However, it is imperative that value reflects both perspectives. Furthermore, the current valuation methods do not account in the change of unit prices, probabilistic behaviour of assets' deterioration and the sectioning of assets.

As a result of the analysis conducted, the Asset Value Loss (AV_L) concept is proposed to address the aforementioned challenges and limitations. The proposed AV_L measure is used as a performance measure in incorporating value in asset management decision. However, other key performance measures impact the value from the perspective of the various stakeholders, for example, the asset capacity and utilization, asset function, location, safety and so on. The performance measures are of different measurement units; for example, Pavement Condition Index (PCI), Annual Average Daily Traffic (AADT), etc. As such, the Multi-Attribute-Utility-Theory (MAUT) is used to unify the units through the use of the utility functions and the development of the AVI. The utility theory is used to capture the asset value considering various performance measures (attributes) to aid decision makers to objectively develop a value driven asset management plan.

A conceptual methodology to develop the AVI as a decision support system for value-based asset management is presented as part of this research. The proposed methodology is demonstrated through a detailed case study using data from the MTO's PMS2. In order to evaluate the effectiveness of the proposed AVI, a comparison with the Do-Nothing option, Needs Assessment, and an Optimization outputs is conducted and analyzed. The prioritization using the AVI produced superior results to that of the optimization model. The AVI model produced higher overall performance of the network by efficiently utilizing the available budget compared to the optimization model.

Deciding how to best allocate limited resources across these various asset classes to provide acceptable performance poses a persistent and difficult challenge for agencies. Asset value holds a great promise to be incorporated in asset management as a performance measure that translates infrastructure condition in monetary terms that can be easily communicated and understood by the stakeholders (agency, policy makers and users). Therefore, can be viewed as a common performance measure for integration mechanism between competing asset management systems. Building on the proposed methodology aforementioned, a value-based cross asset management methodology is presented in this research. The proposed methodology was demonstrated through a mixed assets case study comprising of 1293 pavement sections and 161 bridges based on data obtained from ICMPA7. The output of the implementation of the proposed methodology arrives at an asset management plan that meets the LOS requirements of the assets and comparable results to that of the needs assessment output.

Finally, a framework for reporting Tangible Capital Assets (TCA) as a result of this research efforts is presented. In addition, a methodology to develop value-based specifications for infrastructure assets is introduced.

Based on the application of the proposed methodology in the case studies discussed above, the following conclusions are observed:

- The proposed methodology presented an approach for integrating asset value in asset management as a decision support system that takes into account value-driven performance measures.
- The MAUT method was used as means of developing the proposed AVI by unifying the units of the various competing performance measures by developing utility functions and assigning

importance weights. A critical review of the agency objectives and policies should be conducted and a sensitivity analysis should be performed to evaluate the impact of utility functions and weights on the overall decision outcome.

- Proposed methodology provides a value-based, structured, justifiable and efficient framework for asset management and cross asset management decision making and fund allocation mechanism using the proposed AVI.
- The proposed AVI can be used as a common indicator for investment trade-off analysis across assets. Further assessment of the application on cross asset trade-off and optimization is considered for future work.
- The proposed value-based asset management framework was demonstrated through a pavement case study and a mixed asset case study of pavement and bridge networks case study; however, the framework is flexible in nature and can be applied to any asset class.
- Integrating asset valuation in asset management as a performance measure strengthens the overall asset management framework. It allows for an optimized and cost-effective management of assets while maintaining or improving asset values

8.2 Contributions

The research endeavor provides a number of potential contributions to the asset management state of the practice. First, this research provides a better understanding of the application of asset valuation in the context of asset management. The research presented the asset value loss concept as an integration method in asset management. This addresses the challenges in incorporating asset valuation in asset management decision making. Furthermore, the research introduced a methodology to integrate asset value in LCCA, a need that has not been addressed in the literature. This allows agencies to evaluate different alternatives life cycle costs while taking into account asset value. As such, this method provides agencies with a means of a quantifiable and justifiable approach to needs assessment and fund allocations. Furthermore, a reporting protocol based on the proposed asset value loss concept is developed which will allow agencies an integrated engineering and financial accounting reporting of TCA resulting in a more efficient and effective capital planning and budget allocation.

Asset valuation is mostly used in terms of financial accounting, i.e. reporting. Moreover, the research introduced a practical methodology that provide guidance in establishing effective asset valuation requirements based on the proposed AVL which can be used in traditional asset management as well as in performance specified type of contracts, such as long term maintenance contracts and other PPP contracts.

To date, some research has been introduced to incorporate asset value into asset management systems; however, there is no comprehensive work done to incorporate asset valuation in asset management practices. The research developed a methodology that integrates asset value as a performance measure through the developed AVI. The proposed methodology provides a value-based, structured, justifiable and efficient framework for asset management and cross asset management decision making and fund allocation mechanism using the proposed AVI. This is important for managing assets in the most optimized and cost-effective ways while maintaining or enhancing the value of these assets.

With the reduced budgets and deteriorating assets, deciding how to best allocate limited resources across asset classes to provide acceptable performance level poses a persistent and difficult challenge for agencies. This research presented a methodology that used the proposed AVI as a common indicator for investment trade-off analysis across assets.

8.3 Future Work

This research provided a solid foundation for moving towards a value-based infrastructure asset management through the proposed AVI. The objectives of this research endeavor have been achieved; however, with continuous effort, extensions to the proposed approach may be considered to further strengthen the asset management framework. Thus, the following areas are recommended for future research:

- The utility theory was utilized to develop the proposed AVI and as a means of unifying key performance measures impacting asset value. Other method can be considered such as the Analytical Hierarchy Process (AHP) and fuzzy analytic hierarchy process. The outcome of the methods can be compared with that of the MAUT.
- In the case studies proposed in this research, various performance measures available in the data were used to develop the AVI including: asset value/ condition, asset utilization, asset function, and remaining service life. Further research is needed to evaluate other key performance measures related to value such as safety, accessibility, convenience, and user satisfaction.
- Land use is not considered in asset valuation methods. Further research is needed to investigate asset criticality/ location impact on asset value and fund allocation, for example, road assets link to a hospital, emergency vehicle routes and schools. A mechanism to quantify and integrate the criticality of assets in the proposed methodology is needed.

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Appendix A

Asset Valuation Statistical Analysis Output

A-1 Asset Valuation Descriptive Statistics (1992 – 2010)

		RC	WDRC	NSV	BV	EPWIP	GASB
1992	Mean	$3,662,068.50	$2,753,070.43	$6,089,791.53	$3,081,124.76	$4,597,985.29	$2,122,130.98
	Std.	$2,092,755.32	$1,603,494.36	$3,896,484.39	$1,907,850.66	$3,050,098.43	$1,737,012.68
	CV	0.57	0.58	0.64	0.62	0.66	0.82
1993	Mean	$3,631,673.33	$2,673,989.81	$6,077,608.41	$2,981,559.55	$4,509,187.61	$1,960,446.31
	Std.	$2,075,385.45	$1,571,972.97	$3,924,652.42	$1,944,619.46	$3,062,922.30	$1,663,615.14
	CV	0.57	0.59	0.65	0.65	0.68	0.85
1994	Mean	$3,822,833.31	$2,728,623.62	$6,460,767.26	$3,005,738.40	$4,663,962.45	$1,920,183.40
	Std.	$2,184,627.28	$1,604,668.27	$4,158,294.00	$2,109,853.96	$3,184,007.92	$1,683,477.61
	CV	0.57	0.59	0.64	0.70	0.68	0.88
1995	Mean	$3,931,596.74	$2,725,050.68	$6,645,140.87	$2,880,656.63	$4,655,640.72	$1,826,010.96
	Std.	$2,246,782.11	$1,636,317.14	$4,276,088.36	$2,194,361.81	$3,227,863.25	$1,663,612.07
	CV	0.57	0.60	0.64	0.76	0.69	0.91
1996	Mean	$3,916,216.05	$2,689,286.82	$6,621,116.42	$2,809,772.18	$4,581,275.97	$1,840,870.84
	Std.	$2,237,992.54	$1,524,116.74	$4,257,601.21	$2,014,427.05	$3,043,700.28	$1,586,032.21
	CV	0.57	0.57	0.64	0.72	0.66	0.86
1997	Mean	$4,078,811.89	$2,950,756.03	$7,021,335.91	$3,211,881.19	$5,101,875.05	$2,154,083.07
	Std.	$2,330,910.88	$1,635,389.13	$4,386,163.60	$2,067,413.47	$3,168,642.44	$1,672,041.29
	CV	0.57	0.55	0.62	0.64	0.62	0.78
1998	Mean	$4,215,407.05	$3,028,250.88	$7,349,028.20	$3,307,957.91	$5,289,483.59	$2,135,523.46
	Std.	$2,408,970.65	$1,632,147.76	$4,487,917.20	$2,032,838.38	$3,104,240.51	$1,625,478.71
	CV	0.57	0.54	0.61	0.61	0.59	0.76
1999	Mean	$4,276,197.39	$3,182,725.67	$7,587,750.82	$3,433,792.17	$5,627,669.10	$2,287,885.30
	Std.	$2,443,710.39	$1,805,623.57	$4,632,148.81	$2,100,332.25	$3,338,881.25	$1,935,622.64
	CV	0.57	0.57	0.61	0.61	0.59	0.85
2000	Mean	$4,775,625.52	$3,567,492.93	$8,564,953.11	$3,866,982.99	$6,426,006.62	$2,680,185.43
	Std.	$2,730,019.33	$2,065,307.55	$5,214,173.56	$2,419,816.99	$3,973,908.90	$2,122,079.73
	CV	0.57	0.58	0.61	0.63	0.62	0.79
2001	Mean	$4,812,690.42	$3,608,825.66	$8,745,879.03	$3,966,487.81	$6,606,248.52	$2,720,781.69
	Std.	$2,750,299.04	$2,024,139.21	$5,328,166.59	$2,358,519.76	$4,061,344.60	$2,058,496.94
	CV	0.57	0.56	0.61	0.59	0.61	0.76
2002	Mean	$4,951,643.12	$3,643,140.21	$9,110,241.73	$4,016,453.80	$6,764,722.89	$2,709,462.95
	Std.	$2,830,641.00	$2,081,344.85	$5,475,763.23	$2,423,464.47	$4,158,179.26	$2,147,035.29
	CV	0.57	0.57	0.60	0.60	0.61	0.79

		RC	WDRC	NSV	BV	EPWIP	GASB
2003	Mean	$5,034,691.08	$3,675,127.15	$9,292,546.23	$4,097,084.84	$6,849,406.63	$2,683,936.83
	Std.	$2,878,115.95	$2,096,251.30	$5,559,095.33	$2,467,632.90	$4,168,134.89	$2,124,983.60
	CV	0.57	0.57	0.60	0.60	0.61	0.79
2004	Mean	$5,513,610.33	$3,949,937.03	$10,246,944.62	$4,293,311.84	$7,410,902.34	$2,829,384.92
	Std.	$3,150,852.41	$2,227,624.11	$6,143,300.89	$2,658,913.25	$4,491,453.77	$2,189,795.20
	CV	0.57	0.56	0.60	0.62	0.61	0.77
2005	Mean	$6,002,130.27	$4,236,758.51	$11,188,152.47	$4,661,509.73	$7,978,485.47	$2,932,860.88
	Std.	$3,430,025.97	$2,418,600.08	$6,664,312.52	$2,992,479.69	$4,842,300.08	$2,346,014.46
	CV	0.57	0.57	0.60	0.64	0.61	0.80
2006	Mean	$6,307,912.99	$4,378,241.22	$11,789,043.11	$4,729,898.61	$8,295,360.85	$2,860,956.73
	Std.	$3,604,771.04	$2,533,642.79	$7,023,335.26	$3,238,131.39	$5,150,098.57	$2,357,154.76
	CV	0.57	0.58	0.60	0.68	0.62	0.82
2007	Mean	$6,953,901.87	$4,792,819.83	$12,996,350.63	$5,087,084.22	$9,021,181.50	$3,051,071.67
	Std.	$3,973,933.08	$2,845,635.95	$7,742,590.03	$3,587,452.96	$5,599,010.48	$2,596,027.23
	CV	0.57	0.59	0.60	0.71	0.62	0.85
2008	Mean	$7,807,896.25	$5,389,672.74	$14,735,016.80	$5,445,990.60	$10,263,218.43	$3,272,265.67
	Std.	$4,461,963.62	$3,171,124.14	$8,762,007.65	$4,175,388.42	$6,381,528.29	$2,827,501.09
	CV	0.57	0.59	0.59	0.77	0.62	0.86
2009	Mean	$7,205,485.98	$5,077,960.09	$13,666,203.88	$5,175,112.81	$9,758,554.26	$3,255,900.90
	Std.	$4,117,705.37	$3,137,876.83	$8,074,973.16	$3,867,347.94	$6,396,577.85	$3,122,876.38
	CV	0.57	0.62	0.59	0.75	0.66	0.96
2010	Mean	$6,879,195.67	$5,121,889.64	$13,122,247.08	$5,267,297.95	$10,039,411.13	$3,626,634.95
	Std.	$3,931,240.87	$3,196,887.15	$7,661,850.81	$3,896,724.68	$6,853,064.80	$3,301,090.00
	CV	0.57	0.62	0.58	0.74	0.68	0.91

Asset Valuation Analysis of Variance Test Output

ANOVA Tests 1992

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
RC	93	$340,572,370.37	$3,662,068.50	$4,379,624,838,189.39
WDRC	93	$256,035,549.62	$2,753,070.43	$2,571,194,176,964.07
BV	93	$566,350,612.53	$6,089,791.53	$15,182,590,630,986.60
NSV	93	$286,544,603.03	$3,081,124.76	$3,639,894,129,117.25
EPWIP	93	$427,612,631.78	$4,597,985.29	$9,303,100,456,565.24
GASB	93	197358181.5	2122130.984	3.01721E+12

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9.57E+14	5	1.91327E+14	30.13527344	4.14E-27	2.230346
Within Groups	3.5E+15	552	6.34894E+12			
Total	4.46E+15	557				

ANOVA Tests 1993

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
RC	93	3.38E+08	3631673	4.31E+12
WDRC	93	2.49E+08	2673990	2.47E+12
BV	93	5.65E+08	6077608	1.54E+13
NSV	93	2.77E+08	2981560	3.78E+12
EPWIP	93	4.19E+08	4509188	9.38E+12
GASB	93	1.82E+08	1960446	2.77E+12

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.01E+15	5	2.02E+14	31.874	1.48E-28	2.230346
Within Groups	3.51E+15	552	6.35E+12			
Total	4.52E+15	557				

ANOVA Tests 1994

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	3.56E+08	3822833	4.77E+12
WDRC	93	2.54E+08	2728624	2.57E+12
BV	93	6.01E+08	6460767	1.73E+13
NSV	93	2.8E+08	3005738	4.45E+12
EPWIP	93	4.34E+08	4663962	1.01E+13
GASB	93	1.79E+08	1920183	2.83E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.22E+15	5	2.44E+14	34.84316	5.49E-31	2.230346
Within Groups	3.87E+15	552	7.01E+12			
Total	5.09E+15	557				

ANOVA Tests 1995

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	3.66E+08	3931597	5.05E+12
WDRC	93	2.53E+08	2725051	2.68E+12
BV	93	6.18E+08	6645141	1.83E+13
NSV	93	2.68E+08	2880657	4.82E+12
EPWIP	93	4.33E+08	4655641	1.04E+13
GASB	93	1.7E+08	1826011	2.77E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.37E+15	5	2.74E+14	37.37171	5.06E-33	2.230346
Within Groups	4.05E+15	552	7.34E+12			
Total	5.42E+15	557				

ANOVA Tests 1996

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	3.64E+08	3916216	5.01E+12
WDRC	93	2.5E+08	2689287	2.32E+12
BV	93	6.16E+08	6621116	1.81E+13
NSV	93	2.61E+08	2809772	4.06E+12
EPWIP	93	4.26E+08	4581276	9.26E+12
GASB				
	93	1.71E+08	1840871	2.52E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.36E+15	5	2.72E+14	39.49753	1.04E-34	2.230346
Within Groups	3.8E+15	552	6.88E+12			
Total	5.16E+15	557				

ANOVA Tests 1997

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	3.79E+08	4078812	5.43E+12
WDRC	93	2.74E+08	2950756	2.67E+12
BV	93	6.53E+08	7021336	1.92E+13
NSV	93	2.99E+08	3211881	4.27E+12
EPWIP	93	4.74E+08	5101875	1E+13
GASB				
	93	2E+08	2154083	2.8E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.44E+15	5	2.87E+14	38.74298	4.11E-34	2.230346
Within Groups	4.09E+15	552	7.41E+12			
Total	5.53E+15	557				

ANOVA Tests 1998

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	3.92E+08	4215407	5.8E+12
WDRC	93	2.82E+08	3028251	2.66E+12
BV	93	6.83E+08	7349028	2.01E+13
NSV	93	3.08E+08	3307958	4.13E+12
EPWIP	93	4.92E+08	5289484	9.64E+12
GASB	93	1.99E+08	2135523	2.64E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.63E+15	5	3.26E+14	43.46005	8.63E-38	2.230346
Within Groups	4.14E+15	552	7.5E+12			
Total	5.77E+15	557				

ANOVA Tests 1999

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	3.98E+08	4276197	5.97E+12
WDRC	93	2.96E+08	3182726	3.26E+12
BV	93	7.06E+08	7587751	2.15E+13
NSV	93	3.19E+08	3433792	4.41E+12
EPWIP	93	5.23E+08	5627669	1.11E+13
GASB	93	2.13E+08	2287885	3.75E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.73E+15	5	3.45E+14	41.43142	3.2E-36	2.230346
Within Groups	4.6E+15	552	8.33E+12			
Total	6.33E+15	557				

ANOVA Tests 2000

SUMMARY

Groups	Count	Sum	Average	Variance
RC	92	4.39E+08	4775626	7.45E+12
WDRC	92	3.28E+08	3567493	4.27E+12
BV	92	7.88E+08	8564953	2.72E+13
NSV	92	3.56E+08	3866983	5.86E+12
EPWIP	92	5.91E+08	6426007	1.58E+13
GASB	92	2.47E+08	2680185	4.5E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.16E+15	5	4.33E+14	39.89211	5.79E-35	2.230525
Within Groups	5.92E+15	546	1.08E+13			
Total	8.08E+15	551				

ANOVA Tests 2001

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	4.48E+08	4812690	7.56E+12
WDRC	93	3.36E+08	3608826	4.1E+12
BV	93	8.13E+08	8745879	2.84E+13
NSV	93	3.69E+08	3966488	5.56E+12
EPWIP	93	6.14E+08	6606249	1.65E+13
GASB	93	2.53E+08	2720782	4.24E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.31E+15	5	4.61E+14	41.73263	1.86E-36	2.230346
Within Groups	6.1E+15	552	1.11E+13			
Total	8.41E+15	557				

ANOVA Tests 2002

SUMMARY

Groups	Count	Sum	Average	Variance
RC	92	4.56E+08	4951643	8.01E+12
WDRC	92	3.35E+08	3643140	4.33E+12
BV	92	8.38E+08	9110242	3E+13
NSV	92	3.7E+08	4016454	5.87E+12
EPWIP	92	6.22E+08	6764723	1.73E+13
GASB	92	2.49E+08	2709463	4.61E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.56E+15	5	5.12E+14	43.82398	5.25E-38	2.230525
Within Groups	6.38E+15	546	1.17E+13			
Total	8.94E+15	551				

ANOVA Tests 2003

SUMMARY

Groups	Count	Sum	Average	Variance
RC	92	4.63E+08	5034691	8.28E+12
WDRC	92	3.38E+08	3675127	4.39E+12
BV	92	8.55E+08	9292546	3.09E+13
NSV	92	3.77E+08	4097085	6.09E+12
EPWIP	92	6.3E+08	6849407	1.74E+13
GASB	92	2.47E+08	2683937	4.52E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.7E+15	5	5.4E+14	45.26158	4.23E-39	2.230525
Within Groups	6.51E+15	546	1.19E+13			
Total	9.21E+15	551				

ANOVA Tests 2004

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	5.13E+08	5513610	9.93E+12
WDRC	93	3.67E+08	3949937	4.96E+12
BV	93	9.53E+08	10246945	3.77E+13
NSV	93	3.99E+08	4293312	7.07E+12
EPWIP	93	6.89E+08	7410902	2.02E+13
GASB	93	2.63E+08	2829385	4.8E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3.43E+15	5	6.87E+14	48.66124	1E-41	2.230346
Within Groups	7.79E+15	552	1.41E+13			
Total	1.12E+16	557				

ANOVA Tests 2005

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	5.58E+08	6002130	1.18E+13
WDRC	93	3.94E+08	4236759	5.85E+12
BV	93	1.04E+09	11188152	4.44E+13
NSV	93	4.34E+08	4661510	8.95E+12
EPWIP	93	7.42E+08	7978485	2.34E+13
GASB	93	2.73E+08	2932861	5.5E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.18E+15	5	8.36E+14	50.22241	7.01E-43	2.230346
Within Groups	9.19E+15	552	1.67E+13			
Total	1.34E+16	557				

ANOVA Tests 2006

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	5.87E+08	6307913	1.3E+13
WDRC	93	4.07E+08	4378241	6.42E+12
BV	93	1.1E+09	11789043	4.93E+13
NSV	93	4.4E+08	4729899	1.05E+13
EPWIP	93	7.71E+08	8295361	2.65E+13
GASB	93	2.66E+08	2860957	5.56E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.84E+15	5	9.68E+14	52.18138	2.57E-44	2.230346
Within Groups	1.02E+16	552	1.86E+13			
Total	1.51E+16	557				

ANOVA Tests 2007

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	6.47E+08	6953902	1.58E+13
WDRC	93	4.46E+08	4792820	8.1E+12
BV	93	1.21E+09	12996351	5.99E+13
NSV	93	4.73E+08	5087084	1.29E+13
EPWIP	93	8.39E+08	9021182	3.13E+13
GASB	93	2.84E+08	3051072	6.74E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.97E+15	5	1.19E+15	53.12505	5.29E-45	2.230346
Within Groups	1.24E+16	552	2.25E+13			
Total	1.84E+16	557				

ANOVA Tests 2008

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	7.26E+08	7807896	1.99E+13
WDRC	93	5.01E+08	5389673	1.01E+13
BV	93	1.37E+09	14735017	7.68E+13
NSV	93	5.06E+08	5445991	1.74E+13
EPWIP	93	9.54E+08	10263218	4.07E+13
GASB	93	3.04E+08	3272266	7.99E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8E+15	5	1.6E+15	55.51984	9.99E-47	2.230346
Within Groups	1.59E+16	552	2.88E+13			
Total	2.39E+16	557				

ANOVA Tests 2009

SUMMARY

Groups	Count	Sum	Average	Variance
RC	93	6.7E+08	7205486	1.7E+13
WDRC	93	4.72E+08	5077960	9.85E+12
BV	93	1.27E+09	13666204	6.52E+13
NSV	93	4.81E+08	5175113	1.5E+13
EPWIP	93	9.08E+08	9758554	4.09E+13
GASB	93	3.03E+08	3255901	9.75E+12

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6.73E+15	5	1.35E+15	51.2365	1.26E-43	2.230346
Within Groups	1.45E+16	552	2.63E+13			
Total	2.12E+16	557				

ANOVA Tests 2010

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
RC	93	6.4E+08	6879196	1.55E+13
WDRC	93	4.76E+08	5121890	1.02E+13
BV	93	1.22E+09	13122247	5.87E+13
NSV	93	4.9E+08	5267298	1.52E+13
EPWIP	93	9.34E+08	10039411	4.7E+13
GASB	93	3.37E+08	3626635	1.09E+13

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.95E+15	5	1.19E+15	45.32675	3.23E-39	2.230346
Within Groups	1.45E+16	552	2.62E+13			
Total	2.04E+16	557				

Minitab® t-Test 1992

Two-Sample T-Test and CI: RC, WDRC
Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3662068	2092755	217009
WDRC	93	2753070	1603494	166275

Estimation for Difference

Difference	95% CI for Difference
908998	(369374, 1448622)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.32	172	0.001

Two-Sample T-Test and CI: RC, BV
Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3662068	2092755	217009
BV	93	6089792	3896484	404047

Estimation for Difference

Difference	95% CI for Difference
-2427723	(-3334470, -1520976)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.29	140	0.000

Two-Sample T-Test and CI: RC, NSV
Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3662068	2092755	217009
NSV	93	3081125	1907851	197835

Estimation for Difference

Difference	95% CI for Difference
580944	(1544, 1160343)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
1.98	182	0.049

Two-Sample T-Test and CI: RC, EPWIP Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3662068	2092755	217009
EPWIP	93	4597985	3050098	316280

Estimation for Difference

Difference	95% CI for Difference
-935917	(-1693359, -178475)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-2.44	162	0.016

Two-Sample T-Test and CI: RC, GASB Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3662068	2092755	217009
GASB	93	2122131	1737013	180120

Estimation for Difference

Difference	95% CI for Difference
1539938	(983381, 2096494)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
5.46	177	0.000

Two-Sample T-Test and CI: WDRC, BV Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2753070	1603494	166275
BV	93	6089792	3896484	404047

Estimation for Difference

Difference	95% CI for Difference
-3336721	(-4201652, -2471790)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-7.64	122	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2753070	1603494	166275
NSV	93	3081125	1907851	197835

Estimation for Difference

Difference	95% CI for Difference
-328054	(-838035, 181926)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-1.27	178	0.206

Two-Sample T-Test and CI: WDRC, EPWIP

Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2753070	1603494	166275
EPWIP	93	4597985	3050098	316280

Estimation for Difference

Difference	95% CI for Difference
-1844915	(-2551408, -1138421)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.16	139	0.000

Two-Sample T-Test and CI: WDRC, GASB Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2753070	1603494	166275
GASB	93	2122131	1737013	180120

Estimation for Difference

Difference	95% CI for Difference
630939	(147271, 1114608)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.57	182	0.011

Two-Sample T-Test and CI: BV, NSV Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6089792	3896484	404047
NSV	93	3081125	1907851	197835

Estimation for Difference

Difference	95% CI for Difference
3008667	(2118821, 3898513)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.69	133	0.000

Two-Sample T-Test and CI: BV, EPWIP Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6089792	3896484	404047
EPWIP	93	4597985	3050098	316280

Estimation for Difference

Difference	95% CI for Difference
1491806	(479035, 2504578)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.91	173	0.004

Two-Sample T-Test and CI: BV, GASB Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6089792	3896484	404047
GASB	93	2122131	1737013	180120

Estimation for Difference

Difference	95% CI for Difference
3967661	(3092278, 4843043)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.97	127	0.000

Two-Sample T-Test and CI: NSV, EPWIP Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	3081125	1907851	197835
EPWIP	93	4597985	3050098	316280

Estimation for Difference

Difference	95% CI for Difference
-1516861	(-2253831, -779890)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-4.07	154	0.000

Two-Sample T-Test and CI: NSV, GASB
Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	3081125	1907851	197835
GASB	93	2122131	1737013	180120

Estimation for Difference

Difference	95% CI for Difference
958994	(431100, 1486888)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.58	182	0.000

Two-Sample T-Test and CI: EPWIP, GASB
Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	4597985	3050098	316280
GASB	93	2122131	1737013	180120

Estimation for Difference

Difference	95% CI for Difference
2475854	(1756476, 3195233)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.80	145	0.000

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Two-Sample T-Test and CI: RC, WDRC
Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3631673	2075385	215207
WDRC	93	2673990	1571973	163006

Estimation for Difference

Difference	95% CI for Difference
957684	(424775, 1490592)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.55	171	0.001

Two-Sample T-Test and CI: RC, BV Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
RC	9 3	363167 3	207538 5	215207
BV	9 3	607760 8	392465 2	406967

Estimation for Difference

Difference	95% CI for Difference
-2445935	(-3356160, -1535710)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.31	139	0.000

Two-Sample T-Test and CI: RC, NSV Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
RC	9 3	363167 3	207538 5	215207
NSV	9 3	298156 0	194461 9	201648

Estimation for Difference

Difference	95% CI for Difference
650114	(68239, 1231988)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.20	183	0.029

Two-Sample T-Test and CI: RC, EPWIP Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3631673	2075385	215207
EPWIP	93	4509188	3062922	317610

Estimation for Difference

Difference	95% CI for Difference
-877514	(-1635158, -119871)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-2.29	161	0.023

Two-Sample T-Test and CI: RC, GASB
Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3631673	2075385	215207
GASB	93	1960446	1663615	172509

Estimation for Difference

Difference	95% CI for Difference
1671227	(1126876, 2215578)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.06	175	0.000

Two-Sample T-Test and CI: WDRC, BV
Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2673990	1571973	163006
BV	93	6077608	3924652	406967

Estimation for Difference

Difference	95% CI for Difference

-3403619	(-4271618, -2535619)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-7.76	120	0.000

Two-Sample T-Test and CI: WDRC, NSV Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2673990	1571973	163006
NSV	93	2981560	1944619	201648

Estimation for Difference

Difference	95% CI for Difference
-307570	(-819293, 204153)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-1.19	176	0.237

Two-Sample T-Test and CI: WDRC, EPWIP Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2673990	1571973	163006
EPWIP	93	4509188	3062922	317610

Estimation for Difference

Difference	95% CI for Difference
-1835198	(-2541136, -1129260)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.14	137	0.000

Two-Sample T-Test and CI: WDRC, GASB Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2673990	1571973	163006
GASB	93	1960446	1663615	172509

Estimation for Difference

Difference	95% CI for Difference
713543	(245269, 1181818)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.01	183	0.003

Two-Sample T-Test and CI: BV, NSV
Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6077608	3924652	406967
NSV	93	2981560	1944619	201648

Estimation for Difference

Difference	95% CI for Difference
3096049	(2197749, 3994348)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.82	134	0.000

Two-Sample T-Test and CI: BV, EPWIP
Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6077608	3924652	406967
EPWIP	93	4509188	3062922	317610

Estimation for Difference

Difference	95% CI for Difference
1568421	(549490, 2587351)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value

3.04	173	0.003

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6077608	3924652	406967
GASB	93	1960446	1663615	172509

Estimation for Difference

Difference	95% CI for Difference
4117162	(3242280, 4992044)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
9.31	124	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	2981560	1944619	201648
EPWIP	93	4509188	3062922	317610

Estimation for Difference

Difference	95% CI for Difference
-1527628	(-2270799, -784457)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-4.06	155	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	2981560	1944619	201648

GASB	93	1960446	1663615	172509

Estimation for Difference

Difference	95% CI for Difference
1021113	(497458, 1544769)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.85	179	0.000

Two-Sample T-Test and CI: EPWIP, GASB
Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	4509188	3062922	317610
GASB	93	1960446	1663615	172509

Estimation for Difference

Difference	95% CI for Difference
2548741	(1834208, 3263274)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.05	141	0.000

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Two-Sample T-Test and CI: RC, WDRC
Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3822833	2184627	226535
WDRC	93	2728624	1604668	166396

Estimation for Difference

Difference	95% CI for Difference
1094210	(539306, 1649114)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.89	168	0.000

Two-Sample T-Test and CI: RC, BV
Method

μ_1: mean of RC

μ_2: mean of BV

Difference: μ_1 - μ_2

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3822833	2184627	226535
BV	93	6460767	4158294	431195

Estimation for Difference

Difference	95% CI for Difference
-2637934	(-3600979, -1674889)

Test

Null hypothesis	H_0: μ_1 - μ_2 = 0
Alternative hypothesis	H_1: μ_1 - μ_2 ≠ 0

T-Value	DF	P-Value
-5.42	139	0.000

Two-Sample T-Test and CI: RC, NSV
Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: μ_1 - μ_2

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3822833	2184627	226535
NSV	93	3005738	2109854	218782

Estimation for Difference

Difference	95% CI for Difference
817095	(195726, 1438464)

Test

Null hypothesis	H_0: μ_1 - μ_2 = 0
Alternative hypothesis	H_1: μ_1 - μ_2 ≠ 0

T-Value	DF	P-Value
2.59	183	0.010

Two-Sample T-Test and CI: RC, EPWIP
Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: μ_1 - μ_2

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3822833	2184627	226535
EPWIP	93	4663962	3184008	330166

Estimation for Difference

Difference	95% CI for Difference
-841129	(-1631825, -50434)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-2.10	162	0.037

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3822833	2184627	226535
GASB	93	1920183	1683478	174568

Estimation for Difference

Difference	95% CI for Difference
1902650	(1338141, 2467159)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.65	172	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2728624	1604668	166396
BV	93	6460767	4158294	431195

Estimation for Difference

Difference	95% CI for Difference
-3732144	(-4647400, -2816887)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-8.07	118	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2728624	1604668	166396
NSV	93	3005738	2109854	218782

Estimation for Difference

Difference	95% CI for Difference
-277115	(-819689, 265459)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-1.01	171	0.315

Two-Sample T-Test and CI: WDRC, EPWIP Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2728624	1604668	166396
EPWIP	93	4663962	3184008	330166

Estimation for Difference

Difference	95% CI for Difference
-1935339	(-2666544, -1204134)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.23	135	0.000

Two-Sample T-Test and CI: WDRC, GASB Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2728624	1604668	166396
GASB	93	1920183	1683478	174568

Estimation for Difference

Difference	95% CI for Difference
808440	(332613, 1284267)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.35	183	0.001

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6460767	4158294	431195
NSV	93	3005738	2109854	218782

Estimation for Difference

Difference	95% CI for Difference
3455029	(2498833, 4411225)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.15	136	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6460767	4158294	431195
EPWIP	93	4663962	3184008	330166

Estimation for Difference

Difference	95% CI for Difference
1796805	(724840, 2868770)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.31	172	0.001

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean

BV	93	6460767	4158294	431195
GASB	93	1920183	1683478	174568

Estimation for Difference

Difference	95% CI for Difference
4540584	(3619614, 5461553)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
9.76	121	0.000

Two-Sample T-Test and CI: NSV, EPWIP
Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	3005738	2109854	218782
EPWIP	93	4663962	3184008	330166

Estimation for Difference

Difference	95% CI for Difference
-1658224	(-2440470, -875978)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-4.19	159	0.000

Two-Sample T-Test and CI: NSV, GASB
Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	3005738	2109854	218782
GASB	93	1920183	1683478	174568

Estimation for Difference

Difference	95% CI for Difference
1085555	(533156, 1637953)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.88	175	0.000

Two-Sample T-Test and CI: EPWIP, GASB
Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	4663962	3184008	330166
GASB	93	1920183	1683478	174568

Estimation for Difference

Difference	95% CI for Difference
2743779	(2005352, 3482206)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.35	139	0.000

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Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3931597	2246782	232980
WDRC	93	2725051	1636317	169678

Estimation for Difference

Difference	95% CI for Difference
1206546	(637547, 1775545)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.19	168	0.000

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3931597	2246782	232980
BV	93	6645141	4276088	443410

Estimation for Difference

Difference	95% CI for Difference
-2713544	(-3703895, -1723193)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.42	139	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3931597	2246782	232980
NSV	93	2880657	2194362	227545

Estimation for Difference

Difference	95% CI for Difference
1050940	(408403, 1693477)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.23	183	0.001

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3931597	2246782	232980
EPWIP	93	4655641	3227863	334714

Estimation for Difference

Difference	95% CI for Difference
-724044	(-1529289, 81201)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-1.78	164	0.078

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3931597	2246782	232980
GASB	93	1826011	1663612	172509

Estimation for Difference

Difference	95% CI for Difference
2105586	(1533304, 2677868)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.26	169	0.000

Two-Sample T-Test and CI: WDRC, BV
Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2725051	1636317	169678
BV	93	6645141	4276088	443410

Estimation for Difference

Difference	95% CI for Difference
-3920090	(-4860256, -2979924)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-8.26	118	0.000

Two-Sample T-Test and CI: WDRC, NSV
Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2725051	1636317	169678
NSV	93	2880657	2194362	227545

Estimation for Difference

Difference	95% CI for Difference
-155606	(-715918, 404706)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.55	170	0.584

Two-Sample T-Test and CI: WDRC, EPWIP
Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean

WDRC	93	2725051	1636317	169678
EPWIP	93	4655641	3227863	334714

Estimation for Difference

Difference	95% CI for Difference
-1930590	(-2672700, -1188480)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.14	136	0.000

Two-Sample T-Test and CI: WDRC, GASB

Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2725051	1636317	169678
GASB	93	1826011	1663612	172509

Estimation for Difference

Difference	95% CI for Difference
899040	(421628, 1376451)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.72	183	0.000

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6645141	4276088	443410
NSV	93	2880657	2194362	227545

Estimation for Difference

Difference	95% CI for Difference
3764484	(2778960, 4750009)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.55	137	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6645141	4276088	443410
EPWIP	93	4655641	3227863	334714

Estimation for Difference

Difference	95% CI for Difference
1989500	(892864, 3086136)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.58	171	0.000

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6645141	4276088	443410
GASB	93	1826011	1663612	172509

Estimation for Difference

Difference	95% CI for Difference
4819130	(3877028, 5761232)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
10.13	119	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	2880657	2194362	227545
EPWIP	93	4655641	3227863	334714

Estimation for Difference

Difference	95% CI for Difference
-1774984	(-2574220, -975749)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-4.39	162	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	2880657	2194362	227545
GASB	93	1826011	1663612	172509

Estimation for Difference

Difference	95% CI for Difference
1054646	(490999, 1618292)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.69	171	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	4655641	3227863	334714
GASB	93	1826011	1663612	172509

Estimation for Difference

Difference	95% CI for Difference
2829630	(2085021, 3574238)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.51	137	0.000

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1996

Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3916216	2237993	232069
WDRC	93	2689287	1524117	158044

Estimation for Difference

Difference	95% CI for Difference
1226929	(672481, 1781377)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.37	162	0.000

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3916216	2237993	232069
BV	93	6621116	4257601	441493

Estimation for Difference

Difference	95% CI for Difference
-2704900	(-3691058, -1718743)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.42	139	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3916216	2237993	232069
NSV	93	2809772	2014427	208886

Estimation for Difference

Difference	95% CI for Difference
1106444	(490359, 1722529)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.54	181	0.001

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3916216	2237993	232069
EPWIP	93	4581276	3043700	315617

Estimation for Difference

Difference	95% CI for Difference
-665060	(-1438452, 108332)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-1.70	168	0.091

Two-Sample T-Test and CI: RC, GASB
Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	3916216	2237993	232069
GASB	93	1840871	1586032	164464

Estimation for Difference

Difference	95% CI for Difference
2075345	(1513740, 2636951)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.30	165	0.000

Two-Sample T-Test and CI: WDRC, BV
Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2689287	1524117	158044
BV	93	6621116	4257601	441493

Estimation for Difference

Difference	95% CI for Difference
-3931830	(-4860686, -3002973)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-8.38	115	0.000

Two-Sample T-Test and CI: WDRC, NSV
Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2689287	1524117	158044
NSV	93	2809772	2014427	208886

Estimation for Difference

Difference	95% CI for Difference
-120485	(-637533, 396562)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.46	171	0.646

Two-Sample T-Test and CI: WDRC, EPWIP
Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2689287	1524117	158044
EPWIP	93	4581276	3043700	315617

Estimation for Difference

Difference	95% CI for Difference
-1891989	(-2590067, -1193912)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.36	135	0.000

Two-Sample T-Test and CI: WDRC, GASB
Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2689287	1524117	158044
GASB	93	1840871	1586032	164464

Estimation for Difference

Difference	95% CI for Difference
848416	(398387, 1298445)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.72	183	0.000

Two-Sample T-Test and CI: BV, NSV
Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6621116	4257601	441493
NSV	93	2809772	2014427	208886

Estimation for Difference

Difference	95% CI for Difference
3811344	(2845143, 4777546)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.80	131	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6621116	4257601	441493
EPWIP	93	4581276	3043700	315617

Estimation for Difference

Difference	95% CI for Difference
2039840	(968344, 3111336)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.76	166	0.000

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	6621116	4257601	441493
GASB	93	1840871	1586032	164464

Estimation for Difference

Difference	95% CI for Difference
4780246	(3847196, 5713295)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
10.15	117	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	2809772	2014427	208886
EPWIP	93	4581276	3043700	315617

Estimation for Difference

Difference	95% CI for Difference

-1771504	(-2519002, -1024006)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-4.68	159	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	2809772	2014427	208886
GASB	93	1840871	1586032	164464

Estimation for Difference

Difference	95% CI for Difference
968901	(444174, 1493628)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.64	174	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	4581276	3043700	315617
GASB	93	1840871	1586032	164464

Estimation for Difference

Difference	95% CI for Difference
2740405	(2036689, 3444121)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.70	138	0.000

Minitab® T-Test 1997

Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4078812	2330911	241704

WDRC	93	2950756	1635389	169582

Estimation for Difference

Difference	95% CI for Difference
1128056	(545053, 1711059)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.82	164	0.000

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4078812	2330911	241704
BV	93	7021336	4386164	454824

Estimation for Difference

Difference	95% CI for Difference
-2942524	(-3960823, -1924225)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.71	140	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4078812	2330911	241704
NSV	93	3211881	2067413	214381

Estimation for Difference

Difference	95% CI for Difference
866931	(229445, 1504416)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.68	181	0.008

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean

RC	93	4078812	2330911	241704
EPWIP	93	5101875	3168642	328573

Estimation for Difference

Difference	95% CI for Difference
-1023063	(-1828296, -217831)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-2.51	169	0.013

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4078812	2330911	241704
GASB	93	2154083	1672041	173383

Estimation for Difference

Difference	95% CI for Difference
1924729	(1337436, 2512021)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.47	166	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	2950756	1635389	169582
BV	93	7021336	4386164	454824

Estimation for Difference

Difference	95% CI for Difference
-4070580	(-5031909, -3109251)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-8.39	117	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
WDRC	9 3	295075 6	163538 9	169582
NSV	9 3	321188 1	206741 3	214381

Estimation for Difference

Difference	95% CI for Difference
-261125	(-800623, 278372)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.96	174	0.341

Two-Sample T-Test and CI: WDRC, EPWIP

Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
WDRC	9 3	295075 6	163538 9	169582
EPWIP	9 3	510187 5	316864 2	328573

Estimation for Difference

Difference	95% CI for Difference
-2151119	(-2882283, -1419955)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.82	137	0.000

Two-Sample T-Test and CI: WDRC, GASB

Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
WDRC	9 3	295075 6	163538 9	169582
GASB	9 3	215408 3	167204 1	173383

Estimation for Difference

Difference	95% CI for Difference
796673	(318163, 1275183)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.28	183	0.001

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	7021336	4386164	454824
NSV	93	3211881	2067413	214381

Estimation for Difference

Difference	95% CI for Difference
3809455	(2814693, 4804216)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.58	130	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	7021336	4386164	454824
EPWIP	93	5101875	3168642	328573

Estimation for Difference

Difference	95% CI for Difference
1919461	(811712, 3027210)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.42	167	0.001

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	7021336	4386164	454824
GASB	93	2154083	1672041	173383

Estimation for Difference

Difference	95% CI for Difference
4867253	(3903354, 5831152)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
10.00	118	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	3211881	2067413	214381
EPWIP	93	5101875	3168642	328573

Estimation for Difference

Difference	95% CI for Difference
-1889994	(-2664873, -1115115)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-4.82	158	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	3211881	2067413	214381
GASB	93	2154083	1672041	173383

Estimation for Difference

Difference	95% CI for Difference
1057798	(513658, 1601938)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.84	176	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	5101875	3168642	328573
GASB	93	2154083	1672041	173383

Estimation for Difference

Difference	95% CI for Difference
2947792	(2213245, 3682339)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.93	139	0.000

Minitab® T-Test 1998

1998

Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4215407	2408971	249799
WDRC	93	3028251	1632148	169246

Estimation for Difference

Difference	95% CI for Difference
1187156	(591289, 1783023)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.93	161	0.000

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4215407	2408971	249799
BV	93	7349028	4487917	465375

Estimation for Difference

Difference	95% CI for Difference
-3133621	(-4177860, -2089382)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.93	140	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4215407	2408971	249799
NSV	93	3307958	2032838	210796

Estimation for Difference

Difference	95% CI for Difference
907449	(262440, 1552458)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.78	178	0.006

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4215407	2408971	249799
EPWIP	93	5289484	3104241	321895

Estimation for Difference

Difference	95% CI for Difference
-1074077	(-1878290, -269863)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-2.64	173	0.009

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4215407	2408971	249799
GASB	93	2135523	1625479	168554

Estimation for Difference

Difference	95% CI for Difference
2079884	(1484781, 2674986)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.90	161	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3028251	1632148	169246
BV	93	7349028	4487917	465375

Estimation for Difference

Difference	95% CI for Difference
-4320777	(-5301664, -3339891)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-8.73	115	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3028251	1632148	169246
NSV	93	3307958	2032838	210796

Estimation for Difference

Difference	95% CI for Difference
-279707	(-813236, 253822)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-1.03	175	0.302

Two-Sample T-Test and CI: WDRC, EPWIP

Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3028251	1632148	169246
EPWIP	93	5289484	3104241	321895

Estimation for Difference

Difference	95% CI for Difference
-2261233	(-2980285, -1542180)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.22	139	0.000

Two-Sample T-Test and CI: WDRC, GASB

Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3028251	1632148	169246
GASB	93	2135523	1625479	168554

Estimation for Difference

Difference	95% CI for Difference

892727	(421451, 1364004)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.74	183	0.000

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	7349028	4487917	465375
NSV	93	3307958	2032838	210796

Estimation for Difference

Difference	95% CI for Difference
4041070	(3030186, 5051954)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.91	128	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	7349028	4487917	465375
EPWIP	93	5289484	3104241	321895

Estimation for Difference

Difference	95% CI for Difference
2059545	(942196, 3176893)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.64	163	0.000

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	7349028	4487917	465375
GASB	93	2135523	1625479	168554

Estimation for Difference

Difference	95% CI for Difference
5213505	(4233086, 6193924)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
10.53	115	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	3307958	2032838	210796
EPWIP	93	5289484	3104241	321895

Estimation for Difference

Difference	95% CI for Difference
-1981526	(-2741490, -1221562)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.15	158	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	3307958	2032838	210796
GASB	93	2135523	1625479	168554

Estimation for Difference

Difference	95% CI for Difference
1172434	(639759, 1705110)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.34	175	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	5289484	3104241	321895

GASB	93	2135523	1625479	168554

Estimation for Difference

Difference	95% CI for Difference
3153960	(2435497, 3872423)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.68	138	0.000

Minitab® T-Test 1999

1999

Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4276197	2443710	253401
WDRC	93	3182726	1805624	187234

Estimation for Difference

Difference	95% CI for Difference
1093472	(471493, 1715451)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.47	169	0.001

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4276197	2443710	253401
BV	93	7587751	4632149	480331

Estimation for Difference

Difference	95% CI for Difference
-3311553	(-4385309, -2237798)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.10	139	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4276197	2443710	253401
NSV	93	3433792	2100332	217794

Estimation for Difference

Difference	95% CI for Difference
842405	(183054, 1501756)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.52	179	0.013

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4276197	2443710	253401
EPWIP	93	5627669	3338881	346226

Estimation for Difference

Difference	95% CI for Difference
-1351472	(-2198497, -504446)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-3.15	168	0.002

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4276197	2443710	253401
GASB	93	2287885	1935623	200715

Estimation for Difference

Difference	95% CI for Difference
1988312	(1350292, 2626332)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.15	174	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3182726	1805624	187234
BV	93	7587751	4632149	480331

Estimation for Difference

Difference	95% CI for Difference
-4405025	(-5425833, -3384217)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-8.54	119	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3182726	1805624	187234
NSV	93	3433792	2100332	217794

Estimation for Difference

Difference	95% CI for Difference
-251066	(-817825, 315692)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.87	179	0.383

Two-Sample T-Test and CI: WDRC, EPWIP

Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3182726	1805624	187234
EPWIP	93	5627669	3338881	346226

Estimation for Difference

Difference	95% CI for Difference
-2444943	(-3223084, -1666803)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.21	141	0.000

Two-Sample T-Test and CI: WDRC, GASB

Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3182726	1805624	187234
GASB	93	2287885	1935623	200715

Estimation for Difference

Difference	95% CI for Difference
894840	(353274, 1436407)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.26	183	0.001

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	7587751	4632149	480331
NSV	93	3433792	2100332	217794

Estimation for Difference

Difference	95% CI for Difference
4153959	(3110404, 5197513)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.88	128	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	7587751	4632149	480331
EPWIP	93	5627669	3338881	346226

Estimation for Difference

Difference	95% CI for Difference
1960082	(791102, 3129061)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.31	167	0.001

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	7587751	4632149	480331
GASB	93	2287885	1935623	200715

Estimation for Difference

Difference	95% CI for Difference
5299866	(4269407, 6330324)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
10.18	123	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	3433792	2100332	217794
EPWIP	93	5627669	3338881	346226

Estimation for Difference

Difference	95% CI for Difference
-2193877	(-3001914, -1385840)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.36	154	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	3433792	2100332	217794
GASB	93	2287885	1935623	200715

Estimation for Difference

Difference	95% CI for Difference
1145907	(561525, 1730289)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.87	182	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	5627669	3338881	346226
GASB	93	2287885	1935623	200715

Estimation for Difference

Difference	95% CI for Difference
3339784	(2548898, 4130669)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.35	147	0.000

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Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	4775626	2730019	284624
WDRC	92	3567493	2065308	215323

Estimation for Difference

Difference	95% CI for Difference
1208133	(503583, 1912682)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.39	169	0.001

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	4775626	2730019	284624
BV	92	8564953	5214174	543615

Estimation for Difference

Difference	95% CI for Difference

-3789328	(-5002717, -2575938)

Test

Null hypothesis	H_0: μ_1 - μ_2 = 0
Alternative hypothesis	H_1: μ_1 - μ_2 ≠ 0

T-Value	DF	P-Value
-6.18	137	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: μ_1 - μ_2

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	4775626	2730019	284624
NSV	92	3866983	2419817	252283

Estimation for Difference

Difference	95% CI for Difference
908643	(158117, 1659168)

Test

Null hypothesis	H_0: μ_1 - μ_2 = 0
Alternative hypothesis	H_1: μ_1 - μ_2 ≠ 0

T-Value	DF	P-Value
2.39	179	0.018

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: μ_1 - μ_2

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	4775626	2730019	284624
EPWIP	92	6426007	3973909	414309

Estimation for Difference

Difference	95% CI for Difference
-1650381	(-2643029, -657733)

Test

Null hypothesis	H_0: μ_1 - μ_2 = 0
Alternative hypothesis	H_1: μ_1 - μ_2 ≠ 0

T-Value	DF	P-Value
-3.28	161	0.001

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: μ_1 - μ_2

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	4775626	2730019	284624
GASB	92	2680185	2122080	221242

Estimation for Difference

Difference	95% CI for Difference
2095440	(1383840, 2807040)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
5.81	171	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
WDRC	9 2	356749 3	206530 8	215323
BV	9 2	856495 3	521417 4	543615

Estimation for Difference

Difference	95% CI for Difference
-4997460	(-6155338, -3839582)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-8.55	118	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
WDRC	9 2	356749 3	206530 8	215323
NSV	9 2	386698 3	241981 7	252283

Estimation for Difference

Difference	95% CI for Difference
-299490	(-954044, 355064)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.90	177	0.368

Two-Sample T-Test and CI: WDRC, EPWIP

Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
WDRC	9 2	356749 3	206530 8	215323

EPWIP	92	6426007	3973909	414309

Estimation for Difference

Difference	95% CI for Difference
-2858514	(-3781879, -1935148)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.12	136	0.000

Two-Sample T-Test and CI: WDRC, GASB

Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	92	3567493	2065308	215323
GASB	92	2680185	2122080	221242

Estimation for Difference

Difference	95% CI for Difference
887307	(278141, 1496474)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.87	181	0.005

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	92	8564953	5214174	543615
NSV	92	3866983	2419817	252283

Estimation for Difference

Difference	95% CI for Difference
4697970	(3512146, 5883794)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.84	128	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean

BV	92	8564953	5214174	543615
EPWIP	92	6426007	3973909	414309

Estimation for Difference

Difference	95% CI for Difference
2138946	(789711, 3488182)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.13	170	0.002

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	92	8564953	5214174	543615
GASB	92	2680185	2122080	221242

Estimation for Difference

Difference	95% CI for Difference
5884768	(4722723, 7046812)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
10.03	120	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	92	3866983	2419817	252283
EPWIP	92	6426007	3973909	414309

Estimation for Difference

Difference	95% CI for Difference
-2559024	(-3517488, -1600560)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.28	150	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	92	3866983	2419817	252283
GASB	92	2680185	2122080	221242

Estimation for Difference

Difference	95% CI for Difference
1186798	(524626, 1848969)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.54	178	0.001

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	92	6426007	3973909	414309
GASB	92	2680185	2122080	221242

Estimation for Difference

Difference	95% CI for Difference
3745821	(2817120, 4674522)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.98	138	0.000

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Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4812690	2750299	285193
WDRC	93	3608826	2024139	209893

Estimation for Difference

Difference	95% CI for Difference
1203865	(504826, 1902903)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.40	169	0.001

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4812690	2750299	285193
BV	93	8745879	5328167	552505

Estimation for Difference

Difference	95% CI for Difference
-3933189	(-5162694, -2703683)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.33	137	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4812690	2750299	285193
NSV	93	3966488	2358520	244567

Estimation for Difference

Difference	95% CI for Difference
846203	(104838, 1587567)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.25	179	0.026

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4812690	2750299	285193
EPWIP	93	6606249	4061345	421142

Estimation for Difference

Difference	95% CI for Difference
-1793558	(-2797987, -789129)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-3.53	161	0.001

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	4812690	2750299	285193
GASB	93	2720782	2058497	213456

Estimation for Difference

Difference	95% CI for Difference
2091909	(1388709, 2795109)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
5.87	170	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3608826	2024139	209893
BV	93	8745879	5328167	552505

Estimation for Difference

Difference	95% CI for Difference
-5137053	(-6307455, -3966652)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-8.69	118	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3608826	2024139	209893
NSV	93	3966488	2358520	244567

Estimation for Difference

Difference	95% CI for Difference
-357662	(-993631, 278307)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-1.11	179	0.269

Two-Sample T-Test and CI: WDRC, EPWIP
Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3608826	2024139	209893
EPWIP	93	6606249	4061345	421142

Estimation for Difference

Difference	95% CI for Difference
-2997423	(-3928023, -2066823)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.37	135	0.000

Two-Sample T-Test and CI: WDRC, GASB
Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3608826	2024139	209893
GASB	93	2720782	2058497	213456

Estimation for Difference

Difference	95% CI for Difference
888044	(297395, 1478693)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.97	183	0.003

Two-Sample T-Test and CI: BV, NSV
Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	8745879	5328167	552505
NSV	93	3966488	2358520	244567

Estimation for Difference

Difference	95% CI for Difference
4779391	(3583669, 5975114)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.91	126	0.000

Two-Sample T-Test and CI: BV, EPWIP
Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	8745879	5328167	552505
EPWIP	93	6606249	4061345	421142

Estimation for Difference

Difference	95% CI for Difference
2139631	(768318, 3510943)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.08	171	0.002

Two-Sample T-Test and CI: BV, GASB
Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	8745879	5328167	552505
GASB	93	2720782	2058497	213456

Estimation for Difference

Difference	95% CI for Difference
6025097	(4852172, 7198023)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
10.17	118	0.000

Two-Sample T-Test and CI: NSV, EPWIP
Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	3966488	2358520	244567
EPWIP	93	6606249	4061345	421142

Estimation for Difference

Difference	95% CI for Difference
-2639761	(-3602195, -1677326)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.42	147	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	3966488	2358520	244567
GASB	93	2720782	2058497	213456

Estimation for Difference

Difference	95% CI for Difference
1245706	(605161, 1886252)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.84	180	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	6606249	4061345	421142
GASB	93	2720782	2058497	213456

Estimation for Difference

Difference	95% CI for Difference
3885467	(2951765, 4819169)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.23	136	0.000

Minitab® T-Test 2002

Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	4951643	2830641	295115
WDRC	92	3643140	2081345	216995

Estimation for Difference

Difference	95% CI for Difference
1308503	(585317, 2031689)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.57	167	0.000

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	4951643	2830641	295115
BV	92	9110242	5475763	570888

Estimation for Difference

Difference	95% CI for Difference
-4158599	(-5429488, -2887709)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.47	136	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	4951643	2830641	295115
NSV	92	4016454	2423464	252664

Estimation for Difference

Difference	95% CI for Difference
935189	(168503, 1701876)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.41	177	0.017

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	4951643	2830641	295115

EPWIP	92	6764723	4158179	433520

Estimation for Difference

Difference	95% CI for Difference
-1813080	(-2848788, -777372)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-3.46	160	0.001

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	4951643	2830641	295115
GASB	92	2709463	2147035	223844

Estimation for Difference

Difference	95% CI for Difference
2242180	(1510966, 2973394)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.05	169	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	92	3643140	2081345	216995
BV	92	9110242	5475763	570888

Estimation for Difference

Difference	95% CI for Difference
-5467102	(-6676743, -4257460)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-8.95	116	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean

WDRC	92	3643140	2081345	216995
NSV	92	4016454	2423464	252664

Estimation for Difference

Difference	95% CI for Difference
-373314	(-1030584, 283957)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-1.12	177	0.264

Two-Sample T-Test and CI: WDRC, EPWIP

Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	92	3643140	2081345	216995
EPWIP	92	6764723	4158179	433520

Estimation for Difference

Difference	95% CI for Difference
-3121583	(-4080489, -2162676)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.44	133	0.000

Two-Sample T-Test and CI: WDRC, GASB

Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	92	3643140	2081345	216995
GASB	92	2709463	2147035	223844

Estimation for Difference

Difference	95% CI for Difference
933677	(318530, 1548825)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.99	181	0.003

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	92	9110242	5475763	570888
NSV	92	4016454	2423464	252664

Estimation for Difference

Difference	95% CI for Difference
5093788	(3858219, 6329357)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.16	125	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	92	9110242	5475763	570888
EPWIP	92	6764723	4158179	433520

Estimation for Difference

Difference	95% CI for Difference
2345519	(930414, 3760623)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.27	169	0.001

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	92	9110242	5475763	570888
GASB	92	2709463	2147035	223844

Estimation for Difference

Difference	95% CI for Difference
6400779	(5186468, 7615089)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
10.44	118	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	92	4016454	2423464	252664
EPWIP	92	6764723	4158179	433520

Estimation for Difference

Difference	95% CI for Difference
-2748269	(-3739951, -1756587)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.48	146	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	92	4016454	2423464	252664
GASB	92	2709463	2147035	223844

Estimation for Difference

Difference	95% CI for Difference
1306991	(640887, 1973095)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.87	179	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	92	6764723	4158179	433520
GASB	92	2709463	2147035	223844

Estimation for Difference

Difference	95% CI for Difference
4055260	(3090409, 5020111)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.31	136	0.000

Minitab® T-Test 2003

2003

Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	5034691	2878116	300064
WDRC	92	3675127	2096251	218549

Estimation for Difference

Difference	95% CI for Difference
1359564	(626648, 2092480)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.66	166	0.000

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	5034691	2878116	300064
BV	92	9292546	5559095	579576

Estimation for Difference

Difference	95% CI for Difference
-4257855	(-5548502, -2967208)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.52	136	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	5034691	2878116	300064
NSV	92	4097085	2467633	257269

Estimation for Difference

Difference	95% CI for Difference
937606	(157589, 1717623)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.37	177	0.019

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	5034691	2878116	300064
EPWIP	92	6849407	4168135	434558

Estimation for Difference

Difference	95% CI for Difference
-1814716	(-2857593, -771839)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-3.44	161	0.001

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	92	5034691	2878116	300064
GASB	92	2683937	2124984	221545

Estimation for Difference

Difference	95% CI for Difference
2350754	(1614373, 3087135)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.30	167	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	92	3675127	2096251	218549
BV	92	9292546	5559095	579576

Estimation for Difference

Difference	95% CI for Difference
-5617419	(-6844244, -4390595)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-9.07	116	0.000

Two-Sample T-Test and CI: WDRC, NSV
Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	92	3675127	2096251	218549
NSV	92	4097085	2467633	257269

Estimation for Difference

Difference	95% CI for Difference
-421958	(-1088130, 244215)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-1.25	177	0.213

Two-Sample T-Test and CI: WDRC, EPWIP
Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	92	3675127	2096251	218549
EPWIP	92	6849407	4168135	434558

Estimation for Difference

Difference	95% CI for Difference
-3174279	(-4136334, -2212225)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.53	134	0.000

Two-Sample T-Test and CI: WDRC, GASB
Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	92	3675127	2096251	218549
GASB	92	2683937	2124984	221545

Estimation for Difference

Difference	95% CI for Difference
991190	(377142, 1605238)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.19	181	0.002

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	92	9292546	5559095	579576
NSV	92	4097085	2467633	257269

Estimation for Difference

Difference	95% CI for Difference
5195461	(3940480, 6450443)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.19	125	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	92	4097085	2467633	257269
EPWIP	92	6849407	4168135	434558

Estimation for Difference

Difference	95% CI for Difference
-2752322	(-3750325, -1754318)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.45	147	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	92	4097085	2467633	257269
GASB	92	2683937	2124984	221545

Estimation for Difference

Difference	95% CI for Difference

Difference	95% CI for Difference
1413148	(743159, 2083137)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.16	178	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
EPWIP	9 2	684940 7	416813 5	434558
GASB	9 2	268393 7	212498 4	221545

Estimation for Difference

Difference	95% CI for Difference
4165470	(3200804, 5130135)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.54	135	0.000

Minitab® T-Test 2004

Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
RC	9 3	551361 0	315085 2	326728
WDRC	9 3	394993 7	222762 4	230994

Estimation for Difference

Difference	95% CI for Difference
1563673	(773625, 2353722)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.91	165	0.000

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
RC	9 3	5513610	315085 2	326728

BV	93	10246945	6143305	6370311

Estimation for Difference

Difference	95% CI for Difference
-4733334	(-6149042, -3317627)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.61	137	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	5513610	3150852	326728
NSV	93	4293312	2658913	275716

Estimation for Difference

Difference	95% CI for Difference
1220298	(376644, 2063953)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.85	178	0.005

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	5513610	3150852	326728
EPWIP	93	7410902	4491454	465742

Estimation for Difference

Difference	95% CI for Difference
-1897292	(-3020639, -773945)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-3.33	164	0.001

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean

RC	93	5513610	3150852	326728
GASB	93	2829385	2189795	227071

Estimation for Difference

Difference	95% CI for Difference
2684225	(1898587, 3469863)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.75	164	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3949937	2227624	230994
BV	93	10246945	6143301	637031

Estimation for Difference

Difference	95% CI for Difference
-6297008	(-7639238, -4954777)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-9.29	115	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3949937	2227624	230994
NSV	93	4293312	2658913	275716

Estimation for Difference

Difference	95% CI for Difference
-343375	(-1053182, 366433)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.95	178	0.341

Two-Sample T-Test and CI: WDRC, EPWIP

Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3949937	2227624	230994
EPWIP	93	7410902	4491454	465742

Estimation for Difference

Difference	95% CI for Difference
-3460965	(-4489195, -2432736)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.66	134	0.000

Two-Sample T-Test and CI: WDRC, GASB

Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	3949937	2227624	230994
GASB	93	2829385	2189795	227071

Estimation for Difference

Difference	95% CI for Difference
1120552	(481468, 1759636)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.46	183	0.001

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	10246945	6143301	637031
NSV	93	4293312	2658913	275716

Estimation for Difference

Difference	95% CI for Difference
5953633	(4579848, 7327418)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.58	125	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	10246945	6143301	637031
EPWIP	93	7410902	4491454	465742

Estimation for Difference

Difference	95% CI for Difference
2836042	(1278157, 4393928)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.59	168	0.000

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	10246945	6143301	637031
GASB	93	2829385	2189795	227071

Estimation for Difference

Difference	95% CI for Difference
7417560	(6077958, 8757162)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
10.97	115	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	4293312	2658913	275716
EPWIP	93	7410902	4491454	465742

Estimation for Difference

Difference	95% CI for Difference
-3117590	(-4187078, -2048103)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.76	149	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	4293312	2658913	275716
GASB	93	2829385	2189795	227071

Estimation for Difference

Difference	95% CI for Difference
1463927	(759038, 2168816)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.10	177	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	7410902	4491454	465742
GASB	93	2829385	2189795	227071

Estimation for Difference

Difference	95% CI for Difference
4581517	(3556641, 5606393)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.84	133	0.000

Minitab® T-Test 2005

Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6002130	3430026	355677
WDRC	93	4236759	2418600	250797

Estimation for Difference

Difference	95% CI for Difference
1765372	(906079, 2624665)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.06	165	0.000

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6002130	3430026	355677
BV	93	11188152	6664313	691057

Estimation for Difference

Difference	95% CI for Difference
-5186022	(-6722915, -3649129)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.67	137	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6002130	3430026	355677
NSV	93	4661510	2992480	310306

Estimation for Difference

Difference	95% CI for Difference
1340621	(409231, 2272010)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.84	180	0.005

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6002130	3430026	355677
EPWIP	93	7978485	4842300	502123

Estimation for Difference

Difference	95% CI for Difference
-1976355	(-3191295, -761415)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-3.21	165	0.002

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6002130	3430026	355677
GASB	93	2932861	2346014	243270

Estimation for Difference

Difference	95% CI for Difference
3069269	(2218337, 3920202)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.12	162	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	4236759	2418600	250797
BV	93	11188152	6664313	691057

Estimation for Difference

Difference	95% CI for Difference
-6951394	(-8407603, -5495185)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-9.46	115	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	4236759	2418600	250797
NSV	93	4661510	2992480	310306

Estimation for Difference

Difference	95% CI for Difference
-424751	(-1212161, 362659)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-1.06	176	0.289

Two-Sample T-Test and CI: WDRC, EPWIP Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	4236759	2418600	250797
EPWIP	93	7978485	4842300	502123

Estimation for Difference

Difference	95% CI for Difference
-3741727	(-4851751, -2631703)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.67	135	0.000

Two-Sample T-Test and CI: WDRC, GASB Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	4236759	2418600	250797
GASB	93	2932861	2346014	243270

Estimation for Difference

Difference	95% CI for Difference
1303898	(614529, 1993266)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.73	183	0.000

Two-Sample T-Test and CI: BV, NSV Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	11188152	6664313	691057
NSV	93	4661510	2992480	310306

Estimation for Difference

Difference	95% CI for Difference

Difference	95% CI for Difference
6526643	(5027631, 8025655)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.62	127	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	11188152	6664313	691057
EPWIP	93	7978485	4842300	502123

Estimation for Difference

Difference	95% CI for Difference
3209667	(1523210, 4896124)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.76	167	0.000

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	11188152	6664313	691057
GASB	93	2932861	2346014	243270

Estimation for Difference

Difference	95% CI for Difference
8255292	(6803966, 9706617)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
11.27	114	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	4661510	2992480	310306
EPWIP	93	7978485	4842300	502123

Estimation for Difference

Difference	95% CI for Difference
-3316976	(-4483105, -2150846)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.62	153	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
NSV	9 3	466151 0	299248 0	310306
GASB	9 3	293286 1	234601 4	243270

Estimation for Difference

Difference	95% CI for Difference
1728649	(950428, 2506869)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.38	174	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
EPWIP	9 3	797848 5	484230 0	502123
GASB	9 3	293286 1	234601 4	243270

Estimation for Difference

Difference	95% CI for Difference
5045625	(3941945, 6149305)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
9.04	132	0.000

Minitab® T-Test 2006

Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean

RC	93	6307913	3604771	373797
WDRC	93	4378241	2533643	262727

Estimation for Difference

Difference	95% CI for Difference
1929672	(1027565, 2831779)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.22	165	0.000

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6307913	3604771	373797
BV	93	11789043	7023335	728286

Estimation for Difference

Difference	95% CI for Difference
-5481130	(-7099878, -3862382)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.70	137	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6307913	3604771	373797
NSV	93	4729899	3238131	335779

Estimation for Difference

Difference	95% CI for Difference
1578014	(586571, 2569458)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.14	181	0.002

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
RC	9 3	630791 3	360477 1	373797
EPWIP	9 3	829536 1	515009 9	534040

Estimation for Difference

Difference	95% CI for Difference
-1987448	(-3274571, -700325)

Test

Null hypothesis	H_0: μ_1 - μ_2 = 0
Alternative hypothesis	H_1: μ_1 - μ_2 ≠ 0

T-Value	DF	P-Value
-3.05	164	0.003

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: μ_1 - μ_2

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
RC	9 3	630791 3	360477 1	373797
GASB	9 3	286095 7	235715 5	244426

Estimation for Difference

Difference	95% CI for Difference
3446956	(2564843, 4329069)

Test

Null hypothesis	H_0: μ_1 - μ_2 = 0
Alternative hypothesis	H_1: μ_1 - μ_2 ≠ 0

T-Value	DF	P-Value
7.72	158	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: μ_1 - μ_2

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
WDRC	9 3	4378241	253364 3	262727
BV	9 3	1178904 3	702333 5	728286

Estimation for Difference

Difference	95% CI for Difference
-7410802	(-8944394, -5877210)

Test

Null hypothesis	H_0: μ_1 - μ_2 = 0
Alternative hypothesis	H_1: μ_1 - μ_2 ≠ 0

T-Value	DF	P-Value
-9.57	115	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: μ_1 - μ_2

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	4378241	2533643	262727
NSV	93	4729899	3238131	335779

Estimation for Difference

Difference	95% CI for Difference
-351657	(-1193171, 489856)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.82	173	0.411

Two-Sample T-Test and CI: WDRC, EPWIP

Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	4378241	2533643	262727
EPWIP	93	8295361	5150099	534040

Estimation for Difference

Difference	95% CI for Difference
-3917120	(-5094257, -2739982)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.58	134	0.000

Two-Sample T-Test and CI: WDRC, GASB

Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	4378241	2533643	262727
GASB	93	2860957	2357155	244426

Estimation for Difference

Difference	95% CI for Difference
1517284	(809281, 2225288)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.23	183	0.000

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	11789043	7023335	728286
NSV	93	4729899	3238131	335779

Estimation for Difference

Difference	95% CI for Difference
7059144	(5472437, 8645852)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.80	129	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	11789043	7023335	728286
EPWIP	93	8295361	5150099	534040

Estimation for Difference

Difference	95% CI for Difference
3493682	(1710785, 5276580)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.87	168	0.000

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	11789043	7023335	728286
GASB	93	2860957	2357155	244426

Estimation for Difference

Difference	95% CI for Difference
8928086	(7405980, 10450193)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
11.62	112	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	4729899	3238131	335779
EPWIP	93	8295361	5150099	534040

Estimation for Difference

Difference	95% CI for Difference
-3565462	(-4811659, -2319265)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.65	154	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	4729899	3238131	335779
GASB	93	2860957	2357155	244426

Estimation for Difference

Difference	95% CI for Difference
1868942	(1049022, 2688861)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.50	168	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	8295361	5150099	534040
GASB	93	2860957	2357155	244426

Estimation for Difference

Difference	95% CI for Difference
5434404	(4272294, 6596514)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
9.25	128	0.000

Minitab® T-Test 2007

Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6953902	3973933	412078
WDRC	93	4792820	2845636	295079

Estimation for Difference

Difference	95% CI for Difference
2161082	(1160413, 3161751)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.26	166	0.000

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6953902	3973933	412078
BV	93	12996351	7742590	802869

Estimation for Difference

Difference	95% CI for Difference
-6042449	(-7826972, -4257926)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.70	137	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6953902	3973933	412078
NSV	93	5087084	3587453	372002

Estimation for Difference

Difference	95% CI for Difference

1866818	(771457, 2962178)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.36	182	0.001

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6953902	3973933	412078
EPWIP	93	9021182	5599010	580590

Estimation for Difference

Difference	95% CI for Difference
-2067280	(-3473014, -661545)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-2.90	165	0.004

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6953902	3973933	412078
GASB	93	3051072	2596027	269195

Estimation for Difference

Difference	95% CI for Difference
3902830	(2930663, 4874997)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.93	158	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	4792820	2845636	295079
BV	93	12996351	7742590	802869

Estimation for Difference

Difference	95% CI for Difference
-8203531	(-9897713, -6509348)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-9.59	116	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	4792820	2845636	295079
NSV	93	5087084	3587453	372002

Estimation for Difference

Difference	95% CI for Difference
-294264	(-1231418, 642889)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.62	174	0.536

Two-Sample T-Test and CI: WDRC, EPWIP

Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	4792820	2845636	295079
EPWIP	93	9021182	5599010	580590

Estimation for Difference

Difference	95% CI for Difference
-4228362	(-5516294, -2940430)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.49	136	0.000

Two-Sample T-Test and CI: WDRC, GASB

Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	4792820	2845636	295079

GASB	93	3051072	2596027	269195

Estimation for Difference

Difference	95% CI for Difference
1741748	(953656, 2529841)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.36	182	0.000

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	12996351	7742590	802869
NSV	93	5087084	3587453	372002

Estimation for Difference

Difference	95% CI for Difference
7909266	(6158542, 9659991)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.94	129	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	12996351	7742590	802869
EPWIP	93	9021182	5599010	580590

Estimation for Difference

Difference	95% CI for Difference
3975169	(2019062, 5931276)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.01	167	0.000

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean

BV	93	12996351	7742590	802869
GASB	93	3051072	2596027	269195

Estimation for Difference

Difference	95% CI for Difference
9945279	(8267459, 11623099)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
11.74	112	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	5087084	3587453	372002
EPWIP	93	9021182	5599010	580590

Estimation for Difference

Difference	95% CI for Difference
-3934097	(-5296144, -2572051)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.71	156	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	5087084	3587453	372002
GASB	93	3051072	2596027	269195

Estimation for Difference

Difference	95% CI for Difference
2036013	(1129456, 2942569)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.43	167	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	9021182	5599010	580590
GASB	93	3051072	2596027	269195

Estimation for Difference

Difference	95% CI for Difference
5970110	(4703929, 7236290)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
9.33	129	0.000

Minitab® T-Test 2008

Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	7807896	4461964	462684
WDRC	93	5389673	3171124	328830

Estimation for Difference

Difference	95% CI for Difference
2418224	(1297515, 3538932)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.26	166	0.000

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	7807896	4461964	462684
BV	93	14735017	8762008	908578

Estimation for Difference

Difference	95% CI for Difference
-6927121	(-8943447, -4910794)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.79	136	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	7807896	4461964	462684
NSV	93	5445991	4175388	432968

Estimation for Difference

Difference	95% CI for Difference
2361906	(1111667, 3612144)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.73	183	0.000

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	7807896	4461964	462684
EPWIP	93	10263218	6381528	661734

Estimation for Difference

Difference	95% CI for Difference
-2455322	(-4049651, -860993)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-3.04	164	0.003

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	7807896	4461964	462684
GASB	93	3272266	2827501	293198

Estimation for Difference

Difference	95% CI for Difference
4535631	(3453591, 5617670)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.28	155	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	5389673	3171124	328830
BV	93	14735017	8762008	908578

Estimation for Difference

Difference	95% CI for Difference
-9345344	(-11259303, -7431385)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-9.67	115	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	5389673	3171124	328830
NSV	93	5445991	4175388	432968

Estimation for Difference

Difference	95% CI for Difference
-56318	(-1129511, 1016875)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.10	171	0.918

Two-Sample T-Test and CI: WDRC, EPWIP

Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	5389673	3171124	328830
EPWIP	93	10263218	6381528	661734

Estimation for Difference

Difference	95% CI for Difference
-4873546	(-6335025, -3412067)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.60	134	0.000

Two-Sample T-Test and CI: WDRC, GASB

Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	5389673	3171124	328830
GASB	93	3272266	2827501	293198

Estimation for Difference

Difference	95% CI for Difference
2117407	(1248110, 2986704)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.81	181	0.000

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	14735017	8762008	908578
NSV	93	5445991	4175388	432968

Estimation for Difference

Difference	95% CI for Difference
9289026	(7297995, 11280057)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
9.23	131	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	14735017	8762008	908578
EPWIP	93	10263218	6381528	661734

Estimation for Difference

Difference	95% CI for Difference
4471798	(2252789, 6690808)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.98	168	0.000

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	14735017	8762008	908578
GASB	93	3272266	2827501	293198

Estimation for Difference

Difference	95% CI for Difference
11462751	(9570732, 13354770)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
12.01	110	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	5445991	4175388	432968
EPWIP	93	10263218	6381528	661734

Estimation for Difference

Difference	95% CI for Difference
-4817228	(-6379115, -3255340)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.09	158	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	5445991	4175388	432968
GASB	93	3272266	2827501	293198

Estimation for Difference

Difference	95% CI for Difference
2173725	(1141095, 3206355)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.16	161	0.000

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	10263218	6381528	661734
GASB	93	3272266	2827501	293198

Estimation for Difference

Difference	95% CI for Difference
6990953	(5558615, 8423291)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
9.66	126	0.000

Minitab® T-Test 2009

Two-Sample T-Test and CI: RC, WDRC

Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	7205486	4117705	426986
WDRC	93	5077960	3137877	325383

Estimation for Difference

Difference	95% CI for Difference
2127526	(1067850, 3187201)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.96	171	0.000

Two-Sample T-Test and CI: RC, BV

Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	7205486	4117705	426986
BV	93	13666204	8074973	837336

Estimation for Difference

Difference	95% CI for Difference
-6460718	(-8319465, -4601970)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.87	136	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
RC	9 3	720548 6	411770 5	426986
NSV	9 3	517511 3	386734 8	401025

Estimation for Difference

Difference	95% CI for Difference
2030373	(874622, 3186125)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.47	183	0.001

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
RC	9 3	720548 6	411770 5	426986
EPWIP	9 3	975855 4	639657 8	663294

Estimation for Difference

Difference	95% CI for Difference
-2553068	(-4111186, -994950)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-3.24	157	0.001

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
RC	9 3	720548 6	411770 5	426986

GASB	93	3255901	3122876	323827

Estimation for Difference

Difference	95% CI for Difference
3949585	(2891768, 5007402)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
7.37	171	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	5077960	3137877	325383
BV	93	13666204	8074973	837336

Estimation for Difference

Difference	95% CI for Difference
-8588244	(-10367036, -6809452)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-9.56	119	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	5077960	3137877	325383
NSV	93	5175113	3867348	401025

Estimation for Difference

Difference	95% CI for Difference
-97153	(-1116336, 922031)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.19	176	0.851

Two-Sample T-Test and CI: WDRC, EPWIP

Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean

WDRC	93	5077960	3137877	325383
EPWIP	93	9758554	6396578	663294

Estimation for Difference

Difference	95% CI for Difference
-4680594	(-6141922, -3219266)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.34	133	0.000

Two-Sample T-Test and CI: WDRC, GASB

Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	5077960	3137877	325383
GASB	93	3255901	3122876	323827

Estimation for Difference

Difference	95% CI for Difference
1822059	(916324, 2727794)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.97	183	0.000

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	13666204	8074973	837336
NSV	93	5175113	3867348	401025

Estimation for Difference

Difference	95% CI for Difference
8491091	(6654597, 10327586)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
9.15	132	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	13666204	8074973	837336
EPWIP	93	9758554	6396578	663294

Estimation for Difference

Difference	95% CI for Difference
3907650	(1799316, 6015983)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.66	174	0.000

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	13666204	8074973	837336
GASB	93	3255901	3122876	323827

Estimation for Difference

Difference	95% CI for Difference
10410303	(8632469, 12188137)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
11.60	118	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	5175113	3867348	401025
EPWIP	93	9758554	6396578	663294

Estimation for Difference

Difference	95% CI for Difference
-4583441	(-6114884, -3051999)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.91	151	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	5175113	3867348	401025
GASB	93	3255901	3122876	323827

Estimation for Difference

Difference	95% CI for Difference
1919212	(901960, 2936464)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.72	176	0.000

Two-Sample T-Test and CI: EPWIP, GASB Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
EPWIP	93	9758554	6396578	663294
GASB	93	3255901	3122876	323827

Estimation for Difference

Difference	95% CI for Difference
6502653	(5042678, 7962629)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.81	133	0.000

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Two-Sample T-Test and CI: RC, WDRC Method

μ_1: mean of RC

μ_2: mean of WDRC

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6879196	3931241	407651
WDRC	93	5121890	3196887	331502

Estimation for Difference

Difference	95% CI for Difference
1757306	(720360, 2794252)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.34	176	0.001

Two-Sample T-Test and CI: RC, BV Method

μ_1: mean of RC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6879196	3931241	407651
BV	93	13122247	7661851	794497

Estimation for Difference

Difference	95% CI for Difference
-6243051	(-8008848, -4477255)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.99	137	0.000

Two-Sample T-Test and CI: RC, NSV

Method

μ_1: mean of RC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6879196	3931241	407651
NSV	93	5267298	3896725	404072

Estimation for Difference

Difference	95% CI for Difference
1611898	(479429, 2744367)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.81	183	0.006

Two-Sample T-Test and CI: RC, EPWIP

Method

μ_1: mean of RC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6879196	3931241	407651
EPWIP	93	10039411	6853065	710630

Estimation for Difference

Difference	95% CI for Difference
-3160215	(-4779340, -1541091)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-3.86	146	0.000

Two-Sample T-Test and CI: RC, GASB

Method

μ_1: mean of RC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
RC	93	6879196	3931241	407651
GASB	93	3626635	3301090	342307

Estimation for Difference

Difference	95% CI for Difference
3252561	(2202112, 4303010)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.11	178	0.000

Two-Sample T-Test and CI: WDRC, BV

Method

μ_1: mean of WDRC

μ_2: mean of BV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	5121890	3196887	331502
BV	93	13122247	7661851	794497

Estimation for Difference

Difference	95% CI for Difference
-8000357	(-9704422, -6296293)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-9.29	123	0.000

Two-Sample T-Test and CI: WDRC, NSV

Method

μ_1: mean of WDRC

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	5121890	3196887	331502
NSV	93	5267298	3896725	404072

Estimation for Difference

Difference	95% CI for Difference
-145408	(-1176844, 886027)

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.28	177	0.781

Two-Sample T-Test and CI: WDRC, EPWIP

Method

μ_1: mean of WDRC

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	5121890	3196887	331502
EPWIP	93	10039411	6853065	710630

Estimation for Difference

Difference	95% CI for Difference
-4917521	(-6468864, -3366179)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-6.27	130	0.000

Two-Sample T-Test and CI: WDRC, GASB

Method

μ_1: mean of WDRC

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
WDRC	93	5121890	3196887	331502
GASB	93	3626635	3301090	342307

Estimation for Difference

Difference	95% CI for Difference
1495255	(555083, 2435427)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.14	183	0.002

Two-Sample T-Test and CI: BV, NSV

Method

μ_1: mean of BV

μ_2: mean of NSV

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	13122247	7661851	794497
NSV	93	5267298	3896725	404072

Estimation for Difference

Difference	95% CI for Difference
7854949	(6092257, 9617642)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.81	136	0.000

Two-Sample T-Test and CI: BV, EPWIP

Method

μ_1: mean of BV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	13122247	7661851	794497
EPWIP	93	10039411	6853065	710630

Estimation for Difference

Difference	95% CI for Difference
3082836	(979576, 5186095)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.89	181	0.004

Two-Sample T-Test and CI: BV, GASB

Method

μ_1: mean of BV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BV	93	13122247	7661851	794497
GASB	93	3626635	3301090	342307

Estimation for Difference

Difference	95% CI for Difference
9495612	(7783470, 11207754)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
10.98	125	0.000

Two-Sample T-Test and CI: NSV, EPWIP

Method

μ_1: mean of NSV

μ_2: mean of EPWIP

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
NSV	93	5267298	3896725	404072
EPWIP	93	10039411	6853065	710630

Estimation for Difference

Difference	95% CI for Difference

-4772113	(-6387823, -3156403)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-5.84	145	0.000

Two-Sample T-Test and CI: NSV, GASB

Method

μ_1: mean of NSV

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
NSV	9 3	526729 8	389672 5	404072
GASB	9 3	362663 5	330109 0	342307

Estimation for Difference

Difference	95% CI for Difference
1640663	(595653, 2685673)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
3.10	179	0.002

Two-Sample T-Test and CI: EPWIP, GASB

Method

μ_1: mean of EPWIP

μ_2: mean of GASB

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sampl e	N	Mean	StDev	SE Mean
EPWIP	9 3	1003941 1	685306 5	710630
GASB	9 3	3626635	330109 0	342307

Estimation for Difference

Difference	95% CI for Difference
6412776	(4852498, 7973055)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
8.13	132	0.000

Appendix B

MTO Pavement Performance Models

Legend: Climatic Zone – Soil Type- Subgrade Category – Traffic Class –Rehabilitation

SO-SS-1-1 FDR+HM Overlay2 (RMSE = 7.63)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.750	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.750	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.800	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-1-1 HM Overlay1 (RMSE = 4.36)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.800	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.571	0.429	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.364	0.636	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.429	0.571	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.800	0.200	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.800	0.200	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-1-1 HM Overlay2 (RMSE = 3.95)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.778	0.222	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.625	0.375	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-1-1 Mill+HM Overlay1 (RMSE = 7.68)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.750	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.800	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.300	0.700	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.200	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.200	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.800	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.800	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.800	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.700	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.800	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.800	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.800
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-1-1 Mill+HM Overlay2 (RMSE = 6.09)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.417	0.583	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.579	0.421	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.222	0.778	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.833	0.167	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.800	0.200	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.750	0.250	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.800	0.200	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-1-1 Recon to AC3 (RMSE = 11.55)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.533	0.467	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.278	0.722	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.364	0.636	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.633	0.367	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.632	0.368	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.727	0.273	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.462	0.538	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.714	0.286	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.727	0.273	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.167	0.833	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-1-3 HM Overlay1 (RMSE = 3.82)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.636	0.364	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.286	0.714	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.545	0.455	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-1-3 Mill+HM Overlay1 (RMSE = 2.78)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.100	0.900	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.250	0.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.636	0.364	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.250	0.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.750	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-1-3 Mill+HM Overlay1 Fwy (RMSE = 4.94)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.643	0.357	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.583	0.417	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.364	0.636	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.300	0.700	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-1-3 Mill+HM Overlay2 (RMSE = 4.93)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.200	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.800	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-1-3 Mill+HM Overlay2 Fwy (RMSE = 5.7)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.458	0.542	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.716	0.284	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.528	0.472	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.643	0.357	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.553	0.447	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.545	0.455	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.545	0.455	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-1-3 Recon To AC Fwy (RMSE = 5.76)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.167	0.833	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.760	0.240	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.524	0.476	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.632	0.368	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.821	0.179	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.455	0.545	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.800	0.200	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-1-3 Recon to AC5 Fwy (RMSE = 5.98)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.578	0.422	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.346	0.654	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.391	0.609	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.385	0.615	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.357	0.643	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.810	0.190	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.636	0.364	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-2-1 CIR + HM Overlay1 (RMSE = 1.24)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.714	0.286	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.609	0.391	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.750	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-2-1 FDR+HM Overlay2 (RMSE = 2.34)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.688	0.313	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-2-1 FDR+HM Overlay3 (RMSE = 6.53)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.538	0.462	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.407	0.593	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.417	0.583	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.714	0.286	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-2-1 HM Overlay1 (RMSE = 4.16)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.611	0.389	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.467	0.533	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.308	0.692	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.571	0.429	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.533	0.467	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-2-1 HM Overlay2 (RMSE = 5.08)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.625	0.375	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.450	0.550	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.563	0.438	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.625	0.375	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.581	0.419	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.765	0.235	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.583	0.417	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.429	0.571	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-2-1 Mill+HM Overlay1 (RMSE = 1.12)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.450	0.550	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.441	0.559	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.239	0.761	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.647	0.353	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.422	0.578	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.457	0.543	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.769	0.231	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.444	0.556	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.750	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.786	0.214	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.571	0.429	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-2-1 Mill+HM Overlay2 (RMSE = 1.502)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.235	0.765	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.548	0.452	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.200	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.585	0.415	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.569	0.431	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.391	0.609	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.529	0.471	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.714	0.286	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.700	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.750	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.700	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-2-1 Recon to AC3 (RMSE = 9.22)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.800	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.698	0.302	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.471	0.529	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.619	0.381	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.612	0.388	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.518	0.482	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.747	0.253	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.829	0.171	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.451	0.549	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.481	0.519	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.535	0.465	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.143	0.857	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.385	0.615
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-2-2 HM Overlay2 (RMSE = 2.48)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.750	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.643	0.357	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.750	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.700	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-2-2 -Mill+HM Overlay2 (RMSE = 0.94)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.543	0.457	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.479	0.521	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.808	0.192	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.455	0.545	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.700	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-2-2Recon to AC3 (RMSE = 1.94)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.200	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.429	0.571	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.857	0.143	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.462	0.538	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.800	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.833	0.167	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.571	0.429	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.375	0.625	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-SS-3-3 Mill+HM Overlay2 Fwy (RMSE = 2.49)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.800	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.571	0.429	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-La-1-1 HM Overlay2 (RMSE = 1.50)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.200	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.586	0.414	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.625	0.375	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.632	0.105	0.263	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.636	0.364	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-La-1-1 Mill+HM Overlay2 (RMSE = 1.27)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.200	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.571	0.429	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.200	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.500	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.800	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

SO-La-1-1 Recon to AC3 (RMSE = 6.24)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.692	0.308	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.231	0.769	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.455	0.545	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.529	0.471	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.520	0.480	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.875	0.125	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.455	0.545	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.714	0.286	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.833	0.167	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.636	0.364	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.750	0.250	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-La-2-1 FDR+HM Overlay2 (RMSE = 2.65)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.600	0.200	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.500	0.375	0.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.556	0.333	0.111	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.769	0.077	0.154	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.250	0.250	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.800	0.200	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-Gr-3-1- FDR+HM Overlay2 (RMSE = 3.84)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.333	0.333	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.500	0.333	0.167	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.600	0.200	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.400	0.400	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.813	0.094	0.094	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.615	0.077	0.308	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.800	0.200	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-Gr-3-1- FDR+HM Overlay3 (RMSE = 2.06)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.688	0.313	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.286	0.429	0.286	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.700	0.200	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.600	0.200	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.800	0.200	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.800	0.200	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-3-1 CIR + HM Overlay1 (RMSE = 4.37)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.800	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.400	0.400	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.636	0.273	0.091	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.167	0.700	0.133	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.500	0.375	0.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.200	0.400	0.400	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.900	0.100	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-3-1- FDR+HM Overlay2 (RMSE = 8.05)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.429	0.286	0.286	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.583	0.167	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.571	0.429	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.625	0.375	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.714	0.143	0.143	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.200	0.400	0.400	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.625	0.125	0.250	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-3-1 - FDR+HM Overlay3 (RMSE = 0.97)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.556	0.111	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.357	0.143	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.550	0.350	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.708	0.292	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.450	0.200	0.350	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.300	0.200	0.500	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.625	0.300	0.075	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-3-1- HM Overlay1 (RMSE = 3.38)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.714	0.286	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.286	0.714	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-3-1 Mill+HM Overlay1 (RMSE = 4.29)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.750	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.167	0.167	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.444	0.556	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-3-1- Mill+HM Overlay1 Fwy (RMSE = 3.31)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.500	0.400	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.739	0.261	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.632	0.368	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.889	0.111	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.700	0.300	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-3-1 Recon to AC3 (RMSE = 7.74)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.714	0.286	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.429	0.571	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-2-1 CIR + HM Overlay2 (RMSE = 1.99)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.429	0.571	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.583	0.417	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.417	0.583	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.545	0.455	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.444	0.556	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.625	0.375	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-2-1- FDR+HM Overlay2 (RMSE = 7.56)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.490	0.510	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.517	0.483	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.214	0.786	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.565	0.435	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.590	0.410	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.522	0.304	0.174	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.438	0.250	0.313	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.706	0.294	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-2-1 - FDR+HM Overlay3 (RMSE = 5.09)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.516	0.484	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.658	0.342	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.292	0.708	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.563	0.438	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.800	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-2-1 HM Overlay1 (RMSE = 8.85)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.400	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.471	0.529	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.269	0.731	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.308	0.692	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.533	0.467	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.385	0.615	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-2-1- HM Overlay2 (RMSE = 5.61)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.353	0.647	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.250	0.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.778	0.222	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.818	0.182	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.545	0.455	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.750	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.429	0.571	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-2-1 - Mill+HM Overlay1 (RMSE = 3.17)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.300	0.700	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.500	0.333	0.167	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.333	0.444	0.222	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.643	0.286	0.071	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.500	0.125	0.375	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.750	0.250	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-2-1 Mill+HM Overlay2 (RMSE = 8.85)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.167	0.500	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.250	0.375	0.375	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.273	0.273	0.455	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.400	0.267	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.400	0.300	0.300	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.438	0.313	0.250	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.733	0.267	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.857	0.143	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.714	0.286	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-2-1 Recon to AC3 (RMSE = 13.38)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.571	0.429	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.571	0.429	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.625	0.375	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.692	0.308	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.571	0.429	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-1-1FDR+HM Overlay2 (RMSE = 5.85)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.300	0.700	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.481	0.519	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.346	0.654	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.653	0.347	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.429	0.571	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.467	0.533	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.545	0.455	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.615	0.385	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.800	0.200	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-1-1- FDR+HM Overlay3 (RMSE = 4.32)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.143	0.857	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.273	0.727	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.385	0.615	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.643	0.357	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.600	0.400	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-1-1- HM Overlay1 (RMSE= 2.19)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.300	0.700	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.700	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

NO-SS-1-1- Mill+HM Overlay2 (RMSE = 12.43)

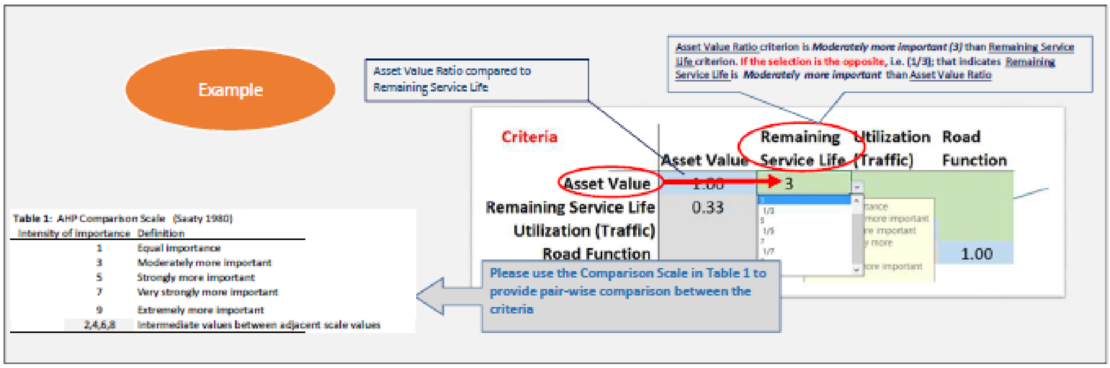
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.250	0.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.100	0.900	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.556	0.444	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.250	0.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.667	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

Appendix C

AHP Sample Survey

Start of Survey

In the following section for the criteria and sub-criteria selected for this study, please select the appropriate importance score between the criteria using the rating matrix (Table 1) as a reference. See illustrative example below:



Criteria	Asset Value Ratio	Remaining Service Life	Utilization (Traffic)	Road Function
Asset Value Ratio	1.00			
Remaining Service Life		1.00		
Utilization (Traffic)			1.00	
Road Function				1.00

Please select the value from the drop-down list in the green cells

Your Consistency n/a

Sub-Criteria	Truck Traffic (ESALs)	Passenger Traffic (AADT)
Truck Traffic (ESALs)	1.00	
Passenger Traffic (AADT)		1.00

Please select the value from the drop-down list in the green cells

Your Consistency O.K.

	High Traffic	Medium Traffic	Low Traffic
High Traffic	1.00		
Medium Traffic		1.00	
Low Traffic			1.00

Please select the value from the drop-down list in the green cells

Your Consistency n/a

	Freeways	Arterials	Collector
Freeways	1.00		
Arterials		1.00	
Collector			1.00

Please select the value from the drop-down list in the green cells

Your Consistency n/a

End of Survey - Thank you!

Appendix D
ICMPA Challenge

Terms of Reference For

The ICMPA7 Investment Analysis and Communication Challenge for Road Assets

'THE CHALLENGE'

Background

The 6th International Conference on Managing Pavements (ICMP6) introduced a new dimension to the series in terms of a "Pavement Management Investment Analysis Challenge".

The Challenge was initiated with a worldwide Call for Expressions of Interest, and 16 teams from North America, South Africa, United Kingdom, New Zealand, and Australia were subsequently invited to carry out an analysis and recommend strategies for managing a defined network of interurban and rural roads.

The overall purpose of the Challenge, as articulated by Laurie Dowling, Chair of the Panel, was to enhance the educative benefits of ICMP6 by providing an opportunity for asset management professionals to demonstrate how good practice could be applied within a range of available procedures and systems.

More specifically the Challenge aimed to identify, encourage, and disseminate good practice in pavement management, to encourage innovation and to provide a forum and documentation illustrating state-of-the-art pavement management systems.

Response to the Challenge, both in terms of the quality of submissions and the interest from conference participants, proved it to be an unqualified success. The final conference proceedings provide details.

A New Challenge

The success of ICMP6 was a key factor in a decision by the organizers of the 7th International Conference on Managing Pavement Assets (ICMPA7), to develop a new Challenge. Since ICMPA7 was still to have a main focus on pavement assets but also to include associated road assets, the Steering Committee recommended an expanded scope for the Challenge

In addition, the Committee suggested a strong emphasis be placed on communicating the message – in other words, both carrying out the analysis and communicating the results in a convincing, comprehensible manner to the "clients".

Scope of the ICMPA7 Challenge

The ICMP6 Pavement Management Investment Analysis Challenge involved a defined network of highly trafficked to lightly trafficked interurban and rural roads. Respondents were encouraged to apply a methodology used in practice as decision support similar to that required by road network investment decision makers

The ICMPA7 Challenge builds upon the ICMP6 Challenge, but is also expanded to incorporate a variety of assets within the right-of-way in addition to pavements. A capital cost, preventive maintenance, rehabilitation, and reconstruction investment analysis will be required that considers pavements, bridges, culverts, and signs. The network will once again be comprised of interurban roads and rural roads with a wide range of traffic volumes. However, in this Challenge the number of lanes is variable. In addition, a budget will not be prescribed. Instead challenge respondents will determine optimum investment levels based on trigger levels of acceptability.

Major emphasis is to be placed on communicating the message to the informed manager as well as to the non-technical or non-administrative such as the public.

General Features of the Area

The network of roads subsequently described generally covers an area of relatively flat to slightly rolling terrain. Subgrade soils are mostly clays, ranging from low to high plasticity. The climate is in a dry, high freeze zone (as defined in the Long Term Pavement Performance, LTPP, study in the Strategic Highway Research Program). Drainage is good over most of the area, with occasional flooding risk in a few low places.

The Road Authority

The road authority is in the state of "Icompa", although it can be recognized that extensive use has been made of data and information from the Province of Alberta. However, organizers of the Challenge have taken the liberty of modifying certain data and information, adding new elements, providing their own technical and cost estimates where available information does not exist, and generally trying to arrange the terms of reference so that respondents can effectively demonstrate state-of-the-art practices in their submission.

The Network to be Analyzed

The network of assets to be analyzed is composed of pavements, bridges, culverts, and signs. The features of each asset are discussed in the following sections. Samples of the spreadsheets for each asset are provided in Appendices, as subsequently described. Challenge respondents to the Call for Expressions of Interest who are invited to prepare a submission will be provided with a website link to the full database.

It should be emphasized that while considerable effort has gone into preparing the database, it is certainly not perfect, and assumptions will undoubtedly be required where inconsistencies appear. However, since the Challenge involves a network level investment and communication challenge, any specific inconsistencies in the database should not impact on the overall results.

Pavement Network

The pavement network is comprised of a total of 1293 road sections spanning 3240 km, covering two road classes, and varying in traffic use, surface age, and condition. The scope of the pavement network is illustrated in Table 1 below. The rural roads (R) span most traffic and condition categories. Inter-urban roads (I) are represented on the medium to very highly trafficked roads.

Table 1: Characteristics of the Road Network

Roughness (m/km IRI)	Surface Age < 6 Years				Surface Age 6-12 years				Surface Age > 12 Years			
	Traffic Volume[1]											
	L	M	H	VH	L	M	H	VH	L	M	H	VH
Good (IRI<1.5)	R	R	I/R	I/R	R	I/R	I/R	I/R	R	I/R	I/R	I/R
Fair (1.5≤IRI<2.0)	-	R	R	I/R	R	I/R	R	I/R	R	I/R	I/R	I/R
Poor (IRI≥2.0)	R	R	-	R	R	R	-	I/R	R	R	I/R	I/R

Note: [1] Traffic volume, L < 1500 AADT, M = 1500-6000 AADT, H = 6000-8000 AADT, VH > 8000 AADT

All pavement sections are located within the same climatic region with consistent sub-soil conditions. Each section has a defined length, width, number of lanes, AADT, soil type, year of construction, base thickness, base material type, most recent treatment, and surface thickness. In addition, surface condition assessments (International Roughness Index, IRI, and others), extent of distresses, and predicted trigger or needs year are specified for all sections.[1] A sample of the information contained within the pavement network spreadsheet is shown in Appendix A.

Structures Network

The structures network file contains three structure types: bridges, culverts, and signs. All structures within the network are situated on the roadways contained within the pavement network. Each structure is referenced to the pavement section in which it is situated.

The bridge component is comprised of 161 bridges. Bridges are one of two basic types, standard bridges which are built according to standard drawings (plans) and major bridges which do not fit the standard bridge plans (due to length, height, or site conditions). Each bridge has a defined bridge length, number of spans, maximum span length, span type, clear roadway width, skew angle, usage, first year in service, and load capacity. In addition, a condition rating, sufficiency rating, and replacement cost is specified for each bridge. A sample of the information contained within the bridge network spreadsheet is shown in Appendix B. Also provided in Appendix B is a table of expected service life for each bridge subtype.

The culvert component of the structures network is comprised of 356 culverts. Each culvert has a maximum diameter, span type, clear roadway width, skew angle, and first year in service. As with bridges, the replacement cost, condition rating, and sufficiency rating of each culvert is specified. A sample of the information contained within the pavement network spreadsheet is shown in Appendix C. Also provided in Appendix C is a table of expected service life for each type of culvert.

The sign component of the structures network is comprised of 45 major signs. Each sign has a defined type and first year in service, as well as a condition rating. A sample of the information contained within the sign network spreadsheet is shown in Appendix D. Also provided in Appendix D is an explanation of expected service life for signs.

[1] These needs years are based on internal section specific performance models which are automatically recalibrated with each annual data upload. For performance prediction after preventive maintenance, rehabilitation, or reconstruction is carried out, straight line performance prediction (e.g. IRI progression) is provided in Appendices, as subsequently described.

Treatments, Service Lives, Unit Costs, and Other Analysis Features

All treatments selected for the pavements and structures should be based on customary practices for the region. To facilitate this, a pavement rehabilitation and preventive maintenance treatment list and selection guideline is provided in Appendix E. Included is a decision tree that incorporates all customary treatment alternatives. The applicability of each alternative, as well as the associated unit cost, expected service life, and expected effect are identified. Also included are the following:

- Reduction in IRI, if any, for each treatment implementation (e.g. relationship between IRI before and after treatment);
- Annual rate of increase of IRI for each treatment-road type combination.

The available treatments, service lives, unit costs, etc. for all bridge, culvert, and sign assets contained within the network are also provided as part of the Challenge, as noted above.

Five vehicle types are defined for the network, as follows:

- Passenger Vehicles
- Recreation Vehicles
- Buses
- Single Unit Trucks
- Tractor Trailer Combinations

Percentage of the AADT volume for each type is outlined in the Appendix F. Since buses generally represent a very small percentage of the total, they might be combined with the tractor trailer combinations as an approximation for vehicle operating cost calculations. As well, recreation vehicles and single unit trucks may be combined.
Increase in vehicle operating costs due to increase in pavement roughness, represented by IRI, is also provided in Appendix F.

The discount rate for investment analysis is specified as 6%. However, challenge respondents may wish to also explore the sensitivity of their analysis to higher and/or lower rates.

The Challenge Issues

The analysis to be performed for an analysis period of 20 years will include the following:

- The budget required to preserve the existing service level for the entire network;

- The effect on service level should the budget be 10% less than or 10% more than that required to preserve the existing service level;
- The incorporation of Vehicle Operating Costs (VOC) in the analysis.

Investments should be broken down into preventive and rehabilitative maintenance and replacement/ reconstruction, which are part of the road authority's capital budgeting. Routine maintenance is carried out in five year term maintenance contracts and is not considered by this capital investment Challenge.[2] Since the interurban part of the network has higher traffic volumes than the rural part, recommendations about a strategic balance of investment will be a part of the Challenge.

A set of policy objectives, as defined by the road authority, are provided in Appendix G. Accordingly, another key part of the Challenge will be to "translate" these into quantifiable parameters such as Key Performance Indicators (KPI's), level of service indices or…………, in communicating the results and recommendations from the analysis.

For those interested in utilizing the HDM4 package, the reset/ calibration factors applicable to the network are provided in Appendix G.

The Solution(s)/ Outcomes

The results of the analysis should be presented in a format suitable for an informed manager. As well, an abbreviated or summarized version understandable to other interested individuals, organizations, or the public at large should be included. This may require further "translation" of the quantified KPI's into such levels of service indicators as A to F, for example.

Submissions should address the issue of low volume network investment versus high volume network investment (eg., the strategic balance previously noted).

The outcomes should include a documentation of any assumptions needed to carry out the analysis as well as an explanation of the analysis methodology. Any additional data or refinements to improve the clarity or transparency of the outcomes should be clearly defined.

Classification of the system or analysis procedures used in relation to the investment decision framework (after Robertson 2002) in Table 2 should be identified.

[2] These contracts are base on schedules of rates and include activities ranging from crack sealing and pothole repairs, to maintenance of signs to litter control to accident response and cleanup to snow and ice control in the winter.

Table 2: Classification of Decision Support Levels for Road Asset Management Systems

Decision Support Level	Dominant Characteristic
1	Basic asset data, rule-based work allocation
2	Project and network level assessment, geographic reference
3	Live cycle cost analysis of agency impacts
4	Life cycle cost analysis of agency and user impacts, economic prioritization
5	Optimum investments within constraints, sensitivity analysis
6	Economic, social, environmental multi-criteria assessment, risk analysis

Basic Rules/ Procedures

The 'Challenge' will be performed within the following framework of basic rules/ procedures:

- It will not aim to select a 'winner' or group of 'winners'; rather, the aim is to identify and disseminate 'good practice'.
- The 'Challenge' should not be construed as merely providing an opportunity to demonstrate an existing pavement or road asset system, but will require respondents to present an innovative, structured response to a stated problem.
- The 'Challenge' responses should be presented and structured as a submission to an informed manager as a real-life case. Also, a summary should be presented as information for other interested organizations or the public at large.

Timetable

January 2007	Issuance of Call for Expressions of Interest, posted on ICMPA7 website and publicized elsewhere in various forms.
April 2007	Deadline for Receipt of Responses
July 2007	Issuance of Invitations, Accompanied by Terms of Reference
December 2007	Draft Submissions for the Challenge and Beginning of Reviews by Panel
February 2008	Feedback from Panel
April 2008	Final Submissions and Preparation for Poster Sessions
June 2008	Conference

Acknowledgements

A number of individuals and organizations have generously contributed to the development of the Challenge. First, special mention and appreciation is extended to Ms Angela Jeffray, BSc, who worked as a Research Associate in all aspects of putting the Challenge package together. The Alberta Department of Infrastructure and Transportation (AIT), who are co-sponsors of ICMPA7, were most helpful and cooperative in providing information and advice, and Dr. Zhiwei He and Mr. Roy Jurgens of AIT certainly should be recognized as well as many of their colleagues in AIT. Finally, the cooperation and advice of the Conference Co-Chair, Dr. Lynne Cowe Falls, and Steering Committee member Dr. Susan Tighe, is sincerely appreciated.

Ralph Haas, Challenge Chair