Development of Tools for Infrastructure Asset Management Cross-Asset Trade-off Analysis and Universal Performance Measure for Public Agencies

by

Milos Posavljak

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Examining Committee Membership

The following served on the Examining Committee for this thesis. The decision of the Examining Committee is by majority vote.

External Examiner	Sue McNeil Emeritus Professor
Supervisor(s)	Shunde Yin / Susan Tighe Associate Professor / Associate Professor
Internal Member	Hassan Baaj Professor, Associate Chair of Research
Internal-external Member	Rob Duimering Associate Professor
Other Member(s)	Ningyuan Li Adjunct Professor

AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this 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.

Abstract

While the modern monetary system, the limited liability corporation, and modern public infrastructure trace their beginnings to past centuries – use of the term "asset" when referring to public infrastructure started at the end of the 20th Century. With advances in computer technology, New Zealand and Australian public agencies were initial adopters and were the first to benefit from mass data availability on road infrastructure. Soon after, North America and the rest of the developed world followed in adopting what today is commonly referred to as infrastructure asset management practices. Infrastructure's purpose remains the same as before – to support economic growth and societal accessibility. However, the new perspective of viewing it as an asset rather than an almost naturally occurring - passive societal commodity - has brought forth demand for increased transparency and evidence-based decision-making. Appropriate timing and action relative to asset's performance and societal growth demands require a complex socio(org)-technical system to maximize the asset's benefits to society and minimize the risk of it turning into a societal liability.

The thesis presents an original approach to improving an organization's decision-making capabilities by operationalizing asset management processes within vertical and horizontal public agency structures. One which uses organizational behaviour theory and operational analysis while leveraging civil engineering industry experience and engineering risk and reliability knowledge to develop-corporate data driven-asset performance measures. A novel horizontal information flow is mapped and introduced as the operationalizing asset management framework. It is used as a guide to shine a light on the asset management process complexities at tactical and operational levels of organizations. A new operational perspective on the definition of asset management is argued, one which sees it as an equal partnership between engineering and financial professionals reinforced with administrative policies and procedures.

The effects of division of labour are reflected in the academic fields of engineering as well. Intra-departmental specializations within civil engineering include transportation, structural, hydrology, and further branching within each. With respect to infrastructure asset management this is a necessity as public agencies typically have a portfolio of varying assets ranging from roads, water distribution, sewer management, facilities, and parks - to name a few. For which different knowledge and skills are necessary in order to provide expert level management sought and claimed by managing agencies. As such, subject matter experts along with finance professionals make up the core team which functions within a compartmentalized structure of administrative policies and procedures. The two degrees of compartmentalization, one in the academic, other in the corporate setting has yielded organizationally silo-ed asset management processes competing for a single source of funding – public monies. Provided that all assets are equally important in providing a singular infrastructure system - as experienced by citizenry – the questions of which and why one is a priority over the other arise when there is a lack of funding for all within a particular time span. The research originally argued the need to use the inherit objectivity of monetary value to provide an objective method of cross-asset trade-off analysis to answer the "which". While organizational theory and engineering experience is used to create new value from untapped potentials of existing organizational processes in creating one objective level playing field from which evidence-based decisions can rapidly be made and cataloged in answering the "why". The research journey identified a significant bottleneck

with the cross-asset item. Specifically, “field inspection of information” showed that the forecasting tools available to municipalities – within single asset classes – do not satisfy minimal scientific standards. Subsequently, it is argued that this is a naturally occurring limitation of the sample space, rather than a “continuous improvement item”. The research found that forecasting infrastructure spending needs according to the scientifically unreliable Age-Based approach overestimates them by 335%. This is compared to the scientifically reliable Consumer-Based approach that is based upon engineering risk and reliability.

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Table of Contents

Examining Committee Membership……...ii
AUTHOR'S DECLARATION iii
Abstract iv
List of Figures ix
List of Tables ……xii
Chapter 1 Introduction 1
1.1 North American Infrastructure Spending (Annual Capital) and Infrastructure Replacement Value 1
1.2 The Corporate Environment 2
1.3 Problem Definition and Research Approach 3
1.4 Organization of Thesis 4
Chapter 2 Research Hypotheses, Objectives and Methodology, and Data Sources 5
2.1 Research Hypotheses 5
2.2 Research Scope and Objectives 5
2.3 Research Methodology 6
2.4 Data Sources 8
2.5 Research Project Framing 8
2.6 Summary of Chapter 9
Chapter 3 Literature Review 10
3.1 Introduction 10
3.2 Academic Institutional Activity 10
3.3 Organizational and Cross-Asset Trade-Off Related Literature 12
3.4 Conclusion 16
3.5 Summary of Findings 20
Chapter 4 Experiment Design and Conduct 21
4.1 Nature, Format, and Location of Raw Information 22
4.2 Vertical and Horizontal Corporate Structure 23
4.3 Categorization of Raw Information According to Horizontal Corporate Structure Areas – Information Flow (Engineering, Finance, Administration) 26
4.4 Corporate Data-Driven Asset Performance Measures 29

4.4.1 Comprehensive Asset Performance Measure – Infrastructure Asset Performance Stock (iPS) 33
4.4.2 Reliability (Risk) Pertaining to Management of Public Infrastructure 40
4.4.3 Active Asset Management Risk 42
4.5 Asset Management System (e.g. Excel based) for Improved Communication Between Engineering, Finance, Administration 43
4.5.1 Internal and External Environments of a Public Infrastructure Managing Agency 44
4.5.2 Technical Development and Implementation 47
4.6 Summary of Findings 50
Chapter 5 Results – Theory of Constraints Application 52
5.1.1 Key Organizational Results 53
5.1.1.1 Theory of Constraints 53
5.1.1.2 Application of Theory of Constraints to Asset Management Systems 54
5.1.1.2.1 Asset Management System Goal 54
5.1.1.2.2 Identifying System's Constraints 54
5.1.1.2.3 Decide How to Exploit Constraints and Subordinate Full Project Effort to Decisions 55
5.1.1.2.4 Elevating System's Constraints 65
5.1.2 Performance and Expenditure Scenarios PSAB 3150 (Age-Based) versus Consumer-Based (Reliability-Risk Engineering) 65
5.1.3 Forecast Analysis PSAB 3150 (Age-Based) versus Consumer-Based (Reliability-Risk Engineering) 92
5.2 Independent repetition of steps for scientific validation and / or field application 97
5.3 Summary of Findings 97
Chapter 6 Conclusions, Limitations, and Recommendations 99
References 102
Appendix A 110
Related Reviewed Infrastructure Asset Management Publications (excluding theses and dissertations) 110
Appendix B - Raw Information 114
Appendix C - Forecast Performance and Expenditure Information 153

List of Figures

Figure 1: Research Methodology Flow Diagram 7
Figure 2: Academic Activity – Open Access Theses and Dissertations (OATD 2017) 11
Figure 3: Academic Activity by Country 1998-2017 12
Figure 4: Academic Activity – Excluding Theses and Dissertations 15
Figure 5: Distribution of Enterprise Adoption Studies by Research Methodology (Basole 2006) 19
Figure 6: Hybrid Project Structure Schematic 25
Figure 7: Corporate Operationalization of Asset Management Processes Framework 27
Figure 8: Documental Asset Management Framework 28
Figure 9: Average or Mean Time to Treatment Derivation 34
Figure 10: Treatment Trigger Derivation 34
Figure 11: Average Annual Deterioration Derivation 35
Figure 12: Asset Performance Reset Post Treatment or Inspection 35
Figure 13: Asset Performance Derivation (Posavljak et al 2019) 35
Figure 14: Scientific Limitation of Forecasting as Applicable to Infrastructure Industry 39
Figure 15: Probability of Failure Schematic (Pandey 2015) 40
Figure 16: Corporate Environment and Uncertainty 46
Figure 17: Phenomena Complexity of Public Infrastructure Asset Management 48
Figure 18: Example of Asset Performance Graph Shown to Stakeholders at Beginning of Project 56
Figure 19: Example of Asset Expenditure Graph Shown to Stakeholders at Beginning of Project 56
Figure 20: Internal Positioning and Information Flow – Public Infrastructure Managing Agency 61
Figure 21: Cross-Section View A – A of Internal Positioning and Information Flow 62
Figure 22: Cross-Section View A – A of Internal Positioning and Information Flow with New Asset Management Processes 63
Figure 23: Scientific Limitations of Forecasting as They Apply to Provision of Public Infrastructure 64
Figure 24: Roads – Age - Based Performance Forecast 68
Figure 25: Roads – Age - Based Expenditure Forecast 68
Figure 26: Roads – Consumer - Based Performance Forecast 69

Figure 27: Roads – Consumer - Based Expenditure Forecast 69
Figure 28: Sidewalks – Age - Based Performance Forecast 70
Figure 29: Sidewalks – Age - Based Expenditure Forecast 70
Figure 30: Sidewalks – Consumer - Based Performance Forecast 71
Figure 31: Sidewalks – Consumer - Based Expenditure Forecast 71
Figure 32: Traffic Lights – Age - Based Performance Forecast 72
Figure 33: Traffic Lights – Age - Based Expenditure Forecast 72
Figure 34: Traffic Lights – Consumer - Based Performance Forecast 73
Figure 35: Traffic Lights Consumer - Based Expenditure Forecast 73
Figure 36: Bridges – Age - Based Performance Forecast 74
Figure 37: Bridges – Age - Based Expenditure Forecast 74
Figure 38: Bridges – Consumer - Based Performance Forecast 75
Figure 39: Bridges – Consumer - Based Expenditure Forecast 75
Figure 40: Sanitary – Age - Based Performance Forecast 76
Figure 41: Sanitary – Age - Based Expenditure Forecast 76
Figure 42: Sanitary – Consumer - Based Performance Forecast 77
Figure 43: Sanitary – Consumer - Based Expenditure Forecast 77
Figure 44: Water – Age - Based Performance Forecast 78
Figure 45: Water – Age - Based Expenditure Forecast 78
Figure 46: Water – Consumer - Based Performance Forecast 79
Figure 47: Water – Consumer - Based Expenditure Forecast 79
Figure 48: Storm – Age - Based Performance Forecast 80
Figure 49: Storm – Age - Based Expenditure Forecast 80
Figure 50: Storm – Consumer - Based Performance Forecast 81
Figure 51: Storm – Consumer - Based Expenditure Forecast 81
Figure 52: Natural Assets – Age - Based Performance Forecast 82
Figure 53: Natural Assets – Age - Based Expenditure Forecast 82
Figure 54: Natural Assets – Consumer - Based Performance Forecast 83
Figure 55: Natural Assets – Consumer - Based Expenditure Forecast 83
Figure 56: Facilities – Age - Based Performance Forecast 84
Figure 57: Facilities – Age - Based Expenditure Forecast 84
Figure 58: Facilities – Consumer - Based Performance Forecast 85

Figure 59: Facilities – Consumer - Based Expenditure Forecast 85
Figure 60: Parks– Age - Based Performance Forecast 86
Figure 61: Parks – Age - Based Expenditure Forecast 86
Figure 62: Parks – Consumer - Based Performance Forecast 87
Figure 63: Parks – Consumer - Based Expenditure Forecast 87
Figure 64: Parking – Age - Based Performance Forecast 88
Figure 65: Parking – Age - Based Expenditure Forecast 88
Figure 66: Parking – Consumer - Based Performance Forecast 89
Figure 67: Parking – Consumer - Based Expenditure Forecast 89
Figure 68: All Assets – Age - Based Performance Forecast 90
Figure 69: All Assets – Age - Based Expenditure Forecast 90
Figure 70: All Assets – Consumer - Based Performance Forecast 91
Figure 71: All Assets – Consumer - Based Expenditure Forecast 91
Figure 72: Typical Age-Based versus Consumer-Based Qualitative Performance 93

List of Tables

Table 1: North American Public Infrastructure Annual Expenditure and Replacement Value 1
Table 2: Related Theses and Dissertations with Respect to Organizational Aspect 14
Table 3: Related Theses and Dissertations with respect to Cross-Asset Trade-Off Aspects 15
Table 4: General “Organizational Behavior” OATD Search 17
Table 5: Dissertation’s Topic Applicable - Organizational Research within Industrial and Systems Engineering Fields 18
Table 6: Experimental Design 21
Table 7: Example of Nature, Format, and Location Analysis 23
Table 8: SME Standard Established Performance Measures (Non-Age Based) (Posavljak et al 2019). 30
Table 9: Corporate Decision Factors – Not Accounted for by SEPMs (Posavljak et al 2019) 32
Table 10: Qualitative Performance Boundaries 36
Table 11: Example Calculation of iPS 36
Table 12: Adjustments to Current Concept of Risk for Asset Management Purposes 41
Table 13: Manufacturing Product-Matrix (Nahimas 2005) 45
Table 14: Asset Information Maturity for One Municipality 49
Table 15: Product-Process Matrix 58
Table 16: Portion of Each Asset Classes with Poor Performance in Initial Year 92
Table 17: Deterioration Rate Analysis (ESL-Estimated Service Life) 94
Table 18: Treatment Cost Analysis 95
Table 19: Age-Based Future Infrastructure Cost Overestimation 96

Chapter 1

Introduction

1.1 North American Infrastructure Spending (Annual Capital) and Infrastructure Replacement Value

If economic growth and societal accessibility are assumed to be the ends and public infrastructure the means, then perhaps a good starting point in separating the two is to estimate their respective monetary values.

Existing literature varies in the type and detail captured of actual public sector spending and related financial information, and the time span to which it corresponds. It ranges from qualitative assertions to quantitative lump sums, and overall asset-centric replacement values. The figures themselves are typically referenced from other publications (e.g. government reports). The research analyzed existing information sources in order to quantify annual capital infrastructure spending for the whole of North America's public infrastructure. It is important to note that both the annual capital and replacement values are subject to competitive construction bidding or letting. As such, future projections are subject to market fluctuations. It is argued that the annual capital expenditure is of significantly greater concern to asset management than the replacement value. Furthermore, it is argued that the asset replacement value – overall or asset-centric- is theoretical and other than giving an idea of the asset's size has minimal asset management process implications.

The Canadian Infrastructure Report Card (2016) and the United States Infrastructure Report Card (2017) were analyzed. Table 1 shows the existing North American annual expenditure and infrastructure replacement value.

Table 1: North American Public Infrastructure Annual Expenditure and Replacement Value

Information Type	Canada*	United States**	North America
Total Existing Annual Expenditure ($Billions)	25	100	125
Overall Infrastructure Replacement Value ($Billions)	1,100	4,400***	5,500

** includes Canadian Infrastructure Report Card asset class categorization: potable water, wastewater, stormwater, roads, bridges, buildings, sport and recreation facilities, transit*

***includes United States Infrastructure Report Card asset class categorization: surface transportation, water/wastewater infrastructure, public parks and recreation (excludes electricity, airports, inland waterways and marine ports, dams, hazardous and solid waste, levees, rail, schools)*

****not readily available, extrapolated from Canada ratio of 25 / 1,100*

The North American infrastructure replacement value is estimated at $ 5.5 trillion dollars. This is 28 % of the annual gross domestic product of $ 19,587 T (Trading Economics 2017). Annual capital expended on

renewing infrastructure is 0.6 % of the gross domestic product. Hence, the annual value of the means to that of the ends is at a ratio of 1 to 157. It is argued that the replacement value and its ratio of 1 to 4 cannot be used in the same context as the term "replacement", which typically refers to project level improvement activities, that are funded through annual capital expenditure, and to a lesser extent through operating expenditure. Replacement of entire asset-centric networks through lump sums equating to their replacement value is not practiced.

The theoretical argument is that Corporate Operationalization of Asset Management (COAM) processes will provide a greater increasing rate of the ratio over time, than would otherwise be the case. A practical argument is that existing engineering, finance, and administrative staffing levels –focused on management rather than actual construction – will not need to be increased in order to manage increasing infrastructure progress. Specifically, border-line artificial intelligence will allow staff to handle exponential growth of information to be considered in the provision of public infrastructure. It is important to note that full requirements of COAM are satisfied only when an organization is forecasting scientifically reliable performance and expenditure scenarios. Perhaps an analogy to potentially help in understanding the practical claim: Between two adversary Navies, only one has access to Sonar. The Sonar advantage manifests itself in the "spotters" ability to locate targets at a significantly higher rate than the opposition. Here the advantaged side represents a managing agency, Sonar the COAM, and increasing infrastructure needs the opposing side.

The following section introduces the mapping of a typical infrastructure managing agency within the context of organizational behaviour theory and operational analysis.

1.2 The Corporate Environment

Public infrastructure asset management is the responsibility of municipal corporations in North America, as well as the provincial / state, and federal government agencies. These include regional municipalities, cities, townships, and villages – typically referred to as local government agencies. In Ontario, the majority of the infrastructure by capital expenditure is managed by local agencies, including roads, transit, sanitary management network, water distribution network, storm management network, facilities (i.e. community centers, public works buildings, etc.), fleet, parks, parking, forestry, wetlands, cemeteries and lands. Highways, airports, energy assets and other intra and interprovincial infrastructure are typically managed by provincial or federal levels of government. Provided that the essence of the research argument relies on understanding and using the corporation as a means of improving the current state of infrastructure asset management practice, it is important to start by examining the phenomena of the corporation. The field of management science was the primary source of aid for that effort.

The corporation is an organization, and it its broadest terms - an organization is defined as a number of positions working together to achieve a specific goal. Limited liability of its members is what separates the incorporated organization or the corporation, from one lacking such recognition by societal authorities. The precursor of today's corporations dates back to the 16th Century. The Muscovy Company is considered the first major joint stock and limited liability company. Charted in 1555 in England, its business focused on trade with Russia (Nahimas 2005).

Fast forward across the industrial revolution and two world wars to the 21st century and the era of information, the field of management science provides ample material on the inner workings of

organizations, the environments they operate within, and their categorization against a variety of different criteria and dimensions.

Today's built infrastructure is managed by private and government corporations (i.e., public agencies), the focus of this research is the latter.

1.3 Problem Definition and Research Approach

Public agencies managing public infrastructure are under increasing pressure to improve their asset management practices in order to maximize infrastructure performance, with limited funding availability.

According to the researcher's industry experience, a significant effort has been put forth over the past two decades by Australian and North American stakeholders to bring asset management from a concept to an industry-wide accepted practice of managing infrastructure. The "What?" of asset management is well understood throughout the industry today. The "How?" has yet to reach the same degree of confidence at tactical and operational agency levels.

The problem is how to fully operationalize asset management practices within tactical and operational levels of public agencies in order to provide increased transparency and objective evidence-based decision-making capabilities - across all assets; provided:

- Current industry's forecasting capabilities are bottlenecked by "age-based" logic lacking scientific basis,
- Asset portfolios include a large variety of different infrastructure types with intrinsically different functionalities and performance measures,
- Subject matter expert knowledge, skill, and experience compartmentalized first in the educational system then in the government corporation,
- Public organizational structure is significantly more rigid compared to the private sector,
- Lack of a central industry authority to provide direction and standards on which asset classes are a priority,
- "Many to many" relationships in current asset management nomenclature; and,
- Large degree of variation between population sizes served and socio-economic environments.

The research approach involved the application of organizational behaviour theory and operational analysis knowledge to develop an operationalizing corporate framework demonstrating common information supply-chain patterns across a variety of public agencies. This supply-chain or flow is one of the theoretical independent variables upon which the rest of the approach is built. The format and the nature of existing corporate information are the other two. Engineering, financial, and administrative knowledge, skill, and experience were used to understand and categorize the information in sequence within the framework. An iterative process was used to develop corporate data-driven performance measures. Varying scenarios of expenditure and resulting asset performance graphs were developed to serve as exhibits of evidence-based decision-making. They were tailored for operational, tactical, and

strategic level positions. The essence of the approach was to ensure the value of existing data and processes was exhausted prior to and if at all collection of new data was necessary. Specifically, data related to historical spending on infrastructure assets. A number of case studies were used to validate the developed framework. The bottleneck of "age-based" forecasting was encountered in each. Its limitations were remedied through the establishment and use of "consumer-based" forecasting, being the main deliverable of corporate operationalization of asset management. Both the asset's physical condition performance and its functional performance, fall under the umbrella of "consumer-based" performance forecasting.

1.4 Organization of Thesis

This thesis is organized into six chapters.

Chapter 1 includes an introduction, and provides the background on infrastructure spending and replacement and the corporate environment. Finally, the problem is defined and the research approach is presented.

Chapter 2 consists of the research's hypothesis, scope, objectives, methodology, and data sources.

Chapter 3 includes a literature review of related academic and published works.

Chapter 4 explains the experiment design and conduct. This includes organizational, infrastructure performance measures, and asset management system aspects.

Chapter 5 shows the results of this active research effort through the application of Goldratt's Theory of Constraints. This includes a three-dimensional plotting of organization with respect to asset management processes. As well as a comparison of current versus proposed forecasting methods of infrastructure performance and expenditure.

Chapter 6 includes the conclusions, limitations, and recommendations.

Appendix A includes a list of related publications excluding theses and dissertations.

Appendix B includes raw information on the historical costing of the model infrastructure network.

Appendix C includes forecasts of performance and expenditure for the model infrastructure network.

Chapter 2

Research Hypotheses, Objectives and Methodology, and Data Sources

2.1 Research Hypotheses

This research proposes the following hypotheses and the objectives attempt to address missing gaps in the literature and in engineering practice. The research hypotheses are the following:

1. Stakeholder surveys and interviews are the dominant modes of empirical research in the field of organizational behaviour theory as it applies to infrastructure asset management. The method of accessing the "corporate conscience" provides additional efficiencies in the effort of continuous organizational improvement, in this case being the application of asset management processes in public organizations.
2. Existing organizational information provides sufficient value to develop corporate data driven – asset performance measures, without new data collection efforts. Research in new data analysis methods could greatly advance technical and economic benefits.
3. Objective decision-making is already occurring within managing agencies to the highest degree possible according to the existing body of knowledge; it is just a matter of communicating it in a systematic manner.
4. Corporate operationalization of asset management processes requires building on top of existing processes rather than altering them or developing independent of them.
5. In order to implement Consumer-Based (reliability-risk engineering) forecasting to support decision-making, resonance of the Consumer-Based mechanism with existing corporate knowledge and processes is necessary.

2.2 Research Scope and Objectives

The goal of the research is to demonstrate an original approach for Corporate Operationalizing of Asset Management (COAM) processes, thereby providing a mechanism for public agencies to improve decision-making capabilities for infrastructure investment and performance.

The scope includes:

- Review of related literature, and identification of existing gaps
- Application of organizational theory principles to asset management
- Application of engineering, finance, and administrative knowledge, skill and experience to asset management
- Utilizing of existing corporate information in developing corporate data driven – asset performance measures,

- Development of objective cross-asset trade-off analysis mechanisms that resonate with existing corporate processes; and,
- Minimization of impact on existing organizational processes.

The research has four unique objectives to contribute to the advancement of the current state of industry practice:

1. Approaching the problem from a strictly corporate point of view of a public agency
2. Attempting to address all infrastructure asset classes typically owned by a municipality
3. Development of a unified performance measure for all infrastructure for objective cross-asset trade-off analysis, which is not based on the analytical hierarchy process
4. Establishing a process framework for sustaining "living" asset management plans

North American and Australian academic, private, and public sources focused on asset management practice have been analyzed. In addition to the current state of the industry, as presented by the sources, the pillars of research include:

- Thirteen years of public agency experience covering the full vertical and horizontal spectrums of the corporation; and,
- Corporate-wide case studies demonstrating alpha and beta application of the arguments within.

2.3 Research Methodology

Figure 1 shows a strategic schematic of the research methodology.

1. Review of current state of the art: A focus is put on asset management implementation and cross-asset trade-off analysis.

2. Determine if the dominant mode of related research is confined to stakeholder survey / interview.

3. Map public infrastructure agency: The process involves the transposition of public equivalents of private product-to-process cycle relationship, intra-organizational goal attainment factors, and supply-chain management.
4. Map flow of information through agency: The main goal is to show the flow of information from the physical infrastructure to the corporate decision makers.

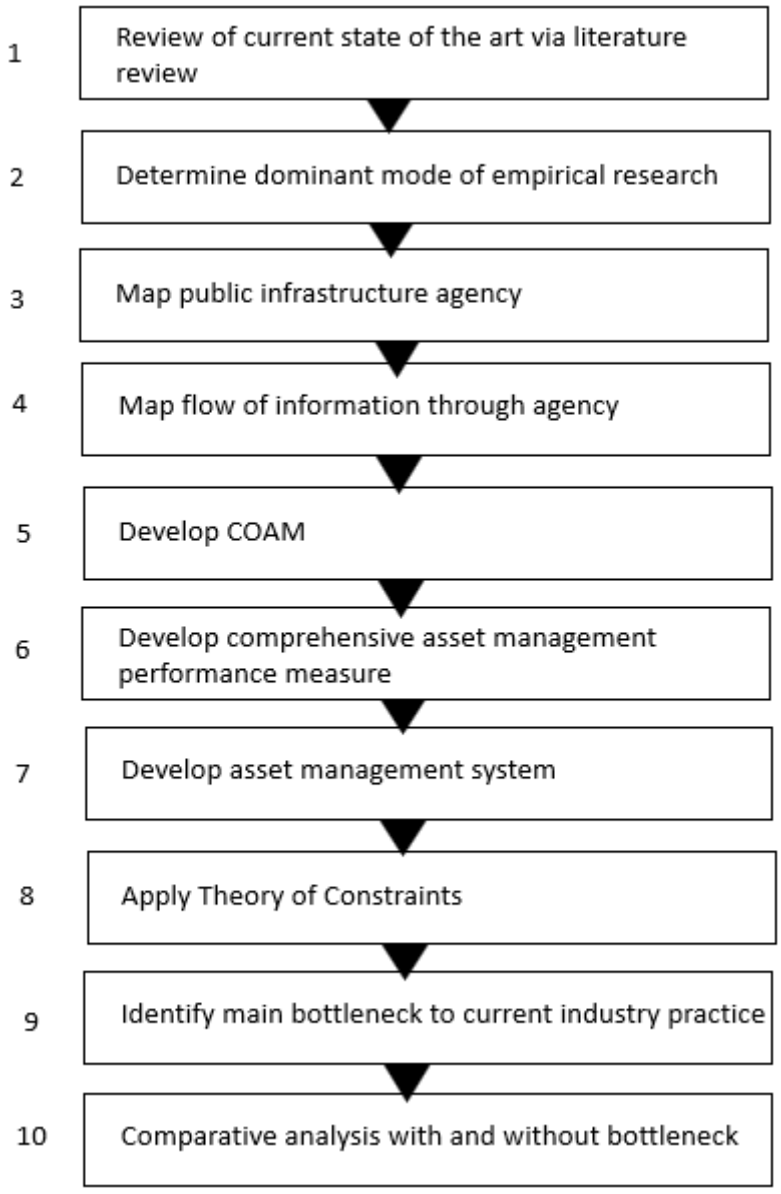


Figure 1: Research Methodology Flow Diagram

5. Develop COAM framework: This item is central to the research. A framework common to all public agencies is developed, focusing on the horizontal information processes. A categorization of real corporate data is included according to past and ongoing professional work experience.

6. Develop Comprehensive Asset Management Performance Measure (CAM): Building on steps 1-5, a "Consumer-Based" performance measure is developed. A measure which inherently incorporates all other previous measures.

7. Develop asset management system to be able to forecast infrastructure performance and corresponding expenditure.

8. Apply Goldratt's Theory of Constraints to define and eliminate bottlenecks to current industry practice.

9. Identify main bottleneck to current industry practice.

10. Conduct comparative analysis of forecasts with and without the bottleneck. Age-Based (with bottleneck) versus Consumer-Based (without bottleneck).

2.4 Data Sources

This active research effort was conducted in collaboration with the City of Waterloo. Specifically, the researcher worked as a Project Manager for the City's first Comprehensive Asset Management Plan. Upon successful delivery of the project, the same approach was applied to the following: City of Mount Pearl, Town of Grand Falls-Windsor, Town of Hampton, Town of Provost, Township of Wainfleet, Township of Seguin, Municipality of Brooke-Alvinston, and Village of Lytton.

In order to protect the privacy of respective municipal information, the infrastructure network model used for this research is not representative of any of the aforementioned, rather it is a fictitious model network. Nonetheless, it is representative of what can be observed in the field.

2.5 Research Project Framing

The purpose of this section is to provide the overall framing of the research effort. As previously mentioned, this was an active research effort. This means that the research material was the result of the researcher performing daily job tasks over a period of two years.

The research methods and results are presented in the context of the existing literature, which is summarized in Chapter 3.

Chapter 4, titled Experiment Design and Conduct, presents the overall structure and municipal context, which was completed in the first five months. Section 4.1 contains the results of analyzing corporate information. Section 4.2 presents the Hybrid Project Structure, which was developed by the researcher for the purpose of executing the project. The Corporate Operationalization of Asset Management (COAM) Processes Framework is found in Section 4.3. It is the result of the researcher studying internal processes of infrastructure managing agencies (i.e., municipalities). Standard Established Performance Measures (SEPMs) and Corporate Decision Factors are found in Section 4.4. SEPMs are infrastructure

performance indicators found to be used by municipalities. Corporate Decision Factors include criteria that are contemplated in infrastructure decision-making as discovered by the researcher. Section 4.4.1 contains the derivation of a Comprehensive Asset Performance Measure called Infrastructure Asset Performance Stock (iPS). Sections 4.4.2 and 4.4.3 speak to risk as it pertains to the management of public infrastructure. Section 4.5 explains the intricacies involved in developing and implementing an asset management system, which includes the integration of new information technology into existing processes.

Chapter 5 contains the results of the active research effort, framed through Goldratt's Theory of Constraints. The material presented in Chapter 5 was produced during the researcher's work in months six to 24 of the project. Section 5.1.1 contains the Key Organizational Results of eliminating negative siloing effects and building on top of existing processes. Section 5.1.1.1 introduces the Theory of Constraints. Section 5.1.1.2 applies the Theory of Constraints by defining the asset management system's goal, identifying the system's constraints, and deciding how to exploit and elevate the system's constraints. Through this process, the main bottleneck to advancing current industry practice was defined to be Age-Based forecasting. Finally, a comparison of Age-Based versus Consumer-Based forecasting was completed.

A novel perspective on the internal organizational complexities of asset management has been presented. Its consideration is recommended for practitioners looking to implement new asset management systems and processes into decades-old practices. The approach eliminates the negative effects of organizational siloing through the application of the Theory of Constraints. In order to transpose this private sector (i.e. manufacturing) theory onto a public agency, 10 years of practical public sector experience was combined with academic research. The Theory of Constraints has increased the effectiveness and efficiency of the manufacturing industry over the past decades and will do the same for the infrastructure management industry. The key to success is building on top of, rather than changing existing processes. This research has presented in unprecedented detail the operational, tactical, and strategic steps necessary for successful asset management processes development, and implementation in a corporate-wide agency setting, for all asset classes owned.

The initial concepts of the presented approach were developed by the researcher during asset management practice at the Investment Strategies Branch of the Ministry of Transportation, Ontario. It was first applied at the City of Waterloo, followed by the Municipality of Brooke – Alvinston, and the Township of Seguin.

2.6 Summary of Chapter

This chapter summarizes the research hypothesis, scope, methodology, data sources, and research project framing that have been used in this thesis. It is key to note a significant overlap between aspects which may typically stand alone as research topics: organizational, infrastructure performance measures, and asset management system.

This research included all three aspects in significant detail, and as such will advance the state of the current art.

Chapter 3

Literature Review

The review of literature is focused on the existing state-of-the-art concept asset management approaches for public infrastructure, holistic application of terminology (i.e. not asset-centric), and cross-asset trade-off analysis.

3.1 Introduction

Prior to explicit inclusion of the term "asset" within infrastructure management the United Kingdom Department of Industry established a Committee for Terotechnology in 1970. Its main purpose was to start the process of developing a systematic approach to managing physical resources. The term was first explicitly applied to infrastructure management in 1984 in South Australian public sector reports lead by Dr. Penny Burns on the "True Cost of Services" and "Cost and Timing of Asset Replacement" (Woodhouse 2014). It is argued that this initiative was the catalyst for the public, academic, and private sectors to come together and use the emerging computer technology to centralize infrastructure inventory data. In North America, the term was officially introduced by the Federal Highways Administration, in their 1999 asset management primer (FHWA 1999).

Since then, guiding documents (e.g. standards, manuals, guides, etc.) have been introduced by respective professional organizations across the developed world, cumulating with an ISO 55000 series of standards. In Ontario, the "Building Together: Asset Management Planning Guide for Municipalities" provides strategic direction for local asset management agencies (e.g. regions, cities, townships, villages). The guide was followed by provincial regulation in 2018, titled "Asset Management Planning for Municipal Infrastructure - O Reg 588/17".

The following section provides an overview of academic institutional activity.

3.2 Academic Institutional Activity

Soon after the introduction of asset management concepts into a traditionally dominated - engineering field, the academic institutions began the research effort of turning them into practice.
Figure 2 illustrates the effort over the past decades.

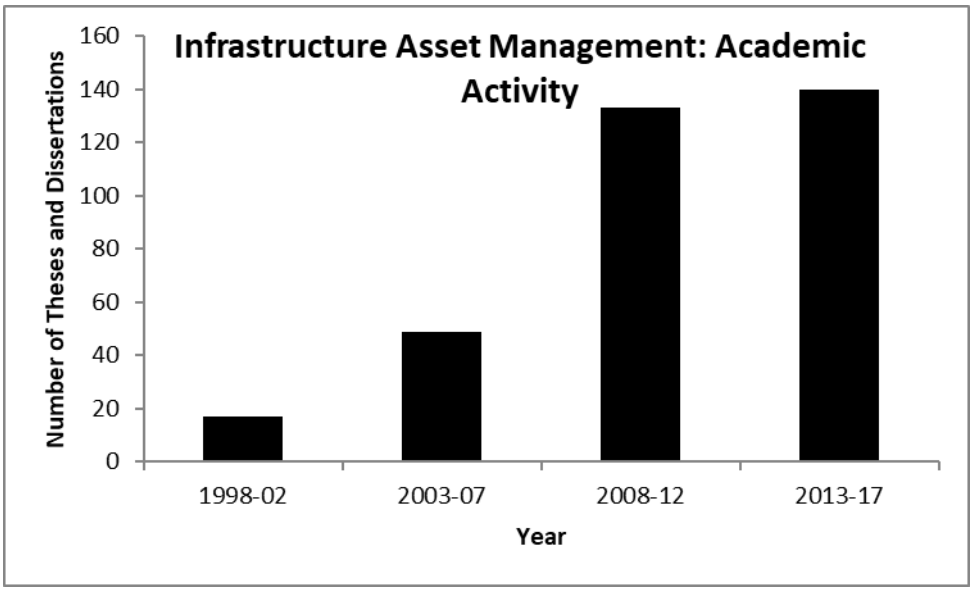


Figure 2: Academic Activity – Open Access Theses and Dissertations (OATD 2017)

The Open Access Theses and Dissertation (OATD) is the source of information, capturing Masters and Doctoral thesis containing the term "infrastructure asset management" in its title or description. While it may not be absolute in capturing the global academic effort it provides a substantial indication of the historical trend. Exponential growth is observed from 1998 to 2012, with plateauing in the last four years – at an annual average of 35 per year.

Figure 3 provides a breakdown by country. US, Canada, and Australia are the top three with New Zealand, UK, and South Africa following - respectively. Out of the 339 available publications to date, 78 are distributed amongst other countries. This is expected as the mentioned ones form the initiating group of the asset management concept, as their economic growth and social accessibility rely heavily on record quantities of public infrastructure.

The research is focused on full corporate operationalization of asset management processes, corporate data-driven – asset performance measures, and objective cross-asset trade-off analysis. These can be placed within the broader categories of org-technical (socio-technical) systems, and performance measure-related research pertaining to infrastructure asset management. A preliminary examination of the OATD available literature yielded 30 thesis/dissertations or 10 % of the overall material categorized as closely related to the proposal. That is, where management of multiple – intrinsically different – asset classes is implied and the subject matter is in full or in-part concerned with organizational or asset performance measure improvements.

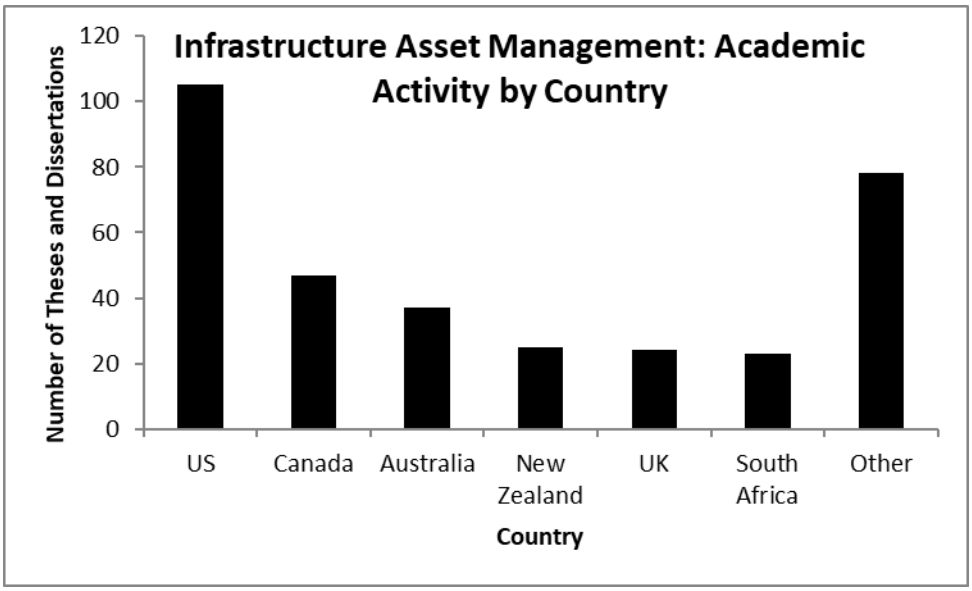


Figure 3: Academic Activity by Country 1998-2017

As the research proposal is concerned with the concept of "full portfolio" management, a preliminary examination of the mentioned publications was done to screen for such perspectives - the results are shown in the following section.

3.3 Organizational and Cross-Asset Trade-Off Related Literature

The proceeding paragraphs provide concise summaries of a more detailed examination of the publications, in their chronological order.

Approximately eight years after the formal introduction of asset management in the US, a state of the practice scan was completed in Kansas counties. "Counties with a population above 50,000 had a 60% response rate, while counties with a population between 5,000 and 50,000 had a 31.2% response rate and counties with a population below 5,000 had a 23.5% response rate...Based on this questionnaire it was found that about 24.2% of the counties surveyed have some sort of an Asset Management system in place…" (Friedrichs 2007). This is indicative of the asset management concept taking root within the managing agencies. Provided that the focus of the research was analyzing the state of the practice, the majority of its material is not directly related to the research at hand. Recommendations concerning "the possibility of creating an inventory database, making cost-effective decisions and choosing available Cost Accounting and Asset Management Software programs" are an exception to this. However, the levels of detail are magnitudes apart, which is natural given the time span difference of the two research efforts.

Next, research of infrastructure asset management from a strictly organizational perspective focused on the "…core capabilities that are necessary to deliver value and sustained asset performance" (Too 2009). The formal research problem was stated as "How can infrastructure organisations improve the performance of their infrastructure assets and contribute value to their organisations?" The answer was provided in the form of a capability model developed through case study research. Strategic management

material from other industries was used to synthesize the theoretical backbone for the model, while in-depth interviews were completed with practitioners to operationalize the theoretical template and create a strategic infrastructure asset management framework. Senior managers were interviewed in phase A followed by operational managers in phase B. The interview information was supplemented with a review of the organizations' published documents and internal files. Subsequent analyses lead to a summary of the needed capabilities for the strategic infrastructure asset management framework and processes execution (Too 2009).

The corporate data driven asset performance measures, and cross-asset trade-off analysis are outside of the scope of the reviewed dissertation as scoped by this research. However, the organizational aspect shares the same essence and perspective with respect to the value of focusing on internal organizational processes in order to improve infrastructure performance. This is evident from its literature review which brings forth points on the importance of not constraining the global effort to analytical tools and technical models. As such an approach is prone to asset-centricity at the expense of the overall infrastructure system. The goals of increased transparency in decision-making and improved processes and performance of infrastructure provision are also shared with this research.

A key difference which is examined by this research is the inherit flexibility needing to change existing organizational structures in order to implement effective asset management processes. This perception is widespread and has for the most part gone unchallenged. While this perspective was necessary in the initial stages of the asset management movement in order to raise awareness a more appropriate alternative will be necessary for the current state of the practice. Specifically, the approach of "building on top" of existing processes rather than changing them is introduced.

One of the noted limitations was how "…The success of a case study is largely dependent on the willingness of the participants to provide information, fully and without bias…" (Too 2009). It is deemed safe to assert that all survey / interview-based studies are subject to the same constraint. Through an extensive review of organizational behaviour literature, the research effort tested the hypothesis that this is the dominant mode of empirical-organizational behaviour research related to infrastructure asset management. According to the reviewed material, the hypothesis is accepted. As such an original approach to circumventing such constraints is demonstrated as applied for this research. In addition to illuminating operational level infrastructure asset management processes, the approach could potentially be applied in other industries.

Finally, in terms of future research Too (2009) suggests that "…It would be interesting to identify the type of relationships that can facilitate the inter-organisational and intra-organisational knowledge transfer, information sharing and close collaboration in order to enhance the performance of infrastructure asset management." This is what the research addresses. Table 2 provides a summary of theses and dissertations incorporating in full or in part the organizational aspect of infrastructure asset management research.

As previously mentioned, the literature review is focused on the implied management of multiple – intrinsically different – asset classes and the subject matter is in full or in part concerned with organizational or asset performance measure improvements. From the table, other than the authors' previous thesis, all the organizational aspects involve interviewing or surveying subject matter experts.

Table 2: Related Theses and Dissertations with Respect to Organizational Aspect

Thesis / Dissertation	Organizational Aspect
Friedrichs 2007	asset management system application via survey of subject matter experts (SME)
Too 2009	organizational asset management capabilities via subject matter expert input
Esmaili 2012	organizational performance via surveying of subject matter experts
Rasa 2012	municipal project priorities via surveying of subject matter experts
Woert 2013	intra-organizational conflict on large engineering projects via SME input
Siriwardhane 2013	stakeholder attributes and salience through perspective of senior management
Mahlangabeza 2013	assessing an agency's asset management practice via subject matter expert input
Shahata 2013	workshop and survey of subject matter experts for risk index development
Posavljak 2013	horizontal asset management information flow via work experience and SME input
Zeb 2014	infrastructure asset management ontology via surveying of subject matter experts
Youssef 2015	asset interdependency and vulnerability via survey of subject matter experts

This is done either to discover new phenomena, get a perspective on existing practices, or supplement sample data sets provided by respective organizations. The research argues that the perspectives of such approaches - although widespread - are not sufficient for full corporate operationalization of asset management processes. The various complexities of infrastructure asset management processes are difficult to capture through this external lens to which academia has been inherently constrained for various reasons. It is argued that both, external and internal approaches are necessary for the practical advancement of the industry practice.

Table 3 summarizes those theses or dissertations focused on overall infrastructure asset performance measure improvements, more specifically on cross-asset trade-off analysis. The material provides a mixture of various prioritization techniques (e.g. analytical hierarchy process, optimization, etc.) and overall performance measures for multiple assets (e.g. utility, index, etc.).

Figure 4 shows the time distribution of other non-asset-centric literature that is related to the research. Its predominant sources are journal articles, but also includes a few books, white papers, and presentations.

Table 3: Related Theses and Dissertations with respect to Cross-Asset Trade-Off Aspects

Thesis / Dissertation	Cross-Asset Trade-Off Aspect
Sharma 2010	multi objective function via generic algorithm
Binhomaid 2012	heuristic and optimization techniques
Carey 2012	holistic methodology for synchronization of ROW works
Shahata 2013	integrated risk index
Posavljak 2013	integration of bridges into pavements
Saad 2014	equal marginal utility per dollar
Wang 2014	analytic hierarchy process, multi attribute utility theory
Youssef 2015	multi attribute utility theory, artificial neural network, fuzzy set theory
Chen 2015	multiple objective optimization techniques
Porras-Alvarado 2016	fair division, performance and value multi-objective optimization

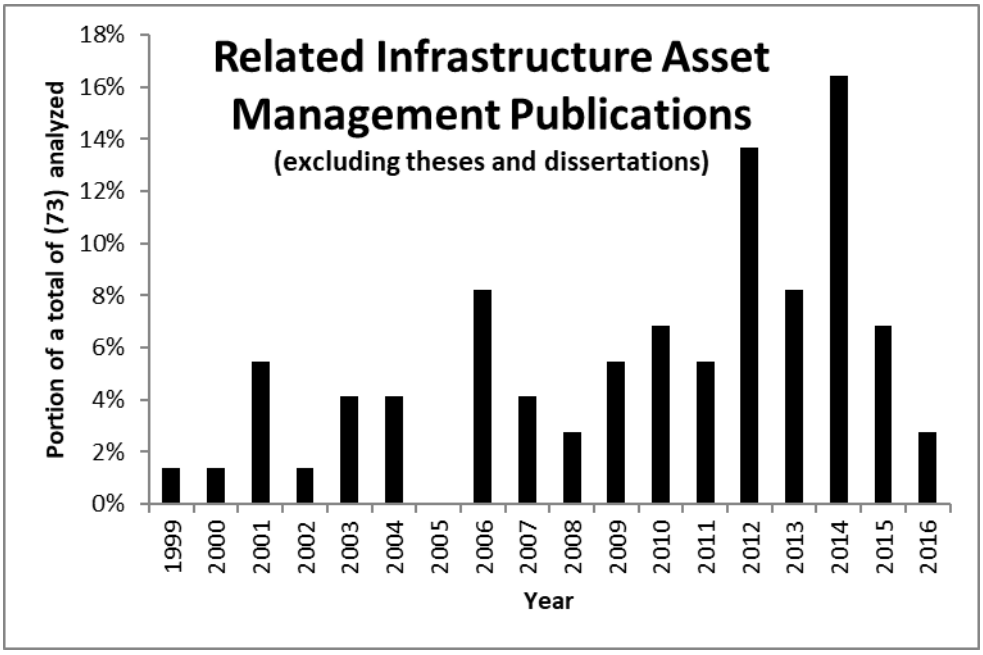


Figure 4: Academic Activity – Excluding Theses and Dissertations

Appendix A contains the list of items making up the figure above. A preliminary analysis of the material indicated a similar mixture of content as that found in the theses and dissertations review. One of the organizational aspects viewed from an external point of view looking at the organization, and various prioritization means to provide maximized overall infrastructure performance. In terms of the essence of an approach to solving the infrastructure challenge, Falls (2001, 2006) has the highest degree of similarity to that of this research. It looks at the common elements between the asset-centric pavement management to that of general asset management and examines how the material of the former can be applied to advance the latter (Falls et al. 2001). Also, the research "explores the links between silo systems and proposes an integration mechanism for cross optimization that recognizes the unique characteristics of individual asset categories." (Falls et al. 2006)

It is interesting to note that Figure 4 indicates a sustained overall average growth trend in related literature from 1999 to 2014, with a sharp decrease in the last three (3) years. While it is not claimed that the literature review accounts for the complete related literature sample space, it is argued that the trend is representative of the sample space.

The traditional approach of surveying, the analytical hierarchy process, and various prioritization techniques appear to be exhausted when it comes to advancing the state of practice at operational and tactical levels of managing agencies. The following three quotes and the respective time frame covered are offered as indications of this. "However, asset management has some issues to resolve in progressing from a framework to an operational reality." (Falls et al. 2001), "While many saw the usefulness, there was also genuine concern about [cross-asset tool] implementation." (Ford et al. 2014), "However, a few gaps need to be bridged before we can adequately conclude that asset management has moved from the stage of 'we believe in it and understand that we need it' into a stage of 'we understand how to do it, are implementing it and it drives our decision-making'; as adequately stated by one of our interviewees." (El-Diraby et al. 2015)

The gaps are indeed several; however, their bridging is of extreme complexity and mosaic detail.

3.4 Conclusion

The research's first hypothesis states:

1.Stakeholder surveys/interviews are the dominant modes of empirical research in the field of organizational behaviour theory as it applies to infrastructure asset management. The method of accessing the "corporate conscience" provides additional efficiencies in the effort of continuous organizational improvement, in this case being the application of asset management processes in public organizations.

In testing the first hypothesis, OATD was used to determine whether the dominant modes of empirical research in the field of organizational behavior are stakeholder surveys and/or interviews.

Initial search included the phrase "organizational behavior" without any category filters on the field of study. A total of 2,737 matches were found, a sample of eight (8) is shown in Table 4.

Table 4: General "Organizational Behavior" OATD Search

OATD phrase search: "Organizational Behavior" ,		Total Matches: 2737, Sample Count: 8, % of Sample Space: 0.29 %
Publication as catalogued	Survey and/or Interview Size	Publication Title
20091201_mogotsi_phd	283 positions	An empirical investigation into the relat...
20151201_delich_phd	181 positions	Organizational Behavior: Perceptions A...
20160801_barone_mstr	258 positions	Bad Boss, What Are You Going to Do? A...
20161101_muzanenhamo_mstr	250 positions	The Relationship Between Change Impl...
20170101_mercer_phd	421,748 position	Influences of Organizational Justice and...
20171206_hsia_phd	33,095 positions	The Role of Organizational Buy-in in Em...
20180901_kostoulas_et_al	230 positions	Successful Organizational Innovation an...
20190101_kjellstrom_phd	not applicable	Outsourcing of Organizational Routines ...

The reviewed publications covered a wide range of organizational aspects, none of which were deemed sufficiently similar to the aspects covered under the scope of this dissertation. Amongst others, these include knowledge retention, employee satisfaction, outsourcing, etc. Seven (7) out of eight (8), or 88% included surveys and/or interviews as the main mode of research. In order to assess modes applied to organizational research closer to that of this dissertation, the search was narrowed down to within the category of "Industrial and Systems Engineering", the results are shown in Table 5.

This adjusted search yielded a total of 96 matches, and 22 samples were reviewed. Surveys and/or interviews were found to be the main modes of research in 15 or 68% of the sample size. Two of these were completed by third parties and then used by researchers. Other modes noted as "not applicable" include exhaustive literature reviews, database information analysis and modelling, case studies, and work experience.

Basole's (2006) dissertation "Modeling and Analysis of Complex Technology Adoption Decisions: An Investigation in the Domain of Mobile ICT" (Information and Communication Technologies) contains an analysis of the research methodology for 365 studies published from 1975 to 2005. Figure 5 shows the results.

Table 5: Dissertation's Topic Applicable - Organizational Research within Industrial and Systems Engineering Fields

OATD phrase search: "Organizational Behavior" within category of "Industrial and Systems Engineering" Total Matches: 96, Sample Count: 22, % of Sample Space: 23%		
Publication as catalogued	Survey and/or Interview Size	Publication Title
19951201_aken_phd	130 positions	Determinants of Team Effectiveness for Cross...
19971120_jung_phd	179 positions	An Empirical Investigation of Tools and Joint P...
20010701_dong_phd	not applicable	Process Modeling, Performance Analysis and ...
20030903_delmotte_phd	third party	A sociotechnical framework for the integration...
20060201_sadia_phd	not applicable	A System Dynamics Approach Linking Employe...
20060801_basole_phd	109 positions	Modeling and Analysis of Complex Technology...
20070720_artis_phd	106 positions	The Effects of Perceived Organizational Support..
20081201_maldonado_phd	not applicable	Influence of Intellectual Capital Intermediaries...
20090101_voshell_phd	12 positions	Planning Support for Running Large Scale Exer...
20100222_li_phd	third party	Multi-Platform Strategy and Product Family D...
20100628_haro_phd	190 positions	An Evaluation of Perceived and Observed Safe...
20100812_kwon_phd	63 positions	A Model Based Design Framework for Interop...
20101215_chearskul_phd	219 positions	An Empirical Investigation of Performance M...
20110614_mitra_mstr	not applicable	Collaborative learning in Open Source Softwa...
20120101_romine_mstr	17 positions	Business Continuity and Resilience Engineerin...
20140101_raqab_mstr	not applicable	Gaining Monitoring Capabilities and Insights i...
20150518_ambler_phd	not applicable	Design in the Modern Age: Investigating the ...
20150811_keathley_phd	124 positions	Empirical Investigation of Factors that Affect...
20160325_wilcox_phd	81 positions	The Role of Trust in University-Industry Rese...
20160418_herrera_restrepo_phd	not applicable	Efficiency-Driven Enterprise Design
20190101_fitzgerald_mstr	not applicable	The IMPActS Framework
20200323_haghighat_phd	354 positions	A Theoretical and Empirical Investigation of ...

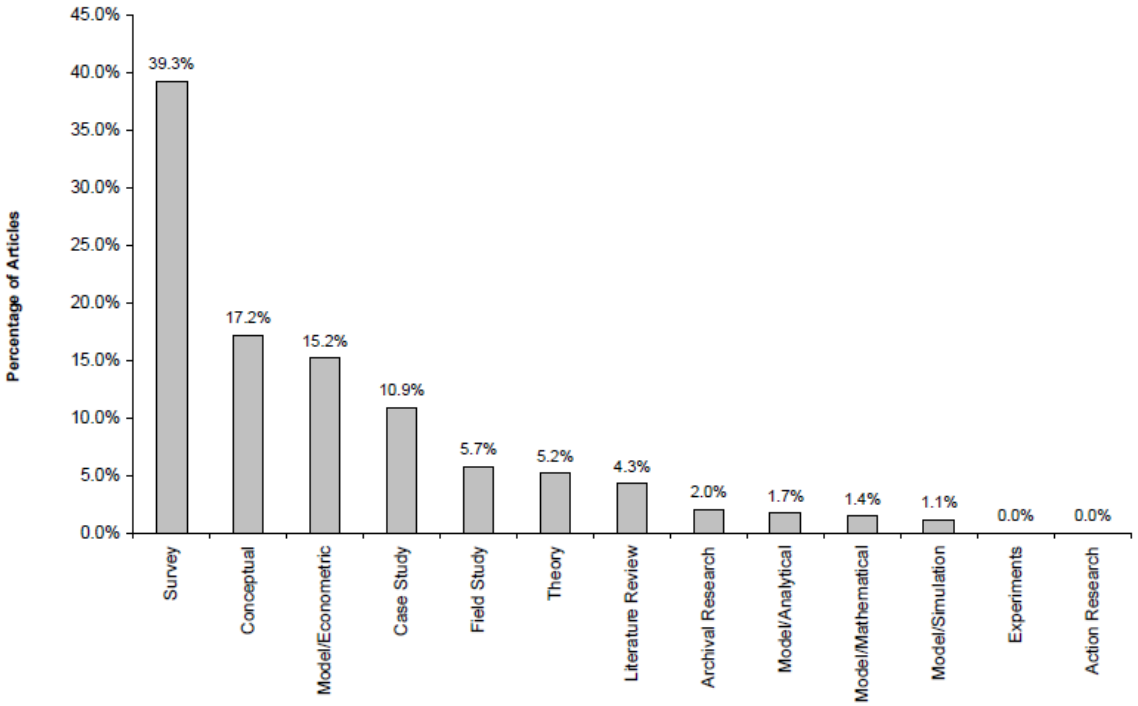


Figure 5: Distribution of Enterprise Adoption Studies by Research Methodology (Basole 2006)

The studies are focused on enterprise adoption of information technologies and excluded doctoral dissertations and working papers. A survey was the most applied methodology at 39.3%, it is unclear whether interviews are included under this category or spread out across the remaining categories. Information Systems and Information Technology (Cateogy I) journals were the primary sources of enterprise adoption research.

Basole noted that "none of the studies included in this review employed an experimental or action research approach", which are the main two modes of the research herein. Central to data experimentation is the creation of an enterprise-wide – asset management system, which is then adopted across the corporation through parallel processes of taking action and doing research.

According to Basole, "…the nature of research on enterprise adoption of ICT (Information and Communication Technologies) is difficult to confine to specific disciplines, relevant material is scattered across various journals, book chapters, and conference proceedings." (Basole 2006). Assuming infrastructure asset management -in addition to the Civil Engineering field – falls within the field of Industrial and System Engineering, the following hypothesis is argued to be true:

1. *Stakeholder surveys and interviews are the dominant modes of empirical research in the field of organizational behaviour theory as it applies to infrastructure asset management. The method of accessing the "corporate conscience" provides additional efficiencies in the effort of continuous organizational improvement, in this case being the application of asset management processes in public organizations.*

It is argued that the novel "corporate conscience" concept is a subset of active research, offering the following efficiencies:

- access to complete horizontal corporate information flow
- access to maximum detail and quantity of information
- ability to plan full-scale bottom-up corporate improvements

that will be explained in detail in Chapter 5. For these reasons, it is argued that the first hypothesis is true.

3.5 Summary of Findings

The literature review has confirmed that related research is to an extent dominated by stakeholder surveys when it comes to the organizational aspect of the research. Compared to an "active research" approach the survey approach is relatively limited with respect to providing a foundation from which to operationalize asset management practice within an organization.

In the reviewed literature, the theme of operationalizing asset management practice as an item that is "still left to do" is prevalent. This is a perspective shared from the earliest to the latest literature available. The initial in-depth literature review was completed in 2017. The OATD was used again in 2024, no additional related literature was found that would change the findings of the initial literature review.

Perhaps the closest finding to the presented research herein is the following: "However, a few gaps need to be bridged before we can adequately conclude that asset management has moved from the stage of 'we believe in it and understand that we need it' into a stage of 'we understand how to do it, are implementing it and it drives our decision-making'; as adequately stated by one of our interviewees." (El-Diraby et al. 2015)

The bridging process, as proposed in this research, is titled Corporate Operationalization of Asset Management (COAM), and the following chapter describes the associated research.

Chapter 4

Experiment Design and Conduct

Corporate operationalization of asset management processes (COAM) does not involve material testing, yet it is important to draw abstract parallels with such experimentation. This approach uses the existing value of academic familiarity with traditional materials engineering design as a framing vessel for the research.

Table 6 shows a generic material testing experimental design and the equivalent COAM elements. This analogy is intended to provide context for the process using an example that is familiar to engineers.

Table 6: Experimental Design

Step	Generic Engineered Material Testing Experiment Design	Equivalent COAM Experiment Design
1	define / measure / test / document raw material properties	examine / document nature, format, and flow of raw corporate information
2	define / measure / test / document engineered material field assembly environment conditions	examine / document vertical and horizontal corporate structure
3	mimic field environment assembly conditions in laboratory	categorize raw information according to horizontal corporate structure areas (engineering, finance, administration)
4	laboratory assembly / production of engineered material sample from raw material	derive corporate data-driven asset performance measures from existing raw corporate information
5	laboratory testing under simulated field environment conditions	create asset management system (e.g. Excel-based) to improve communication between engineering, finance, administration
6	variance of independent variables, studying of respective relationship	run various asset performance vs. expenditure scenarios
7	drawing of conclusions and limitations	drawing of conclusions and limitations
8	independent repetition of steps for scientific validation and / or field application	independent repetition of steps for scientific validation and / or field application

The goal of a generic engineering material research effort may be to demonstrate how a new material could shorten the production duration of structural members (e.g. prefabricated floor slabs) thereby providing a mechanism for the manufacturer to improve its efficiency and customer options. One of the many possible sub-goals or constraints could be that the new material must be produced in such a way as to minimize the cost of incorporating it into existing production lines. Hence, if there were two new material options that outperformed a third one, only within the realm of new material characteristics, but

underperformed in terms of minimizing existing production line cost-the third option would be recommended for implementation.

Similarly, the goal of the research is to demonstrate an original approach for corporate operationalizing of asset management (COAM) processes, thereby providing a mechanism for public agencies to improve decision-making capabilities for infrastructure investment and performance. Such that out of the many available sub-goals or constraints, the main or guiding one for this research is to minimize implementation duration into existing corporate processes. Hence, every research detail is subject to this constraint. For example, even though a complex multi-objective optimization is arguably "more powerful" and "finds the absolute optimal solution" from an academic point of view - a simpler, less powerful heuristic prioritization was recommended due to a lower implementation impact on the existing organizational processes. In essence, provided the complexity of managing municipal infrastructure systems, incremental improvements must be as simple as possible. Introduction of unnecessary complex heuristics – for which existing information nature, format, and flow require change - just because they are "more powerful" from an academic point of view; significantly impacts the efficiency and effectiveness of the goal of minimizing implementation duration into existing corporate processes.

Ten years of practical experience suggests that this constraint of minimal impact to existing organizational processes must be satisfied in order to fully operationalize asset management processes at operational and tactical levels across the corporation. The constraint's argument originates from vehicle manufacturing research. Specifically, one which states that successful process adjustments ensure that an improvement in one unit (e.g. position, section, division) does not create non-absorbable input variety by another unit downstream (Duimering et al. 1993).

The following sections provide details on the experiment design steps.

4.1 Nature, Format, and Location of Raw Information

The first step is to ensure that all existing corporate information is analyzed. All means just that, all information, other than personally sensitive information, which is typically kept secure by a Human Resources unit. Nature refers to what the information is describing (e.g. asset condition data, financial data), while format refers to the information's form (e.g. access database, word file, spreadsheet, SQL server, etc.). Location refers to organizational units where the information typically resides.

While this may seem like a standard-exceeding effort, it is actually the minimum necessary for those who have yet to go through the process of COAM. Failure to execute this step is the equivalent of testing pavement cores, having extracted only the top surface course from the field – a representative cross-section is missing.

Another example of traditional engineering terms for this step is the conduct of a topographical survey of a construction site prior to designing a structure. Table 7 contains an example of analyzed information.

Such analysis forms the foundation of COAM. The following section looks at the flow of the analyzed information across the corporation.

Table 7 shows the quantity of information involved in COAM available in the different organizational units : Infrastructure Management, Operations and Maintenance, Financial Planning, and Accounting. This information is the bedrock of asset management processes upon which new ones are built. The data comes from one of the municipalities the researcher worked with. The numbers represent the quantity of information in related applications, databases, files, etc. as analyzed by the researcher. Similar to how a topographical survey for construction provides a starting point for design, in this case, this information provides the starting point when designing an asset management system.

Table 7: Example of Nature, Format, and Location Analysis

Information Source	Infrastructure Management	Operations and Maintenance	Financial Planning	Accounting
Number of Excel sheets	51	51	135	51
Average number of columns	11	15	19	22
Average number of rows	397	74	142	1020
Number of Access tables	37			
Average number of columns	19			
Average number of rows	9121			
Number of GIS tables	58			
Average number of columns	58			
Average number of rows	7574			
Exported Application Excel sheets	7	8		
Average number of columns	22	36		
Average number of rows	1406	6352		
Number of hardcopies	377	1252	127	127
Core Applications	Pavement	Maintenance	Financial	Accounting
	Management	MS	MS A	MS A
	System (MS),		Financial	Accounting
	Facility MS,		MS B	MS B
	Mapping MS,			Accounting
	Pipes MS,			MS C
	Geographical			
	MS			

4.2 Vertical and Horizontal Corporate Structure

The detailed study of vertical and horizontal corporate structures provides the all-important organizational dimension to COAM. Without this the previous materials analogy has no representative cross-section to test. Arguably one of the most concise definitions of asset management is: “Asset management is a systematic process of maintaining, upgrading, and operating physical assets cost-effectively. It combines

engineering principles with 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." (FHWA 1999). Assuming this definition to be absolute, the removal of any term from it would render it irrelevant as a definition. Therefore, the only entity that fulfills its terms in full is not one position, unit, section, division, or department, but rather the whole and complete organization. It is therefore essential to analyze in detail the least complex entity performing the full range of activities as listed by the definition above – which is the entire corporation.

Over 100 organisational structure schematics (readily available online) of public infrastructure agencies were reviewed. Their format was found to be exclusively constrained to a typical pyramidical perspective. Inherit to this view is the decreasing number of positions moving up the structure, and vice versa. Also, moving up the pyramid, the ability to allocate resources (and overall responsibility) increases, while detailed subject matter knowledge decreases, and vice versa.

For COAM, it was important to show a hybrid project organizational schematic, one showing the typical authoritative (i.e. pyramidical) positional relationship lines, as well as those supporting them from a "horizonal" point of view. Figure 6 shows an example of such a schematic, created by the researcher for the purposes of the project

The "Steering Committee", "Project Sponsor", and "Project Team" are predominantly focused on overseeing the overall effort of implementing asset management. Their strategic guidance ensures external and internal stakeholder input is addressed accordingly. The "Project Manager" and "Consultant" work directly with "Primary Support" and "Subject Matter Experts". "Primary Support" (PS) positions and associated units are those which to varying extents are affected during the planning, development, implementation, and maintenance of COAM. Following a review of the information used by the PS position (i.e. nature, format, and location), 30-minute interviews were conducted with each Primary Support position. In total 18 PS interviews were conducted. "Subject Matter Expert" (SME) positions are those that typically have a direct relationship with infrastructure. This can range from engineering project managers to staff that operate the infrastructure. Following study of information used by SME positions, 30-minute interviews were conducted with them as well. In total 24 SME interviews were conducted. From this collaborative effort involving knowledge exchange, the flow of relevant information throughout the corporation was defined, as discussed in the following section.

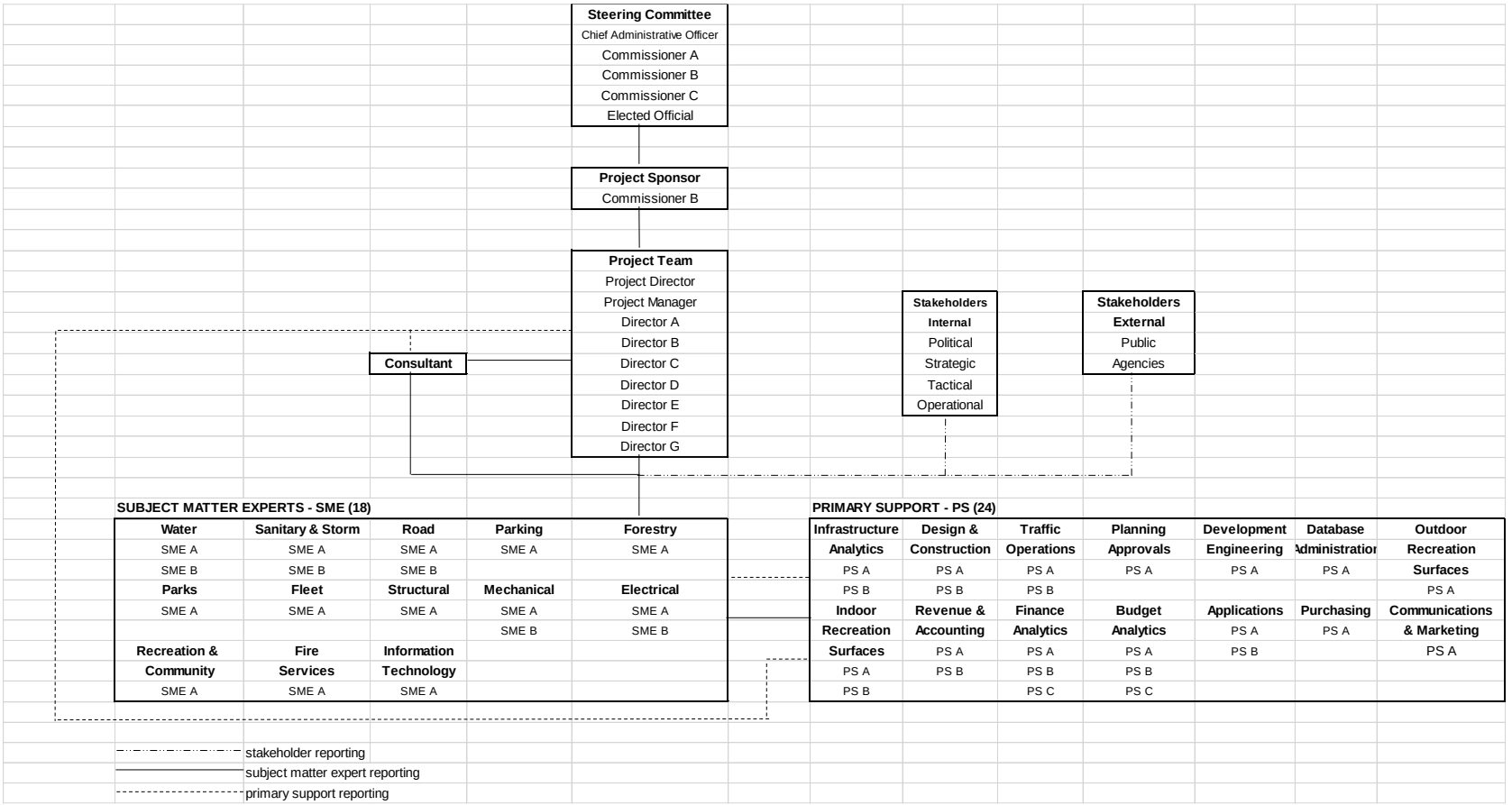


Figure 6: Hybrid Project Structure Schematic

4.3 Categorization of Raw Information According to Horizontal Corporate Structure Areas – Information Flow (Engineering, Finance, Administration)

As in the study of operational analysis, it is important to map out how the corporate structure supports the flow of raw information to manage public infrastructure. This is equivalent to mapping out a manufacturing process or a supply chain, which can then be analyzed for bottlenecks deterring productivity or optimal product quantity to maximize profitability. Lessons from the field of operational analysis are transposed onto corporate asset management processes. This step subsequently yields a Corporate Operationalization of Asset Management Processes Framework. It is used as the bedrock when it comes to operationalizing processes with minimal impact on those currently existing. The three main categories, which are further disaggregated in Chapter 5, are engineering or subject matter experts, finance, and administration. The categorizations of this step will subsequently provide the means for corporate data-driven asset performance measures. Figure 7 contains the COAM Process Framework.

The framework describes the general horizontal asset management process flow which takes place across an asset management agency, thereby providing an alternate visual to the typical "silo" structure view.

- Box 1 represents the physical environment within which the tangible capital assets exist.
- Box 2 indicates the flow of information from the assets to Infrastructure Management sections or units. These typically contain nodes (e.g. excel spreadsheets, databases, etc.) of high information concentration, such as project lists, maintenance prioritizations, asset performance data, etc. In general, asset needs are generally converted into capital projects through collaboration with Financial Planning. Maintenance programs are developed and carried out by Operational Maintenance sections or units.
- programs are developed and carried out by Operational Maintenance sections or units.
- Box 3 indicates the flow of information from Infrastructure Management sections to the Financial Planning section. Information from across the organization is aggregated as per financing policies and procedures and used in the budget cycle process.
- Box 4 indicates the carrying out of tangible capital valuation and reporting as per the PSAB 3150 (PSAB 3150 2017), while
- Box 5 shows an example of the overall business administration examples that govern the first four (4) boxes. For example, yearly budgets and forecasts which are created through the efforts described in boxes 1-4 are approved by the Council. Once approval is obtained, the flow is reversed as allocations reach the necessary points within the organization until necessary improvements to infrastructure are carried out.

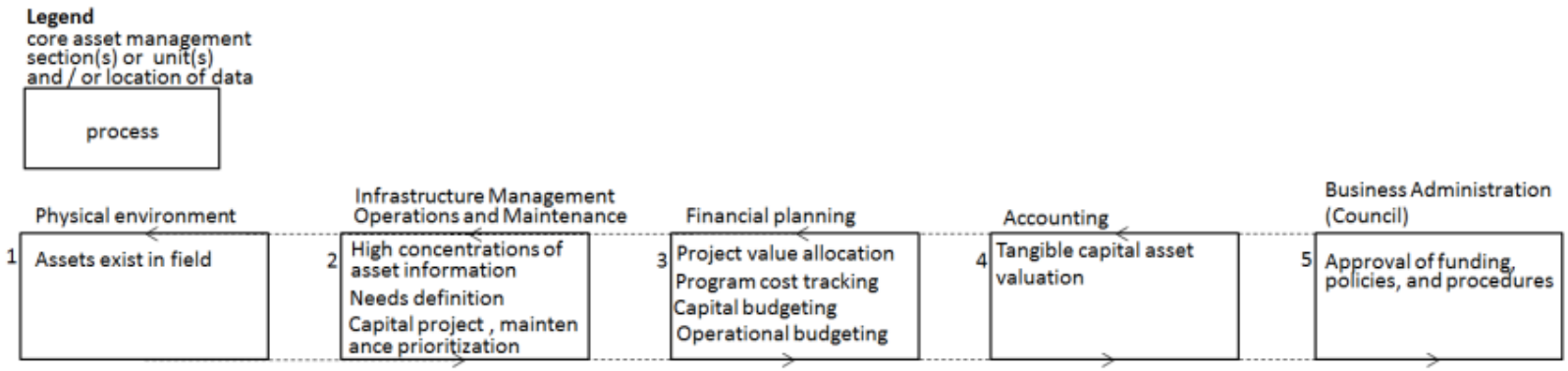


Figure 7: Corporate Operationalization of Asset Management Processes Framework

It is important to note that the COAM Process Framework described shows the general information flow from the assets to the funding approval authority, and back to the assets in the form of improvement treatments; it does not preclude the regular micro information exchanges that may occur outside of the general process lines described within the framework.

Asset management literature developed to date typically does not explicitly differentiate between organizational and documental elements within framework diagrams; this can sometimes lead to confusion by parties attempting to adhere to them. In order to minimize such occurrences, a separate Documental Asset Management Framework is necessary as shown in Figure 8.

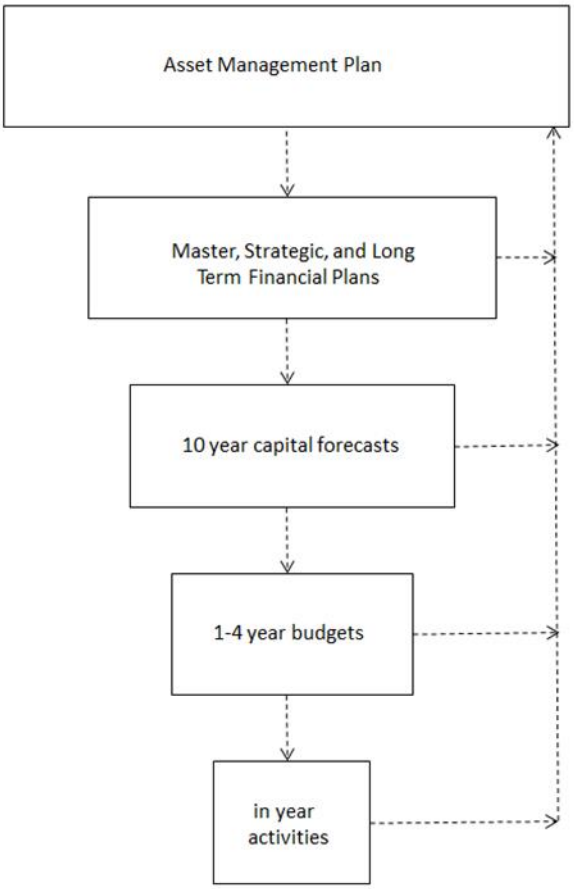


Figure 8: Documental Asset Management Framework

In the context of Canadian municipalities the Asset Management Plan is the starting and final point of all planning-related activity regarding tangible capital asset needs and allocations, including addressing any relevant information from existing Master, Strategic, and Long-Term Financial plans. Any available capital and operational budgets, and 10-year forecasts create the initial backbone of the plan but will in subsequent years be derived from the Asset Management Plan. The plan is the practical output of COAM and allows for more efficient and effective internal communication between the engineering (subject

matter expert), financial, and administrative professionals when it comes to infrastructure planning. The same efficiencies are then projected onto external municipal communication with the public, other levels of government, etc. The plan spans the next 25 years, covering respective entire lifecycles of assets within the time window. For assets with designed lifecycles greater than 25 years, the forward-looking time span of 25 years provides sufficient lead time for their treatment cycles.

The plan includes but is not limited to the following asset classes: roads, sidewalks, road illumination, bridges and culverts, sanitary sewer collection, water distribution, storm sewer collection, facilities, parks, fleet, equipment, and furnishings.

The plan's purpose is to allow the municipal administration to allocate infrastructure funding according to the expected infrastructure asset performance (expected level of service) over time. There are two overarching categories of performance measures, one defined by professionals or the industry, and the other defined by public stakeholder input. The following section contains further details on performance measures.

4.4 Corporate Data-Driven Asset Performance Measures

Following the study of the organizational and informational aspects of public infrastructure management, the remaining key items to be examined are the performance measures used for each of the infrastructure asset classes.

Table 8 contains the performance measures per each asset class that are used and readily accepted by the industry over the past decades. For this dissertation, these measures are termed as "Standard Established Performance Measures" or SEPMs. Their sources can be traced back to academic and industry efforts in defining asset performance.

One unexpected, but critical finding of the research was that the asset's age had become the predominant SEPM for current and future forecasted asset performance. In Canada, this is the result of the Public Sector Accounting Board's directive "PSAB 3150" from 2008. However, independent of PSAB 3150, managing agencies that do not have the resources (which is the majority of them) to collect non-age-based SEPMs, are by default "stuck" with exclusive age-based forecasting.

With this finding, the research effort shifted from attempting to solve the "cross-asset trade-off analysis" challenge to "scientific-based" rather than "age-based" single asset-class forecasting. It is argued that this challenge requires solution before "cross-asset trade-off analysis" can comprehensively be looked at.

Concerning taxonomy, it is argued that the term "asset performance" is the overall arching term when describing an asset's current or future expected "level of service" provided to the public. This term then breaks down into two categories: conditional and functional, as shown in Table 8. These include SEPMs taught at respective educational institutions that have been used in the industry for decades now. In addition to them, there is another set of condition-based and functional performance measures that the local community can expect and define. However, these are typically looked at as an explicit means to "engage the public" in local decision-making, and can through discussion with professionals (i.e. public servants) be traced back to SEPMs shown in Table 8.

Table 8: SME Standard Established Performance Measures (Non-Age Based) (Posavljak et al 2019).

Asset Class	Condition-Based Asset Performance		Functional Asset Performance	
	Established	Example	Established	Example
Roads	x	Pavement Condition Index	x	Average Daily Traffic
Sidewalks		Frequency of Surface Distress	x	Trip Hazards
Trails		Frequency of Surface Distress	x	Trip Hazards
Sanitary	x	PACP* Score	x	Flow Capacity
Water	x	Break Frequency	x	Flow Pressure
Storm	x	PACP Score	x	Flow Capacity
SWM**	x	Sediment Volume	x	Storage Volume
Facilities	x	Facility Condition Index	x	Disability Access
Fleet	x	Distance Travelled	x	Capacity to Address Demand
Parks		Mix of Other Asset Classes	x	Variety of Activities Available
Forestry	x	Tree Health	x	Canopy Spread
Parking	x	Pavement Condition Index	x	Capacity to Address Demand
Fire		See Fleet, Facilities and Equipment	x	Response Time
Equipment		Extent of Wear and Tear	x	Capacity to Address Demand
IT***		Extent of Wear and Tear	x	Capacity to Address Demand
Cemeteries		Mix of Other Asset Classes	x	Capacity to Address Demand

*PACP - Pipeline Assessment Certification Program, **SWM- Stormwater Management, ***IT – Information Technology

The limitation of only age-based performance forecasting (i.e. PSAB 3150) is that SEPMs are ignored. While a mix of age-based and SEPMs can, through professional management, be used for decision-making in the short term (i.e.1-3 years), the forecaster is left with only age-based forecasting for mid to long-range forecasts, as SEPMs cannot be collected in the future. One would think that the solution here is to forecast the SEPMs over the mid to long-range as well. However, another unexpected research discovery is that there is a whole other set of variables exclusive of SEPMs that arguably play a more significant role in decision-making. For this research, they have been termed "Corporate Decision Factors", Table 9 lists these core factors. These factors apply to all asset classes.

The first column shows the nomenclature of the Corporate Decision Factors affecting forecasting, while the second column provides specific examples of each factor.

It is important to note that once an infrastructure managing agency reaches "decision-time" concerning approving a budget (i.e. Box 5 in Figure 7), it has only five options for capital projects and maintenance activities submitted by subject matter experts and financial planning:

1. Approve all
2. Delay a selected number of
3. Bring forward a select number of
4. Modify boundaries and nature of work for a selected number of
5. Disapprove all

Before elected officials (i.e. municipal council) make these decisions, subject matter experts and financial planners take into consideration the Corporate Decision Factors in preparing the proposed budget. Council typically goes through the same set of factors, plus their political sway, and typically, few, if any, changes are made before approving the budget.

The approval may carry an increase in the taxes to be paid by the public in the coming years. It directly impacts their "pocket" and therefore their standard of living. In order to ensure minimal fluctuations of these increases (i.e. socio-economic stability), it is necessary to plan beyond the three-year span, because infrastructure projects typically take one to three years to complete. If the forecasts beyond three years do not account for the Corporate Decision Factors and are only age-based as per PSAB 3150, there is a risk of unnecessary socio-economic instability.

Table 9: Corporate Decision Factors – Not Accounted for by SEPMs (Posavljak et al 2019)

Corporate Decision Factors Directly Affecting Past, Present and Future Asset Performance	Examples of Questions / Comments Considered by Public Administrations Making Infrastructure Asset Management Decisions
Economies of Scale	"In order to group projects in proximity, we have to delay or move up treatment of certain assets."
Level of Service - Community Category	"'Good' asset performance category for our small town and 'Good' for a larger city is not the same, nor should it be."
Funding Capacity	"We have maxed out all possible funding means, this is the best we can do without exponentially raising taxes."
Project Delivery Capacity	"Even if we had the funds to address all needs according to SEPMs*, we would have to drastically expand our project management team, and then decrease it once the backlog needs are addressed."
Specific Funding Accommodation	"The global green infrastructure fund is providing funding only for these specific assets, therefore we are moving up their treatment."
Cost Sharing Potential	"The regional government is treating this regional road in year X, we should wait or move up our underground work to line up with their timing."
New Design Standards Accommodation	"If we go with the replacement of the asset as planned, the like-for-like replacement does not meet the new standard, therefore let's push it out until we have the funds for the option that does meet the new standards."
Portion of Asset Network Expressed by SEPMs	"Do we know what sort of overall impact this project will have on the overall performance of the network? Perhaps another project should go forward first."
Timeliness of SEPMs* Information	"How up to date is our SEPMs* information which we are taking into account for decision making?"
*Subject Matter Expert (e.g. engineering) Established Performance Measures	

The only plausible means to switch from an age-based (PSAB 3150) to a scientific-based forecasting model is to analyze previous decades of infrastructure spending. This is because only that information inherently holds the Corporate Decision Factors which played a role in yielding the community's infrastructure to date. Excluding such information from forecasting neglects two essential factors of municipal infrastructure management:

1. Interdependence of different asset classes among assets providing holistic infrastructure services, and
2. Uniqueness of each community.

Forecasting individual SEPMs - which is currently the dominant mode in the industry – neglects the "oneness" of all asset classes in providing "infrastructure service" to the community.

Painting of all individual asset classes and their components (e.g. pipe sections) with singular Estimated Service Lives (i.e. PSAB 3150) neglects the uniqueness of individual components' environments (e.g. corrosivity of soil surrounding section of pipe), of asset classes (e.g. various construction techniques used across decades) and socio-economical uniqueness of each community that the infrastructure serves.

In order to avoid the above generalization, new comprehensive and implicitly objective asset performance measures are necessary. Engineering risk and reliability principles are applied to develop deterministic asset deterioration rates for the most granular level of asset inventory within each asset class. This subsequently sets up a layer of information that is ready for probabilistic risk calculations. Provided that the deterministic risk is based on actual corporate data, theoretical calculations, such as the assignment of relative risk scores, are avoided.

The comprehensiveness and implicit objectivity are based on the use of actual corporate data (i.e. SEPMs and Corporate Decision Factors). The data is a by-product of engineering/subject matter expert, finance, and administrative decision-making over the decades of infrastructure asset management, while the product is the infrastructure itself. The following section derives the Comprehensive Asset Performance Measure CAM.

4.4.1 Comprehensive Asset Performance Measure – Infrastructure Asset Performance Stock (iPS)

Before deriving a comprehensive measure, it is important to discuss the level of objectiveness which it can obtain. It is assumed that its objectivity is proportional to the objectivity of the environment it is derived from. As such, the following discussion is necessary about the environment from which corporate numbers are generated that in turn are used to derive a comprehensive asset performance measure.

The professionals compete for various agency positions through job competitions posted by managing agencies. Prior to an interview, their curriculum vitae must satisfy a set of requirements pertaining to education, knowledge, skill, and work experience. It is assumed that the educational institutions of the developed world are leading, and therefore produce world-leading professionals in all areas of

employment, including engineering, finance, and administration. This leads to another assumption, which is that these educational institutions cover the topics of economic, social, and environmental impacts of decision-making to the highest degree of objectivity possible, based on the existing body of knowledge. If a strictly binary approach is taken to these assumptions, their negation would imply otherwise, subsequently challenging the free market value of such educational programs and their products (i.e. professionals within infrastructure managing agencies), which are valued in the billions of annual dollars in North America. The one question used by some individuals to do just that is: "But how do we know that we made the right decisions in the past?" A question that does not warrant consideration given the subject matter at hand. Therefore, it is argued that these objective decision-making processes take into account asset design, condition, economies of scale, social and environmental impacts, and financial and administrative implications – the theory and practice of which would initially be taught at appropriate college and university programs. Since, objective decision-making processes, yield objective by-products (i.e. corporate data), it is argued that deterioration rates and accompanying performance measures derived from the corporate data created by such professionals are also objective. The following figures (Figures 9-13) show the comprehensive asset management performance measure derivation, For the purposes of this dissertation, and potential future industry use, these measures have been coined as "Infrastructure Asset Performance Stock" (iPS) as published in the Institute of Civil Engineers' Journal of Infrastructure Asset Management (Posavljak et al 2019):

$$m_{tt} = \frac{1}{n}\sum_{1}^{n}(t_a - t_{pa}) \qquad \text{(Equation 1)}$$

where,

m_{tt} is the asset's mean time to treatment or improvement activity

n is the number of treatments or improvement acitivites

t_a is the year of treatment or improvement activity

t_{pa} is the year of the previous improvement activity

Figure 9: Average or Mean Time to Treatment Derivation

Mean Time to Treatment is derived from corporate information. Specifically, by reviewing financial, subject matter expert (e.g. engineering), and administrative information, year of initial construction and subsequent treatment years are defined.

$$TT_{iPS} = 1 - AAD_{iPS}(m_{tt}) \qquad \text{(Equation 2)}$$

where,

TT_{iPS} is the asset's treatment trigger or improvement activity iPS threshold value

m_{tt} is the asset's mean time to treatment or improvement activity

Figure 10: Treatment Trigger Derivation

Asset's Treatment Trigger is the value at which a treatment is applied when forecasting future performance.

$$AAD_{iPS} = \frac{1}{n}\sum_{1}^{n}\frac{c_i}{r_i(t_a - t_{pa})} \quad \text{(Equation 3)}$$

where,
AAD_{iPS} is the average annual deteriortion of iPS
n is the number of treatments or improvement acitivites
c_i is the cost of treatment or improvement activity
r_i is the cost of asset replacement
t_a is the year of treatment or improvement activity
t_{pa} is the year of the previous improvement activity

Figure 11: Average Annual Deterioration Derivation

It is argued that the Average Annual Deterioration is the yearly consumption of the asset, hence the term "Consumer-Based" approach. Furthermore, it is argued that the total deterioration over a time span is equal to the value of the treatment that was applied at the end of the time span. For example, the value of a home renovation is how much a particular home has deteriorated since first being constructed.

$$iPS_{t_{Ti}} = 1(SEPM_S) \quad \text{(Equation 4)}$$

where,
$iPS_{t_{Ti}}$ is the asset performance after last asset treatment or inspection (1 to 0)
$SEPM_S$ is the value of the Subject Matter Expert Established Performance Measure as inspected, but scaled to a range of 1 to 0

Figure 12: Asset Performance Reset Post Treatment or Inspection

It is argued that the performance of an asset goes back to a value of "1" after a treatment. This does not mean that it is in brand new condition, but rather, that it is the best achievable condition provided the managing agency's financial capacity and expectations from the asset. However, if the asset is inspected after treatment, its current performance can be adjusted by entering a value of less than "1" into the above equation under variable $SEPM_S$.

$$iPS_{t_o} = iPS_{t_{Ti}} - AAD_{iPS}(t_o - t_{Ti}) \quad \text{(Equation 5)}$$

where,
iPS_{t_o} is the asset performance in current or any future year (1 to - ∞)
$iPS_{t_{Ti}}$ is the asset performance after last asset treatment or inspection (1 to 0)
AAD_{iPS} is the annual asset deterioration (1 to 0)
t_o is the current or future year for which perfomance is being calculated
t_{Ti} is the year of last asset treatment or inspection

Figure 13: Asset Performance Derivation (Posavljak et al 2019)

Current asset performance is calculated by subtracting deterioration from its last treatment or inspection performance value.

Table 10 shows the qualitative performance boundaries of iPS.

Table 10: Qualitative Performance Boundaries

Performance Ranges		
Good	$1 \geq \boldsymbol{iPS} > (1 - TT_{iPS})/2$	
Fair	$(1 - TT_{iPS})/2 \geq \boldsymbol{iPS} > TT_{iPS}$	
Poor	$TT_{iPS} \geq \boldsymbol{iPS}$	

(Posavljak et al 2019)

Table 11 contains an example of the iPS calculation.

Table 11: Example Calculation of iPS

asset A			
year of construction 1989			
year of first treatment 2011			
reconstruction value $682,344			
treatment cost $284,469			
year of iPS calculation - 2018			
m_{tt} = 2011-1989			
= 22			
TT_{iPS} = 1-(0.0189)22			
= 0.5842			
AAD_{iPS} = ($284,469/$682,344)/(2011-1989)			
= 0.0189			
t_o = 2018	iPS_{2011} = 1		
iPS_{2018} = 1 - 0.0189(2018-2011)			
= 0.868			

A value of 0.868 yields a qualitative performance category of "Good", as per Table 10. It was found that in order to increase the ease of communication with municipal practitioners, the deterioration rate above required scaling such that the treatment trigger for all assets in the inventory was equal to 0.

Subsequently, the top half between 1 and 0 is in "Good" performance, the bottom half is Fair performance, below 0 is "Poor" performance, requiring asset treatment. A "1" does not necessarily mean that the asset is "perfect" from a professional or public point of view, but that, given the community's capacity, it is a 1 from a holistic corporate point of view.

It is very important to note that the above forecasting mechanism's goal is to project the future 25-year infrastructure performance and required funding at an aggregate level. Specifically, the budget and associated projects and maintenance activities according to what the desired or expected performance level of infrastructure as a whole is at the time of forecasting. The inherent scientific limitation of single entity forecasting is present in this application as is in, for example, the automobile insurance industry. Specifically, past vehicular accidents and claims are analyzed at an aggregate level, in order to set future individual insurance policies, which are aggregated according to driver characteristics and driving/living environment. There is yet to be a scientific forecasting means to reliably predict which vehicle and when is due for an accident. Similarly in banking, the historical return and delinquency rates on loans are analyzed at an aggregate level, and subsequent future forecasts are set. In the consumer goods industry, historical purchases are analyzed at an aggregate level, to forecast future aggregate supply needs. The purpose of the above examples is to draw quick-basic parallels between the infrastructure industry and other industries, to help in understanding the scientific limitations of forecasting as applied to infrastructure. A deeper study of each example is outside the scope of this research.

The goal is to have an overall budget that is sufficient enough to meet the overall expected performance, single-asset forecasts are not necessarily reliable, as this is an inherent scientific limitation of forecasting in general. Figure 14 provides further details on this important matter. It was developed to educate staff on what the limitations of infrastructure forecasts are. Step 1 is the setup of a database for forecasting; there are several assets (in this case, ten assets) to be forecast over a period of time (in this case, ten years). In Step 2, once the iPS value reaches TT_{iPS}, an average treatment value is forecast. These are single-asset forecasts, which are added up in Step 3 to provide an aggregate forecast. In Step 4, adjustments of single asset forecasts are made by staff in the 1–3-year window concerning cost and timing. This is due to having more available information regarding the assets at the time of "acting upon them", rather than when they were forecast years earlier. The main factors impacting the single asset forecast adjustments are in Tables 8 and 9.

It is interesting to note, while the generation of information (i.e., historical information) for forecasting, for example in the car insurance industry is created in seconds (i.e., vehicle crash), it takes years for the same to occur in the infrastructure industry. That is, for construction projects to be selected based on competing needs and a limited budget. Unlike the vehicle insurance industry, which does not influence where, when, and who is going to crash next, the infrastructure industry directly influences the 1-3, sometimes 1–5-year window of projects. Again, this is necessary, as there is typically more relevant

information available for decision-making at the time of "acting upon them", rather than when they were first forecast years earlier.

Through deduction, the corporate data-driven asset performance measures provide a window into the corporate perception of infrastructure performance and its subsequent behaviour in managing it. It is argued that evidence-based decision-making already occurs within agencies, it is just a matter of communicating it systematically. The next section discusses the types of risk that can pertain to asset management as applied to public infrastructure.

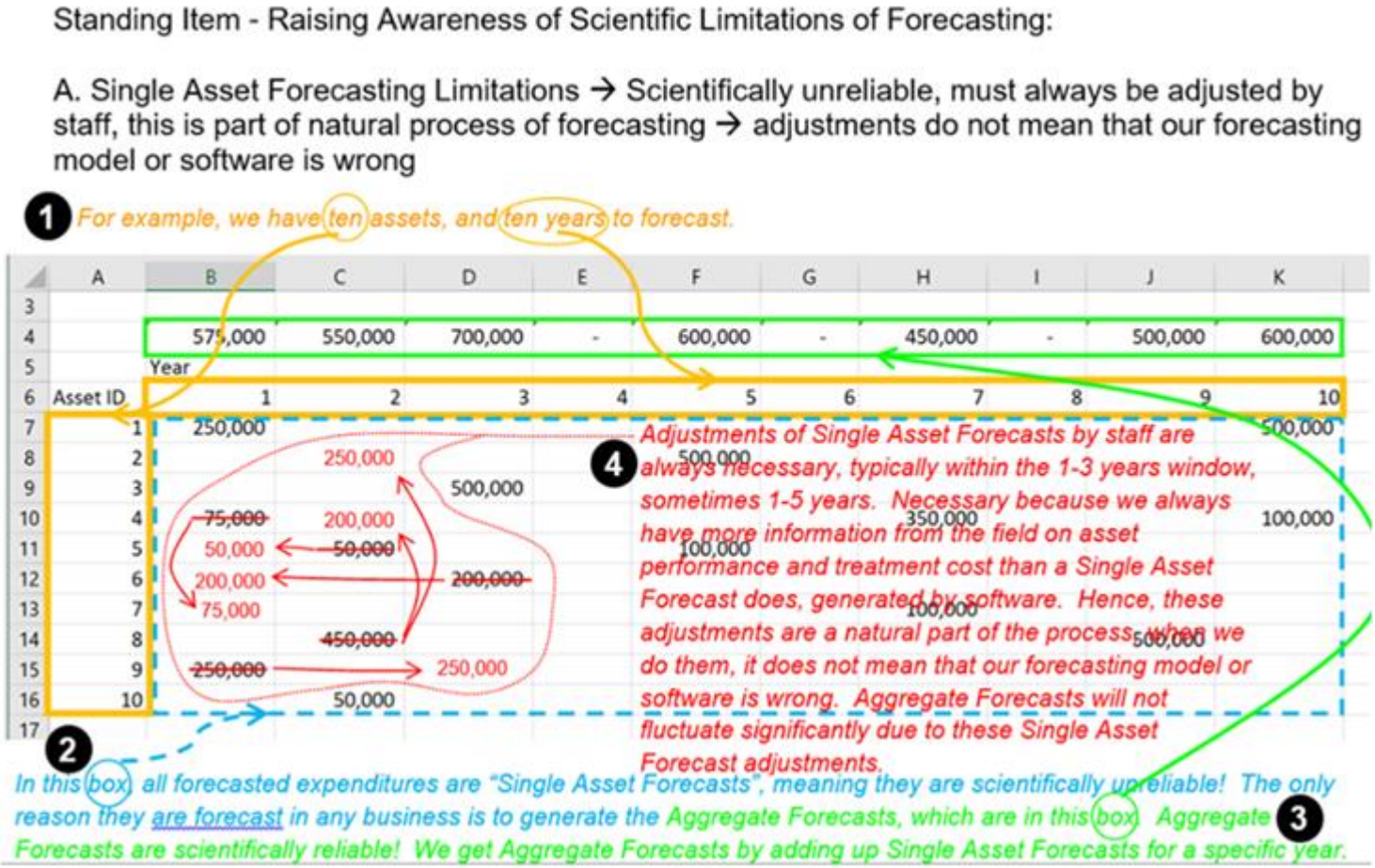


Figure 14: Scientific Limitation of Forecasting as Applicable to Infrastructure Industry

4.4.2 Reliability (Risk) Pertaining to Management of Public Infrastructure

At present, the majority of risk-based asset management planning regresses to an arbitrary probability of failure and consequence of failure scores or qualitative ratings. They are obtained through subject matter expert consultation and typically involve setting up a risk matrix, which is then applied to the asset inventory to obtain a risk rating for each individual asset or its components. The approach assumes that the higher the risk score the higher on the list of priorities the component is. The approach is effective in highlighting critical infrastructure (e.g. infrastructure surrounding emergency services) by rating it on the higher end of the scale relative to non-critical infrastructure (e.g. infrastructure surrounding empty land lots). However, when it comes to the probability of failure it is far from the precision of steel beam design, where different dimensions of web, flange, span, and welds have been studied extensively over the past century.

The antonym of the probability of failure is lifetime reliability. This "classical" reliability theory is concerned with predicting 'failure-free' operation within a specific period of time. Its development leads back to post WWII when academia was employed to study the reliability of military communications systems. Through statistical analysis, time to failure and its probability are estimated for a specific time period, by subtracting it from one (or 100 %) the reliability is obtained for the same time period. A similar statistical approach was applied to civil engineering systems (e.g. steel beam design) but with respect to stress (demand) versus strength (capacity) producing probability functions that are not explicitly time-sensitive. Subsequently, construction design standards for civil engineering systems are based upon a reliability of 0.99999. The likelihood that demand will exceed capacity is 0.00001, which is schematically represented by the area of the shaded region in Figure 15 (Pandey 2015).

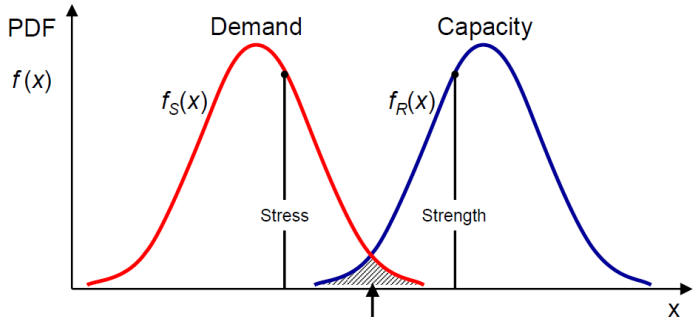


Figure 15: Probability of Failure Schematic (Pandey 2015)

It is argued that in practice this reliability is even greater if the number of failures divided by the number of infrastructure assets built to date in North America is taken as an indicator of future (post-design) probability of failure. Hence, with such a low inherent probability of failure for the built infrastructure and no readily available quantified costs or consequences of failure (e.g. social and economic cost of infrastructure failure around a sports venue) the industry appears to be tied to arbitrary and qualitative ratings of probability and consequence of failure, and therefore risk as it relates to asset management.

This arbitrary or relative risk is satisfactory to identify the theoretical risk of specific infrastructure areas relative to other areas but lacks the reliability that is necessary for asset management planning. For example, agencies are under pressure to allocate limited funding to those assets whose performance is deemed as needing improvement before others. If the arbitrary risk approach is used to prioritize improvement activities, rather than using the asset performance, then there is a possibility that agencies would budget for "high" risk assets. Agencies also miss the chance to add funds as that risk does not materialize, as the designed reliability of civil infrastructure is 0.99999. This would subsequently provide room for a situation where assets needing treatment due to poor performance cannot be treated as their arbitrary risk rating is lower. Does this preclude the use of risk as a performance measure in asset management planning? On the contrary, it is essential, but the risk needs to be tailored to the business of managing infrastructure performance rather than "ensuring infrastructure does not fail". Considering a strictly binary point of view, the latter is the primary goal of initial construction, while the former is the primary goal upon construction. Table 12 shows the proposed adjustments in the application of engineering risk and reliability concepts to infrastructure asset management.

Table 12: Adjustments to Current Concept of Risk for Asset Management Purposes

Approach	Risk	Probability of Failure	Consequence of Failure
Current	arbitrary or qualitative scale	arbitrary or qualitative scale	arbitrary or qualitative scale
	based on subject matter expert input	based on subject matter expert input	based on subject matter expert input
Recommended	cost	probability of multiple treatments before reaching mean time to treatment	average treatment cost
		based on corporate data	based on corporate data

There are a series of treatments or improvement activities that are necessary throughout the service life of the asset to ensure its performance. The absolute majority of the expended funds by public agencies today are for this purpose, followed by a significantly smaller portion on new construction. Hence, the research proposes the application of lifetime reliability analysis, specifically adjusting the focus from Mean Time to Failure (m_{ttf}) to Mean Time to Treatment (m_{tt}). Where m_{tt} and average treatment cost are obtained through the analysis of corporate data. Unlike traditional engineering problems, where the goal is to avoid reaching the m_{ttf}, asset management planning is concerned with "making the right investment at the right time and place". Therefore, the goal is to align, as closely as possible, future expenditures with projected m_{tt}. Risk profiles are gained by determining the probabilities of one or more treatments being needed before reaching m_{tt}. iPS's derivation and deterioration rate depend on m_{tt}.

While this section focused on risk related to infrastructure failure and the need for adjustments in the approach, in order to increase its influence on improvement activity prioritization, the next section introduces a novel concept within the field of infrastructure asset management.

4.4.3 Active Asset Management Risk

This section is presented as a deeper, concise, and relatively "quick look" at the direction the study of risk could take in the future. Further details beyond what is presented are outside the scope of this thesis.

It is assumed that the reason the military invested in understanding the risks or reliabilities associated with its communications systems is that certain stakeholders noticed deficiencies in their application during WWII. Deficiencies, which perhaps, if adequately addressed, would yield more effective results for the same army at the next opportunity.

A parallel can be drawn to the concept of active asset management risk. Rather than concentrating on the risk of infrastructure underperformance, which is an intrinsic part of the infrastructure management field, the focus is on the risk associated with the failure of asset management processes within managing agencies. The short-term goal is to spur the discussion on the topic. The mid and long-term goal is to provide a means for industry experts to gauge asset management process effectiveness. The concept is presented in three categories: defining elements of risk, defining risk, and quantifying the probability of failure.

Elements of risk include:

- nature of information,
- information format, and,
- and information flow.

Nature refers to what phenomena the information describes (e.g. performance measure), the format refers to the information structure (e.g. excel list, pdf document, etc.), and the flow refers to COAM Process Framework shown in Figure 7.

The flow is composed of three main categories

- subject matter experts or engineering,
- finance, and,
- and administration.

These are then disaggregated into seven more specific "information flow stations" representing a typical horizontal organizational information flow. These include:

- Capital works,
- Meeting analysis,
- Individual analysis,
- Maintenance works,
- Monthly financial reporting,
- Budget requests, and,
- Budget preparation.

The above are instances in a typical business cycle where it would be beneficial to have access to quantified current and future asset performance.

The station-element relationship is used to quantify the probability of failure, and eventually the risk.

Risk is defined as the probability of failure multiplied by consequence, where failure is assumed to be an occurrence of asset management processes failing to generate future (quantified) asset-performance graph(s) in a timely manner at any point in the information flow.

The probability of failure is assumed to be directly proportional to uncertainty. Where uncertainty is assumed to be lack of required information for the creation of performance graphs. For the nature of information element, uncertainty is assumed to be directly proportional to the interpretation effort necessary to generate a future (quantified) asset-performance graph. With respect to the information format element, uncertainty is assumed to be directly proportional to the number of formats existing within an information station. Finally, for the information flow element, uncertainty is assumed directly proportional to the number of stations a particular information station is displaced from the infrastructure (physical environment). Next, relative arbitrary values are used to postulate actual degree of uncertainty for each element of risk, and for the overall system. A normal distribution can be used to generate the probability density and cumulative density function curves for the probability of failure.

Future research may include refinement of failure distribution(s), quantification of consequences, and analysis of means to minimize risk. These include but are not limited to hard copy asset management plans, software(s), professional management, and Excel tools.

The following section discusses the intricacies of creating a means to this end. That is the creation of an asset management system that inherently – if appropriately implemented – minimizes active asset management risk.

4.5 Asset Management System (e.g. Excel based) for Improved Communication Between Engineering, Finance, Administration

This section explains the approach taken in creating an asset management system to help professionals manage infrastructure systems. This is not a standalone software but an org-technical system. It cannot and is not intended to "automate" professional skill, knowledge, and expertise. Automation and subsequent minimization of labour costs is one of the main selling points of software in labour-intensive industries such as manufacturing. The research argues through theoretical and practical analysis of the complexities involved in managing infrastructure that such attempts are not financially or practically feasible. Furthermore, while an org-technical system cannot eliminate existing professional costs it can - through systemized communication of asset investment and performance across the enterprise – address the growing pressures faced by public infrastructure agencies, without increasing professional costs over the short, mid, or long-term. The analogy of a small Navy (managing agency) introducing Sonar into its fleet before its widespread use, and the other large Navy (infrastructure needs) not having one hopefully paints a vivid scene of the enormous advantage the former has over the latter opposing side.

The system is not intended to be a predictor of future reality, but rather a "just-in-time factory" for future scenarios of asset performance and expenditure from the most granular asset information to the overall network. A factory, which as any manufacturing facility, requires continuous improvement in order to stay current.

The construction of an asset management system, which is necessary for COAM processes, starts with a focus on the organizational part of the org-technical system.

4.5.1 Internal and External Environments of a Public Infrastructure Managing Agency

Manufacturing, retail, and information technology are the civilian industries that appear to fill the majority of the management science research and application sample space. They happen to be dominated by private organizations (this includes publicly traded companies). This research aimed to apply the knowledge of the field to demonstrate how corporate operationalization of asset management practice is possible within a public agency setting. This included the development of a corporate data-driven performance measure to improve communication and decision-making capabilities when it comes to public infrastructure investment and performance.

The following discussion on the factors affecting organizational goal attainment reflects the type of knowledge shared at a corresponding university program as experienced by the researcher.

The intra-organizational broad categories affecting its level of goal attainment include goal orientation, performance measure definition, unit transparency, and bottlenecking. The first (goal orientation) speaks to the degree to which its members are aware and understand the particular organization's goal(s). The second (performance measure definition) focuses on their ability to develop, implement, and refine as needed appropriate performance measures. Unit transparency is the degree of detail to which external stakeholders can know the internal "daily-on goings" beyond the unit's formal communication terminology. Bottlenecking is associated with supply-chain management and focuses on identifying and remedying points that affect overall productivity, in this case the systematization of asset investment and performance communication across the organization.

Operational analysis theory provides a categorization of organizations according to the internal process-product relationship. Table 13 shows a manufacturing product- matrix used for such categorization and examples of where specific industries fit in that characterization.

Table 13: Manufacturing Product-Matrix (Nahimas 2005)

Process structure /Process lifecycle stage	I Low volume, low standardization, one of a kind	II Multiple products, Low volume	III Few major products, higher volume	IV High volume, high standardization, commodity products
I Jumbled Flow (job shop)	Commercial Printer			Void
II Disconnected Line flow (batch)		Heavy Equipment		
III Connected Line flow (assembly line)			Auto Assembly	
IV Continuous flow	Void			Sugar Refinery

The vertical axis of the table indicates the type of internal process employed, while the horizontal axis indicates the type of variety and volume of product that results. Examples of the two extremes of a job shop and continuous flow are a shoe repair shop, and an oil refinery, respectively.

This research maps the public management agency onto the above matrix in Section 5.1.1.2.3.

Mapping of the internal environment provides essential information on the conditions under which the technical component of the asset management system must function. This information is necessary for the proper design of the asset management system.

Organizational behavior theory categorizes organizational environments according to the type of uncertainty faced by an organization in its attempts to maintain its goals, and the rate at which the environment itself changes. Uncertainty is the broad term used as a categorize the many external factors that can affect goal attainment. Its sources include but are not limited to product cycle, competitors, global economic trends, and geo-politics.

This research specifies the public infrastructure agency position within the spectrum and related implications.

Figure 16 attempts to capture the corresponding main sources of external uncertainty relative to organizational environments, as well as trends of inherent process transparency, formal adjustment requirements for internal process changes, mutual adjustment requirements for internal process changes, and organizational structural rigidity.

General sources of uncertainty are mirrored across the figure's diagonal, with public infrastructure itself being the main source for municipal administrations, with respect to capital expenditures. It should also be noted that a non-negligible portion of operational expenditures is tied to the maintenance of existing infrastructure.

The necessary "perceived amount" of transparency (i.e. looking from outside in) in order for an organization to achieve its goals, increases moving from an information technology to a municipal administration environment. The same trend is applicable concerning structural rigidity.

Internal process changes vary between two extremes: formal and mutual adjustment. The former typically requires documentation, while the latter can be facilitated via verbal or visual communication. With increased inherent transparency and structural rigidity, the requirement for formal adjustments increases, while room for mutual adjustments decreases. The example of a "garage tech start-up" versus a municipal administration illustrates this varying range of effort necessary in order to achieve internal process change while seeking the organizational goals.

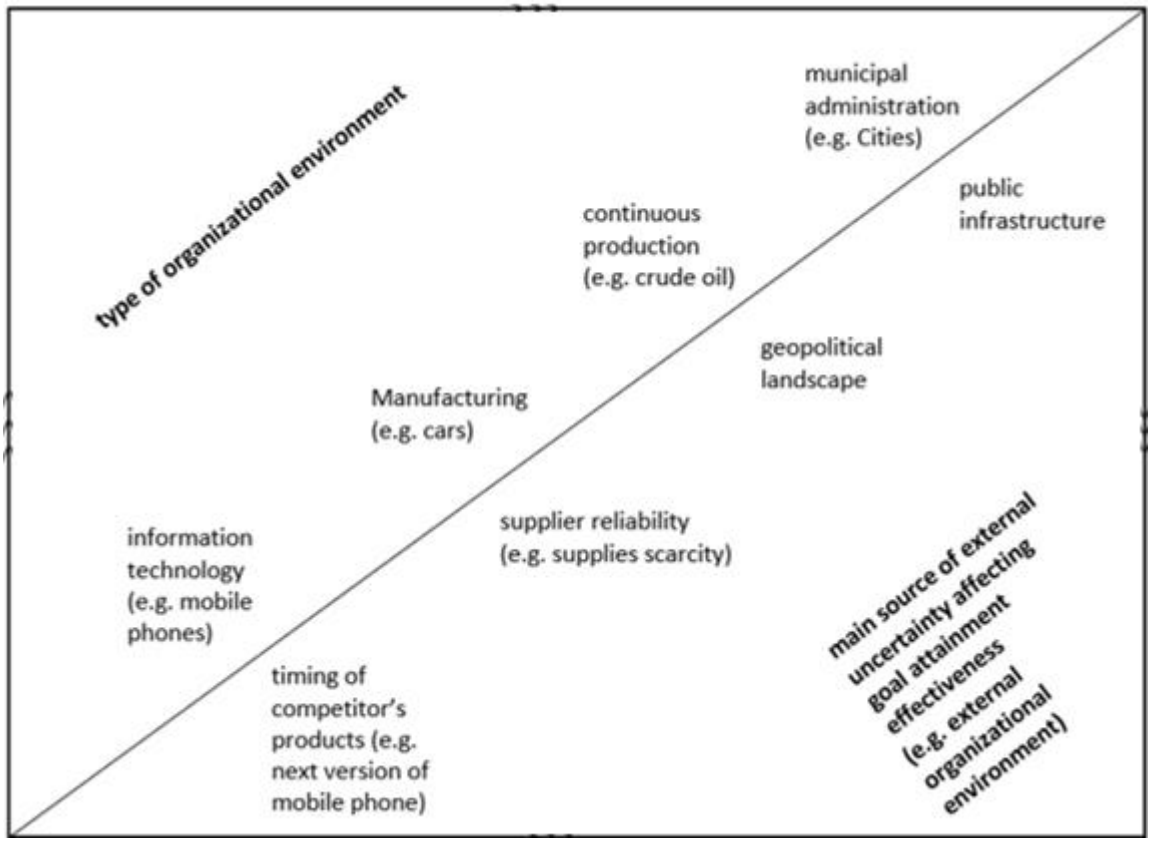


Figure 16: Corporate Environment and Uncertainty

Once the internal and external environments of a public agency have been given consideration, and an approach devised and applied to minimize potential negative influences on progress, the development and implementation of the technical portion of the system may occur.

4.5.2 Technical Development and Implementation

Two decision support systems have been developed, one for large and the other for smaller municipalities. Discussion of the concept, development, and implementation for both is included in this section.

The following are key points related to the timely development and implementation of technical information systems to support COAM processes:

1. Its purpose is not to replace existing information systems but rather to work with them.
2. Its purpose is not to automate the application of professional knowledge, skill and expertise necessary for infrastructure asset management, but rather to act as a net for capturing the application's resulting information in a format which can be systematically communicated through existing lines of organizational communication and authority.
3. Its output must at a minimum provide graphs of standardized aesthetic design showing investment and corresponding infrastructure performance across a variety of planning horizons covering at least 25 years.
4. Its internal information architecture development (i.e. programming code) cannot be solely under the authority of inexperienced municipally staff.
5. Data integration with other information technology systems, and organizational processes cannot practically be automated, should not be referred to as a "manual" process, and is to be professionally managed.

Analyzing the implications of these points to provide a technical information system in tune and resonating with existing organizational processes is crucial for corporate operationalization of asset management. Once the technical information system has been built, its capabilities require testing with real corporate data.

Gaps between technical information systems and corporate processes exist that limit the system's potential to support asset management decision-making. Two common expectations of technical information systems (i.e. software) contribute to the preservation of these gaps. One is user-friendliness, being one of the top priorities (if not the top), and the other is that the software will significantly improve the efficiency and/or fundamentally change the existing "traditional" modus operandi. Millions of mobile phone applications strive for such status, whether it is reinventing the hospitality industry (e.g. Airbnb) or personal transportation services (e.g. Uber). Other success stories include Facebook and Twitter, however, it is important to note that the modus operandi of these services are far from the complexity of a public agency managing infrastructure and community services. Airbnb mimics accommodation arrangements, Uber - taxi service arrangements, and the latter two social interactions. Unlike the activities necessary for managing societal infrastructure, these do not require professional levels of education, knowledge, experience, and skill. Figure 17 provides a visual schematic of a select few – but widely spread – phenomena, and their relative complexity, and the systems that manage or aid them.

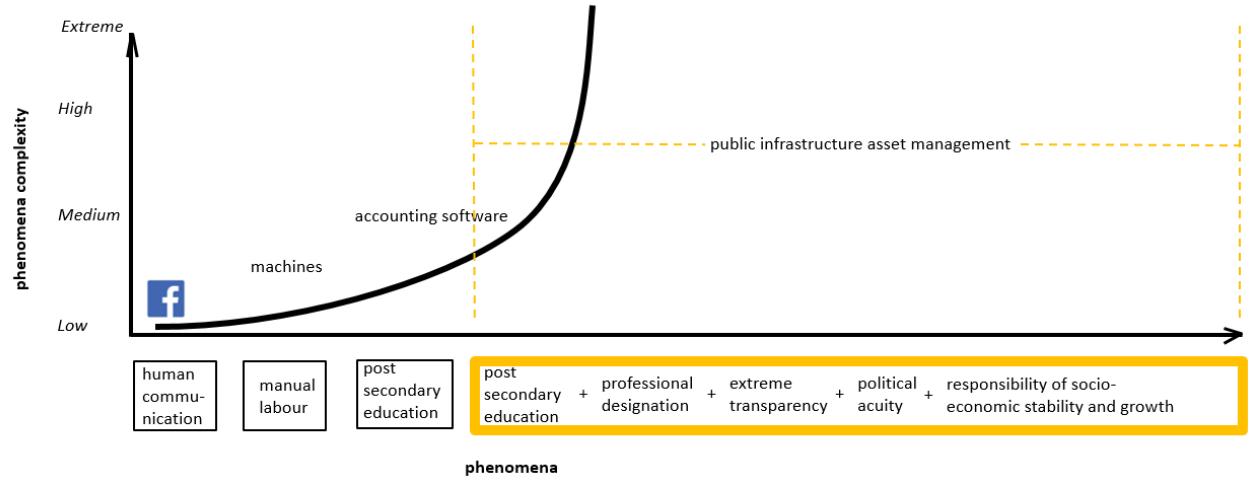


Figure 17: Phenomena Complexity of Public Infrastructure Asset Management

To address the gap between technical systems and corporate processes, this research recommends that in the systems' design, development, and implementation; the aspects of user-friendliness and "game-changing" take a back seat to serving (not replacing) professional judgment. One of the first steps to achieving this is to ensure that the technical system development process has access to the same quantity and variety of information as the professional.

Another gap concerning the technical information systems is the inability to house all infrastructure information (e.g. expenditure, performance, etc.) in one system. Causes include intrinsically different asset physical properties, functions, etc., and different asset information maturity levels. Table 14 shows the different maturity levels for one municipality. The level of maturity concerning COAM refers to the necessary level of effort needed to create future projections of required expenditure and associated asset performance; the effort is the inverse of the indicated maturity. The last column describes the maturity of information with respect to other municipalities.

Table 14: Asset Information Maturity for One Municipality

Asset Class	Proportion of Total Infrastructure	Maturity of asset information with respect to corporate asset management operationalization (COAM)	Maturity of asset information with respect to rest of industry
Transportation	31.5%	High	Average
Facilities	16.5%	High	Above Average
Sanitary	16.2%	High	Above Average
Water Distribution	13.3%	Medium	Average
Storm Collection	12.6%	Low	Average
Parks	3.7%	Low	Average
Stormwater Management	3.4%	Low	Average
Fleet	0.9%	High	Above Average
Parking	0.6%	High	Above Average
Fire Services	0.5%	Medium	Average
Forestry	0.4%	High	Above Average
Information Technology	0.2%	Medium	Average
Furniture and Fixtures	0.1%	Low	Average
Cemeteries	0.1%	Low	Average
Lands	N/A	Medium	Average

Decades of asset-centric performance measure development has led to the existing ones being the dominant decision-support factors for professionals. Hence, there is hesitation to apply different and new ones to decision processes as they have not yet stood the test of time. This is paradoxical, as the application is necessary to begin the test of time. The research addresses this challenge by ensuring that new performance measures, where necessary, can be cross-referenced back to existing ones, as well as, deriving performance measures through formulas where the variables are readily available within existing corporate information.

In terms of implementing technical information systems for asset management, typically, already-built (off-the-shelf) applications are slightly adjusted or customized. This is done through system requirements usually described in the Requests for Proposals and then through workshops and interviews with staff. As the annual business cycle requires tens of millions of data fields to be manipulated by professionals in the delivery of services, written and verbal descriptions to communicate the complexities and details of this

mass data, and its complete interaction with organizational structures are limited. To alleviate this bottleneck, research recommends supplementing the existing approach by having unrestricted access to all corporate-wide information or as coined for this dissertation to the "corporate conscience". While this sort of exposure may seem excessive, it significantly minimizes the dissonance between the technical information system and corporate processes. Such access is to be handled with hyper-sensitivity. Its only scope of use is to derive expenditure vs. asset performance scenarios that can readily be produced from the existing information quantities and varieties within the operational, tactical, and strategic levels of the organization. Notions of any other type of use, such as auditory, will significantly undermine the effort of effective technical information system development.

Existing technical information systems do not typically allow an agency to maintain a "living" asset management plan. Current practices yield hard copy plans which once completed sit on office shelves and take an almost equivalent effort to update. This is sub-optimal as agencies have uncertainties from the external environment (e.g. resident demands, fluctuating economy, etc.) which the hard copy plans do not account for or can provide adjusted future forecasts for. This gap is a result of the limitations mentioned previously; having user-friendliness as one of the top priorities in system development, the inability to incorporate all assets into one forecasting system, and the typical approach to system development. Hence, bridging these gaps through the proposed approaches opens the potential for "living" asset management plans.

The following section contains the summary of findings for this chapter.

4.6 Summary of Findings

The above sections speak to three very different – but intertwined - components of the research:

1. Infrastructure management agency as an organization,
2. Infrastructure performance measures, and
3. Asset management system.

Under the organizational study aspect, the internal and external environments were mapped. Internally, the flow, format, and nature of information were defined. A project structure schematic was provided, which was used as a means during this active research effort. Through the project, the COAM Process Framework was developed.

Typical subject matter expert-established performance measures (SEPMs) were provided, and corporate decision factors were defined. From existing corporate information, a new comprehensive performance measure was derived. This measure implicitly accounts for SEPMs and corporate decision factors, and is based on engineering risk and reliability principles.

Finally, the external organizational environment was mapped to provide greater organizational context. This was followed by a discussion on the technical development and implementation of an asset management system.

Through the material presented in the above sections, it is argued that the following hypotheses (originally presented in Section 2.1) are true:

2. *Existing organizational information provides sufficient value to develop corporate data-driven asset performance measures, without new data collection efforts. Research in new data analysis methods could greatly advance technical and economic benefits.*
3. *Objective decision-making is already occurring within managing agencies to the highest degree possible according to the existing body of knowledge; it is just a matter of communicating it systematically.*
4. *Corporate operationalization of asset management processes requires building on top of existing processes rather than altering them or developing independently of them.*

The following Chapter contains the main results of the research obtained through the application of Goldratt's Theory of Constraints.

Chapter 5

Results – Theory of Constraints Application

The experiment (described in Chapter 4) focused on implementing and sustaining asset management systems and associated processes. A corporate-wide approach was applied to infrastructure-managing agencies, of varying size, asset portfolios, and asset management maturity. At the end of the undertaking, each had developed the capability of readily generating "living" asset management plans. This, in turn, systemized communication between finance, engineering, and administration when it came to asset expenditure and performance planning. It is important to note that all studied environments appear to be operating at maximum capacity, therefore, additional resources - or reprioritization of existing resources - are required to readily exercise this new capacity. Perhaps the most appropriate retrospective analogy is that of medical researchers gaining access to microscopes.

The approach was based upon Goldratt's Theory of Constraints that has traditionally been applied to for-profit organizations within the manufacturing industry. By tailoring its principles to the public sector, it was possible to eliminate the negative effects of organizational siloing within a relatively short period. With the typical constraints of limited data availability and cross-unit dissonance lifted, an asset management system with buy-in from all positions was able to come to light. This section provides a detailed description of the sequence of decisions, which had to be made and acted upon to successfully plan, develop, and implement a comprehensive asset management system for all asset classes owned by the agencies. These asset classes include roads, sanitary, water, storm, stormwater management, facilities, parks, forestry, parking, fleet, fire services, fixtures, information technology, and cemeteries. The Theory of Constraints application resulted in a three-pronged approach: 1) analysis of all existing information, 2) development of performance measures, and 3) optimization of professionals' decision-making.

A global effort by the developed world's academic, public, and private sectors, spanning approximately two decades, has yielded a specific culture within the public infrastructure managing agencies. A culture of asset management interest and practice, where the awareness of "what" asset management is, appears to be high. Hence, it is argued that the focus is gradually turning towards the "how" at the operational and tactical levels of the organization, in addition to the already established strategic perspectives. An example of this direction can be found in the NCHRP Report 806 "*Guide to Cross-Asset Resource Allocation and the Impact on Transportation System Performance*". Although it does not include full deployment of its methodology (tool) within a managing agency, one chapter of the three core chapters was allocated to the implementation process. In nationwide consultations with experts "…many saw the usefulness, there was also genuine concern about implementation". The concerns range from details regarding specific assumptions within the analytical hierarchy process to the silo structure of existing agency processes (Maggiore et al 2015).

In Canada, a similar study focused on the implementation of asset management processes was completed. It found the key challenges to be inadequate human resources, lack of a common asset management model, and inadequate use of technology (El-Diraby et al 2015).

The goal of this active research effort was an asset management system implementation aimed at yielding maximum value from existing corporate information and processes. By applying lessons learned from the manufacturing industry, it was possible to neutralize the negative effects of organizational silos. Subsequently, an opportunity to systematize asset management-related communication, between intrinsically different units, presented itself.

The following section demonstrates the organizational results of this research effort.

5.1.1 Key Organizational Results

The necessary time and effort for asset management system implementation by a public agency was minimized, through:

- Application of Goldratt's Theory of Constraints,
- Elimination of negative siloing effects. and,
- Building on top of existing processes.

The following sections contain the strategic, tactical, and operational items, intrinsic to successful cases of asset management processes development, and implementation in a corporate-wide agency setting.

The aim of the active research effort was to explain the approach taken in developing and implementing asset management systems across public agencies, for a variety of asset classes. The strategic, tactical, and operational aspects of the approach have been presented, along with the resulting deliverables.

The application of Goldratt's Theory of Constraints to public agencies was the central theme explored. Typically used by for-profit organizations, its transposition into the public sector was based upon 10 years of practical experience in various positions and public agencies by the researcher.

The challenges and opportunities identified in the NCHRP Report 806 "*Guide to Cross-Asset Resource Allocation and the Impact on Transportation System Performance*" (Maggiore et al 2015), and the University of Toronto's "*Analyzing Approaches Used by Ontario Municipalities to Develop Road Asset Management Plans: Initial Insights"* (El-Diraby et al 2015) were addressed.

5.1.1.1 Theory of Constraints

Dr. Eliyahu M. Goldratt conceived the Theory of Constraints (Dettmer 1997). It is comprised of five general steps:

1. Identify the system constraint(s).
2. Decide how to exploit the constraint(s).
3. Subordinate everything else to decision(s).
4. Elevate the constraint(s).
5. Continuous repetition of Steps 1-4.

At the aggregate level, the system is composed of three items: throughput, inventory, and operating expense. “Throughput is the rate at which the entire system generates money through sales (product or services). Inventory is all the money the system invests in things it intends to sell. Operating expense is all the money the system spends turning Inventory into Throughput.”

The goal of the for-profit system (organization) is “Making more money, now and in the future…But it’s clearly different in the case of a not-for-profit (infrastructure managing agency)”

Due to the lack of a universal nonmonetary measure of value that could account for a non-profit’s Throughput (or goal), Goldratt suggests not expanding the effort to develop one, but rather to concentrate on elevating the system’s constraints, as such “Progress towards the organization’s goal can be assumed.” (Dettmer 1997)

5.1.1.2 Application of Theory of Constraints to Asset Management Systems

The 1999 Federal Highways Administration’s and the 2015 Federation of Canadian Municipalities’ definitions of asset management appear to encompass all that occurs within an infrastructure-managing agency. Starting with “Asset management is a systematic process…” and “Asset Management is an integrated approach …”, respectively.

Rephrasing and boiling down both definitions to a few words, it can be said that professional knowledge and skill (i.e. staff) combined with technology is the Asset Management System.

Given that public agencies are a type of non-profit organization, developing a universal nonmonetary measure of their goal achievement, (e.g. sustainable infrastructure) was outside the scope of this research.

5.1.1.2.1 Asset Management System Goal

Whereas the ultimate goal of delivering sustainable infrastructure is an external one, it is argued that the primary internal goal for an asset management system is the ability to quantify asset performance and generate corresponding expenditure graphs promptly at any point within the information flow of the organization. This allows professionals at all related positions to see current and future asset performance (from the most granular level of asset inventory to any aggregate level) and expenditure based upon decisions they are contemplating. Amongst other plausible reasons, it is argued that the lack of such ability, throughout the industry at the present, can be attributed to a lack of “all able” software and/or organizational siloing. The focus of this research effort was the latter, while the former was addressed implicitly. Specifically, designing an approach that eliminates the negative effects of siloing, allowed for the creation of appropriate software.

5.1.1.2.2 Identifying System’s Constraints

From the main constraint of organizational siloing, the following four constraining effects are derived:

- Obstructed view of existing raw information,
- Limited access to corporate-wide information flow,
- Limited corporate data-driven performance measure development, and

- Mistakenly equating the term “system” to software.

5.1.1.2.3 Decide How to Exploit Constraints and Subordinate Full Project Effort to Decisions

In research partnerships with municipalities, from the beginning of each effort, it was important to demystify asset management for the stakeholders. This involves taking the concept from its strategic heights motto of “It is a completely new way of doing things”, to its practical trench work of “You are already doing it, we are just building on top of it.” Here, Lewin’s Change Theory of “Unfreezing-Change-Refreeze” (Lewin 1947) was applied. While implementing or operationalizing asset management processes requires new processes, practical experience has indicated that the word “change” may not be the most accurate or beneficial to use. Lewin’s theory concerns group or organizational psychology as it relates to changing their behavior. The first stage involves “unfreezing” of current mindsets or perceptions, the second, a move towards new behavior, and the last, where the new becomes the norm. After almost two decades of “It is a completely new way of doing things”, fieldwork has indicated that stakeholders with this mindset are reluctant to take practical steps under such a motto. Primarily, this is because, in practice, they have already been managing public infrastructure for decades. The organizations they are a part of boast an annual value of staff knowledge and skill in the millions to hundreds of millions of dollars. The operation of the assets cannot be put on an “annual shutdown” while new asset management processes are implemented. Hence, the latter motto was applied which yielded immediate buy-in from the strategic stakeholders (e.g. senior management) to “unfreeze” their current mindset with respect to asset management. It is important to note that the former motto was appropriate for industry awareness raising of asset management, where the latter would have been ineffective. Next, to catalyze new stakeholder behavior, it was decided that a concrete result of this behavior had to be promised. One which is significantly more tangible at tactical (e.g. supervisor) and operational (e.g. subject matter expert) levels than strategic items such as “more sustainable infrastructure”. The promised result, which yielded buy-in from stakeholders, was the delivery of two graphs for each asset class. One graph showed 25-year asset performance, and the other showed the corresponding required expenditure. Figures 18 and 19 provide examples of such graphs.

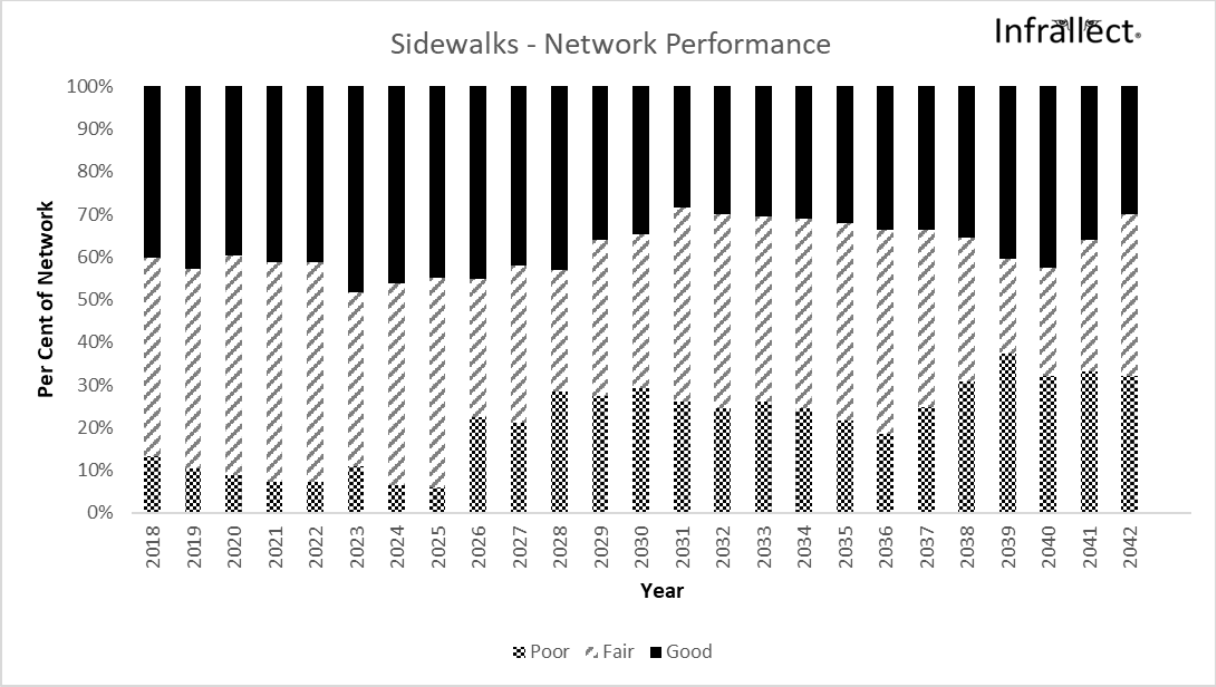


Figure 18: Example of Asset Performance Graph Shown to Stakeholders at Beginning of Project

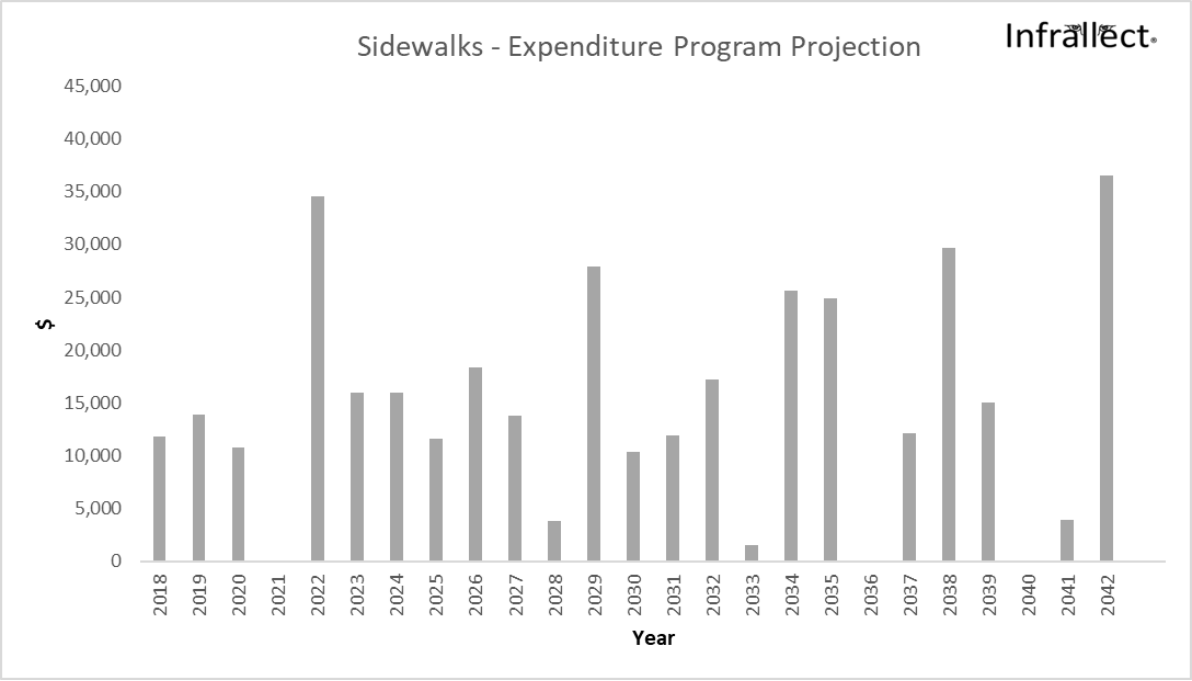


Figure 19: Example of Asset Expenditure Graph Shown to Stakeholders at Beginning of Project

It was explained to the stakeholders that while the project effort was going to have an overall effect of "more sustainable infrastructure", the processes' spearheads were the graphs. Given the widespread use of similar visual representations in everyday life (e.g. weather forecasts, market trading, etc.) their face value benefit was immediately evident to stakeholders. However, typically, then came the questions; which, as the stakeholders explained, were the questions they expected others to ask of them: "What information underlies the graphs? How do you know that it is correct?" The response was: "The graphs are based upon the nature (i.e. the what?), format, and flow of existing corporate-wide financial, subject matter expert (e.g. engineering), and administrative information. We are not going to use any industry averages unless we need to. With respect to correctness, you have already been producing relevant information (i.e. a by-product of previous decisions) and using it for decades. It is already tailored to this particular infrastructure network. The only difference is that now, we will use it to allow you to see the future performance of the assets you are tasked with taking care of."

Rarely, there would be a follow-up question: "What is performance based upon?" The response was: "We are not going to confine your decision-making to only one perspective of performance. First, we will create a graph according to an existing performance measure, if one exists. For example, the age of an asset. However, since correlation does not necessarily equal causation, we would be looking at generating another, slightly more complex measure than just age-based. For example, taking into account condition inspections to date, setting an initial condition, and then using the estimated service life to project future deterioration. It will be an ongoing improvement process of performance measures. Ultimately, we are looking to move away from age-based analysis, which typically overestimates needs, and move towards Consumer-Based forecasting [application of reliability (risk) theory]."

The "refreezing" step practically translates into the future use of these graphs for individual and team contemplation during decision-making processes. With the stakeholders confident with the practical details of the project effort and its output, the next decision was to look towards other industries where similar efforts had already taken place.

In order to bring the planning, developing, and implementing of an asset management system and its processes from a "it has never been done before" to a "that is how it was done over there" project, it was decided to look towards the manufacturing industry. With the introduction of information technology (i.e. computers) in the late 1970s and early 1980s, there was ample academic literature and knowledge to turn to in 2018. To minimize the abstractness of soft products (e.g. reports, lists, databases, etc.) produced by professional knowledge and skills, they were considered as manufactured goods within a manufacturing plant. The first step was to define what type of a plant was in question. Table 15 shows a Product-Process matrix. While a manual labor and robot-based for-profit cannot be arranged in a jumbled, job shop flow to produce high volume standardized products, it is argued that a professional knowledge-based public agency can be. Furthermore, given that continuous upkeep of infrastructure is necessary to maintain the status of "developed" world, it is argued that internal workings of an agency also have characteristics of a continuous flow. The effects of shutting down the agency would have similar effects on society as that of shutting down oil production – certain uncertainty.

Figure 20 illustrates the typical internal positioning and corporate-wide information flow within an agency.

On the left side are the "raw materials" or infrastructure asset classes existing within the physical environment. Moving right, subject matter experts (e.g. engineers) are the first to collect information on its status. In collaboration with supporting positions (e.g. application administrators), they analyze the information and establish the required improvement activities. Together, they collaborate with finance (e.g. financial planning positions) to transform the requirements into appropriate format, according to standard financial accounting practices. In a typical budget preparation process, there is an iterative exchange of information between the various positions in order to prepare a budget document for approval by senior management and/or elected officials (not shown in Figure 20).

Table 15: Product-Process Matrix

Process structure /Process lifecycle stage	I Low volume, low standardization, one of a kind	II Multiple products, Low volume	III Few major products, higher volume	IV High volume, high standardization, commodity products
I Jumbled Flow (job shop)	Commercial printer			Void Infrastructure Managing Agency
II Disconnected Line flow (batch)		Heavy Equipment		
III Connected Line flow (assembly line)			Auto Assembly	
IV Continuous flow	Void			Sugar Refinery

For an infrastructure managing agency (e.g. City of Waterloo) of approximately 250 office positions, 40 provide the core, of the already existing asset management processes. As the goal of the project efforts was to provide these positions with increased decision-making capabilities, it was important to map out the existing areas of high information concentration. These were treated as potential bottlenecks according to the manufacturing plant analogy.

The Theory of Constraints states that overall productivity is constrained by the weakest link or bottleneck within the supply chain. Through use of already available supervisor-supervisee organizational diagrams, the 40 positions making up the corporate-wide, asset management information supply chain were identified. Next, access to corporate-wide information technology - network drives - was obtained to analyze the nature and format of information at each position or the "corporate conscience". Subsequently, one-on-one interviews were conducted with the staff of the various positions. The purpose

of the meetings was to discuss the previously mentioned analysis, but also to map out the position-to-position information flow or exchange.

It is important to note that the most critical link for the project efforts was the attainment of corporate-wide information access (or access to the "corporate conscience"), but without the need to expend effort on navigating organizational silos. Three types of silos were identified: positional, departmental, and asset class information stream, as shown in Figures 21, and 22, to be interpreted in conjunction with Figure 20. Conceptually, the wall thickness of each represents the relative magnitude of necessary effort required by a professional of reasonable knowledge and skill, in order to "tear down the silos" and develop "new" asset management focused information flows. There is a widespread conception within the industry that this is necessary in order for an agency to advance asset management processes. To the contrary, it is argued that such attempts are not only unnecessary, but also impractical. Unnecessary, because one can "tap" into the silos from the "top" to the most granular subject matter expert, finance, and administrative information available for each asset class. Impractical, because existing processes are equivalent to a continuous production flow of crude oil in the private sector. Any disruption can have serious adverse effects on the stability of the community being served. In this case, considering all public agencies as one, their communities add up to be the Western Civilization. As such, governments are tasked with providing a stable foundation for socio-economic growth. Disturbing the foundation will cause increased stress on the organizations, social fabric and function that rest on top of the infrastructure assets.

Figure 21 shows the "A – A" cross-sectional view of the diagram previously shown in Figure 20. Before implementation of new asset management processes, the generation and use of asset performance graphs was constrained to the subject matter expert silo, as represented by the two multi-coloured rectangles resting on top of the positional silo. Information flows are shown through dashed lines, with arrows indicating directions of information flow. Decision points are represented with hatched circles.

Figure 22 shows the difference in the ability to generate quantified asset performance and corresponding expenditure graphs in a timely manner at any point within the organizational information flow, as represented by multi-coloured rectangles and lozenges. New asset management processes rest on top of the existing ones. By "tapping" of raw siloed information, corporate data-driven performance measures were derived, which were then used to generate asset performance and expenditure graphs. The graphs were shared via existing lines of communication and authorization (i.e. the corporate-wide information flow) for decision-making at operational, management, and senior management decision-making points. Hence, optimizing professional decision-making.

Corporate data-driven asset performance measures include existing ones (e.g. Pavement Quality Index, Facility Condition Index, estimated service life, etc.), as well as the creation of a new comprehensive and implicitly objective Consumer-Based asset performance measure. For this, engineering risk and reliability principles were applied to develop deterministic asset deterioration rates for the most granular level of asset information inventory, within each asset class. This subsequently set up a layer of information, which is ready for probabilistic risk calculations. Provided that the deterministic risk is based on actual corporate data, the use of theoretical calculations such as the assignment of relative risk scores can be avoided.

By having corporate-wide access, the effort yielded significant value from such corporate data, which would have otherwise gone unused. Subsequently and unexpectedly, this unused information is the underlying data necessary to properly apply reliability (risk) engineering to all infrastructure. The following section contains the essence of this positive unexpected discovery.

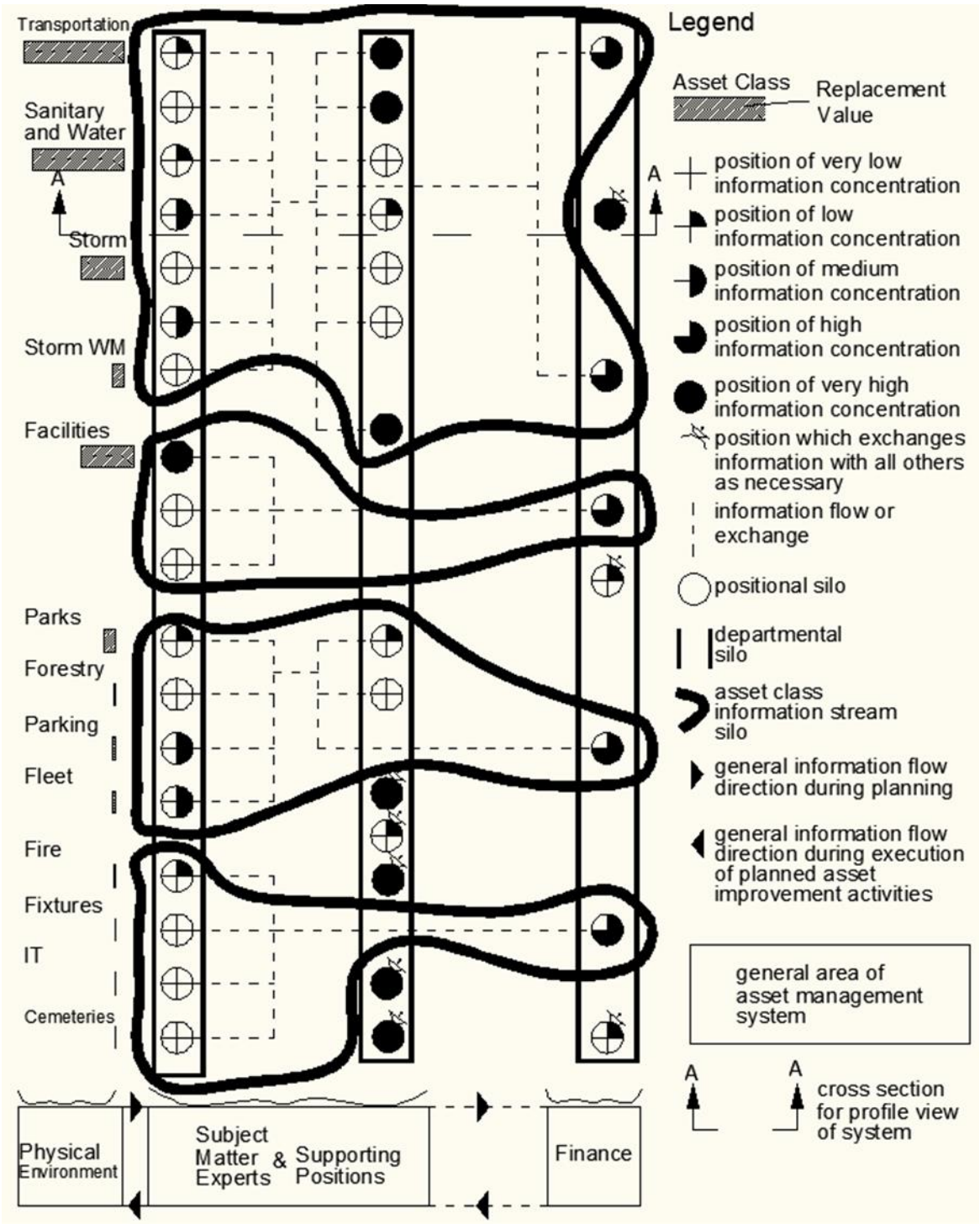


Figure 20: Internal Positioning and Information Flow – Public Infrastructure Managing Agency

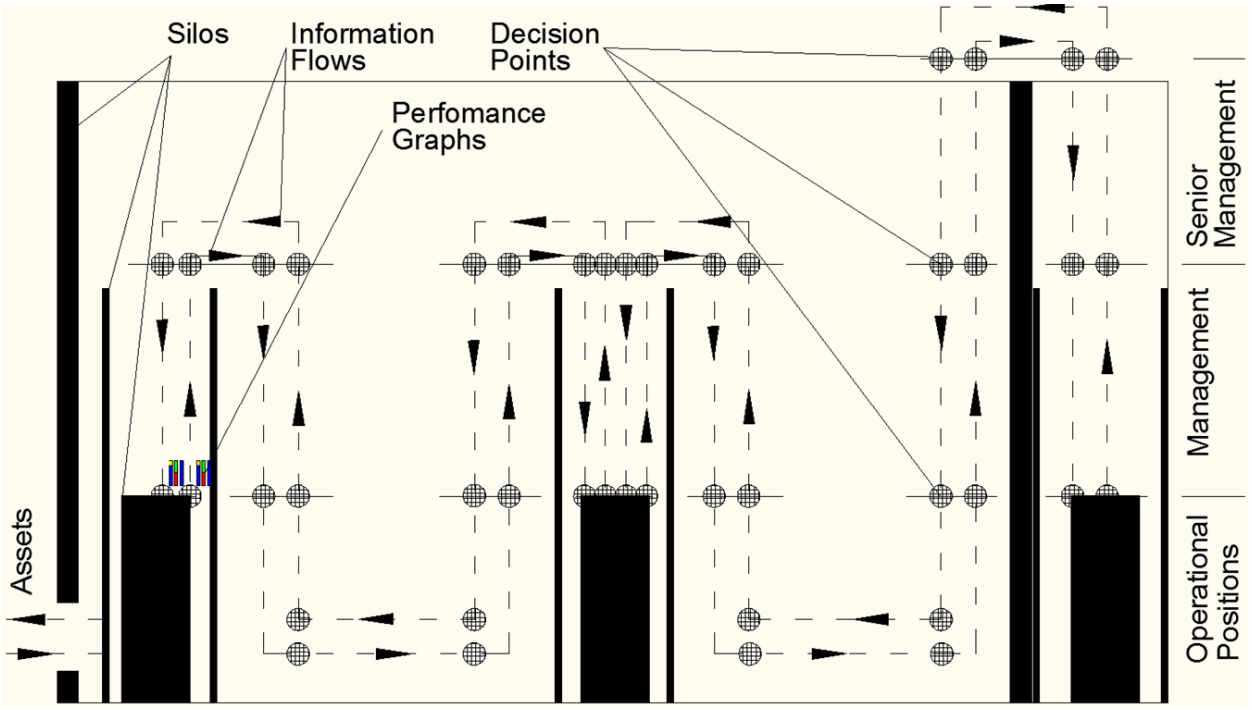


Figure 21: Cross-Section View A – A of Internal Positioning and Information Flow

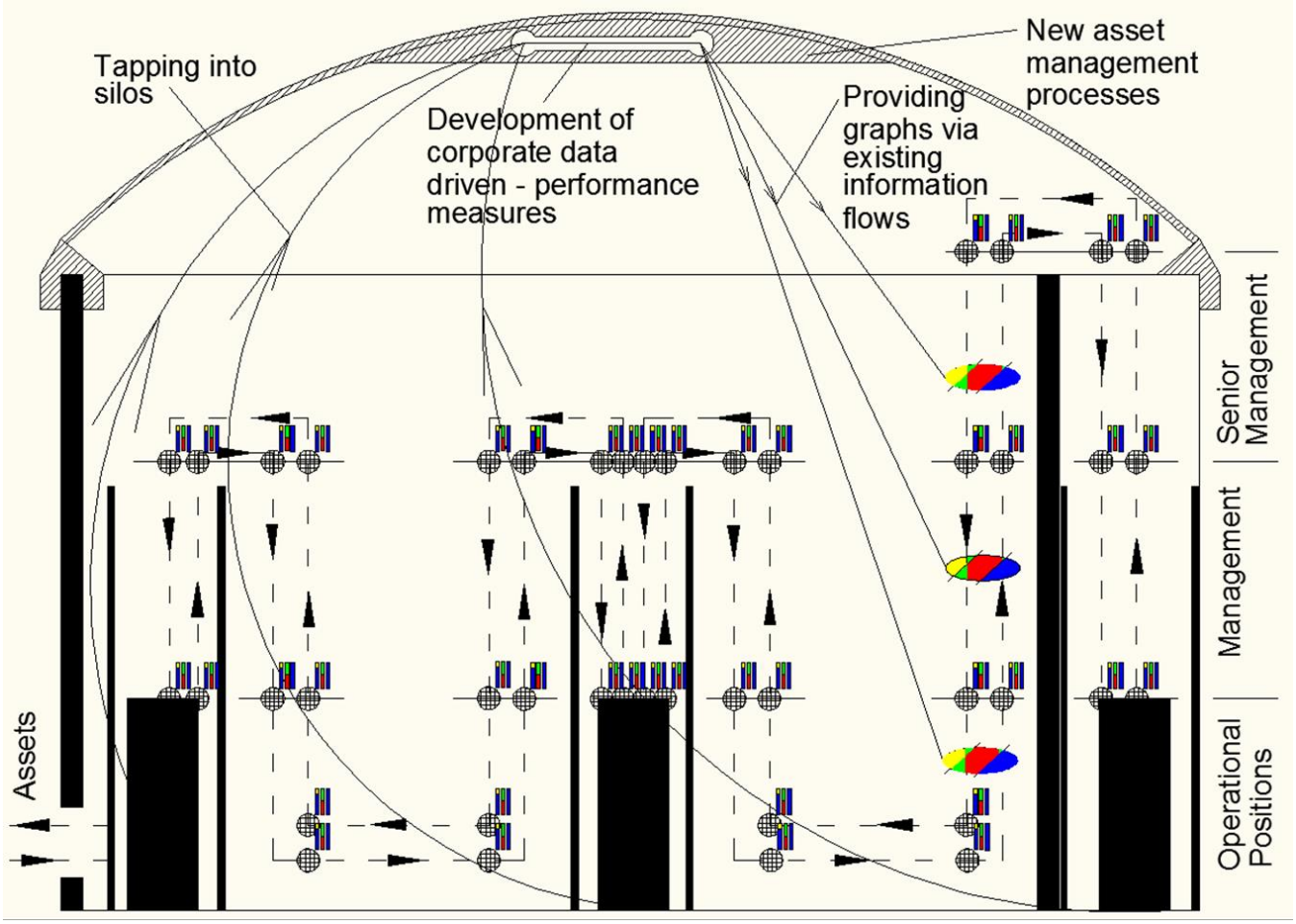


Figure 22: Cross-Section View A – A of Internal Positioning and Information Flow with New Asset Management Processes

5.1.1.2.3.1 Positive Unexpected Research Discovery – Main Bottleneck to Current Industry Practice

Working very closely with Canadian municipalities, it was evident that a decades-long record of infrastructure treatments was the "unused and archived" information. From there, it was a matter of properly defining the sample spaces of the engineered systems to which the treatments occurred. Figure 23 frames the scientific limitations of forecasting as they apply to the provision of physical infrastructure.

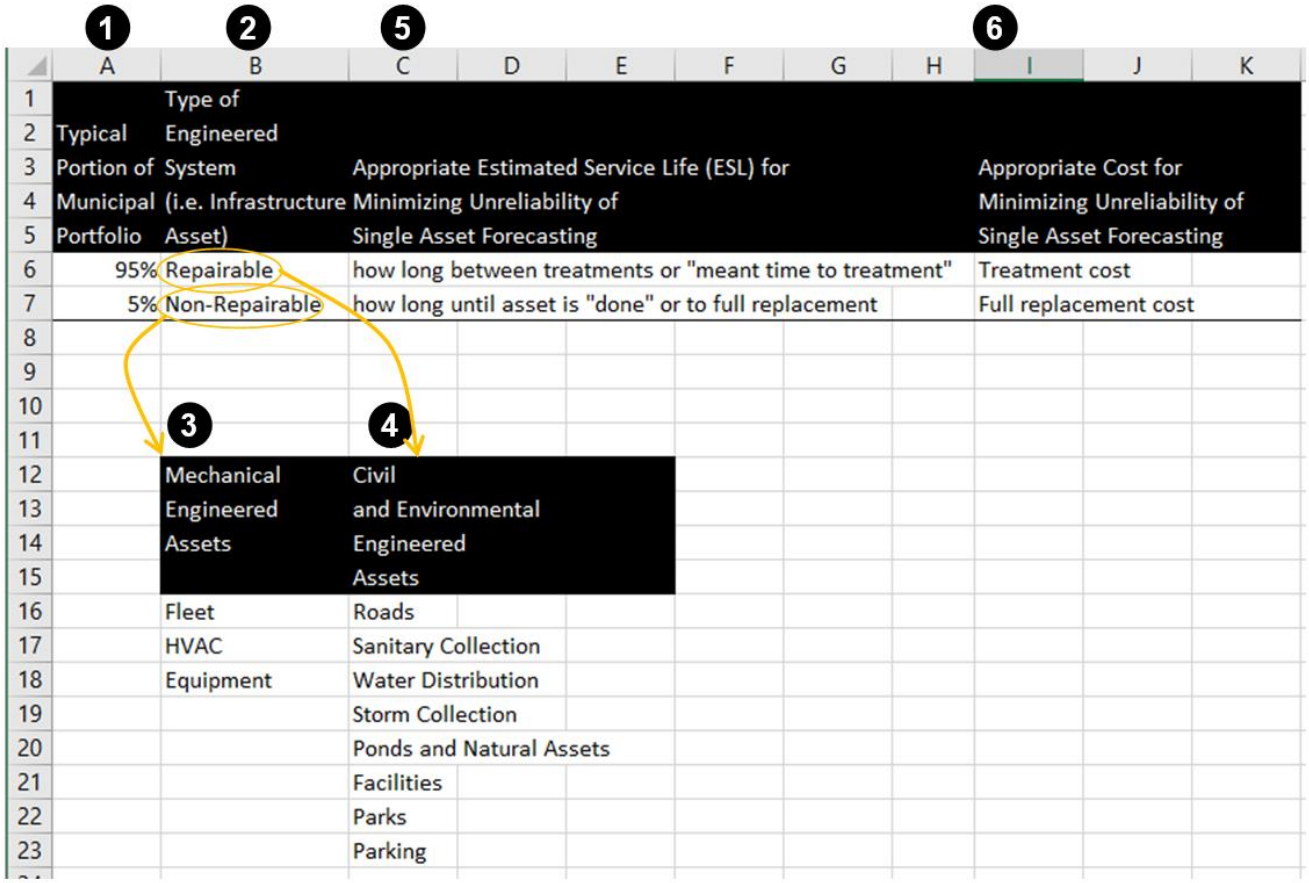


Figure 23: Scientific Limitations of Forecasting as They Apply to Provision of Public Infrastructure

Currently, there appears to be a general lack of industry awareness of the scientific limitations of forecasting when it comes to the provision of public infrastructure. If one follows the numbered steps in Figure 23, the essence of this bottleneck is the industry's lack of use of the terms "repairable and non-repairable engineered or built systems". Proper educational courses are required from various service providers in order to alleviate this constraint.

The discoveries in Figure 23 and Table 9 ultimately led to the identification of the bigger constraint or problem, which requires a solution before scientifically sound cross-asset trade-off analysis can occur on an entire infrastructure portfolio.

It is therefore argued that this research provides an original perspective on the provision of public infrastructure, by adjusting the original thesis frame to include this positive unexpected research discovery.

5.1.1.2.4 Elevating System's Constraints

The above-described decisions and undertakings included:

- Applying lessons from the manufacturing industry,
- Providing visuals of asset management processes within public agencies,
- Exposing the development of the technical system to the same quantity and variety of information as professionals are exposed to on a daily basis, and
- Explaining to all stakeholders that the term "system" does not equate to "software".

Their realization subsequently led to the elevation of the following system constraints, caused by organizational siloing:

- Obstructed view of existing raw information,
- Limited access to corporate-wide information flow,
- Limited corporate data-driven performance measure development, and
- Mistakenly equating term "system" to software.

With the constraints lifted, it was possible to generate asset performance and expenditure graphs at any decision point across the corporation and the entire asset portfolio.

5.1.2 Performance and Expenditure Scenarios PSAB 3150 (Age-Based) versus Consumer-Based (Reliability-Risk Engineering)

Other than in this research, working technical information systems covering all municipal infrastructure do not exist yet. This includes the following asset classes at a minimum: transportation, sanitary, water distribution, storm, facilities, parks, forestry, parking, fleet, fire services, furniture and fixtures, equipment, information technology, cemeteries, wetlands, and public art. A system that allows professionals with existing corporate data to:

- Forecast asset performance and expenditure of the entire portfolio in one (1) graph,

- Forecast asset performance and expenditure of individual asset classes, and
- Forecast asset performance and expenditure of sub-asset classes, and their most granular (if necessary for decision-making) components.

Under this experimental step, outputs form the technical information system are shown for the following asset classes: roads, sidewalks, traffic lights (i.e. intersection improvements), bridges, sanitary, water, storm, natural assets (i.e. creeks), facilities (i.e. buildings), parks, and parking.

This "artificial" portfolio of assets is based on real corporate information from a number of different municipalities. Appendix B contains the raw information, which has been anonymized and numerical values have been off-set by a factor to protect it from unauthorized use outside of this research.

The resulting portfolio excludes non-repairable systems: fleet, furniture and fixtures, equipment, information technology, cemeteries, and public art. This is because they typically make up less than 5% of a municipal portfolio. Also, use of PSAB 3150's estimated service lives was found to be scientifically viable. PSAB 3150 is Canada's Public Sector Accounting Board directive on how to account for and report tangible capital assets in government financial statements.

Stormwater management ponds are also excluded from the portfolio as once built, they are typically dredged, rather than repaired. The dredging frequency and cost can be forecast via the technical information system as an operational performance measure. However the topic is outside the scope of this research.

The following 48 graphs are intentionally contained in the main text of the dissertation in order to provide the reader with a practical sense of the magnitude of the task (i.e. comparing minimum two scenarios per asset class) public servants have in managing an infrastructure portfolio. The researcher prepared the graphs using a specialized forecasting software called "Infrallect", which the researcher also developed during the research effort, as discussed in Section 4.5 The model infrastructure network is representative of a municipality ranging from 10,000 to 30,000 residents. A 25-year "look-out" window was deemed sufficient even for those assets with life cycles larger than 25 years. This is based on the premise that a lead time of 25 years is sufficient for any action that needs to be taken in year 0 in order to have sufficient funds in year 25. The starting year's performance distribution is first modeled and then adjusted as necessary according to any existing condition assessment or other factors from Tables 8 and 9. Age-based graphs show the forecast performance according to PSAB 3150's logic, while Consumer-Based show the forecast according to engineering risk and reliability principles. The former treats repairable infrastructure systems (e.g. roads, pipes, buildings, etc.) as non-repairable, and assigns a full-replacement cost at the end of the life cycle. The latter treats repairable infrastructure systems as just that, and therefore forecasts an average treatment cost rather than full-replacement. Please refer to Figure 23 for further details.

Figures 24 to 71 contain performance and expenditure graphs for roads, sidewalks, traffic lights, bridges, sanitary pipes, water pipes, storm pipes, natural assets, facilities, parks and recreation, parking, and all assets as one; respectively. The same trend is observed in all figures as in Figures 68 and 70, which is a greater "poor" performance projection by the Age-Based approach compared to the Consumer-Based

approach, provided relatively equal annual funding. The key Age-Based versus Consumer-Based analysis follows the graphs in Section 5.1.3

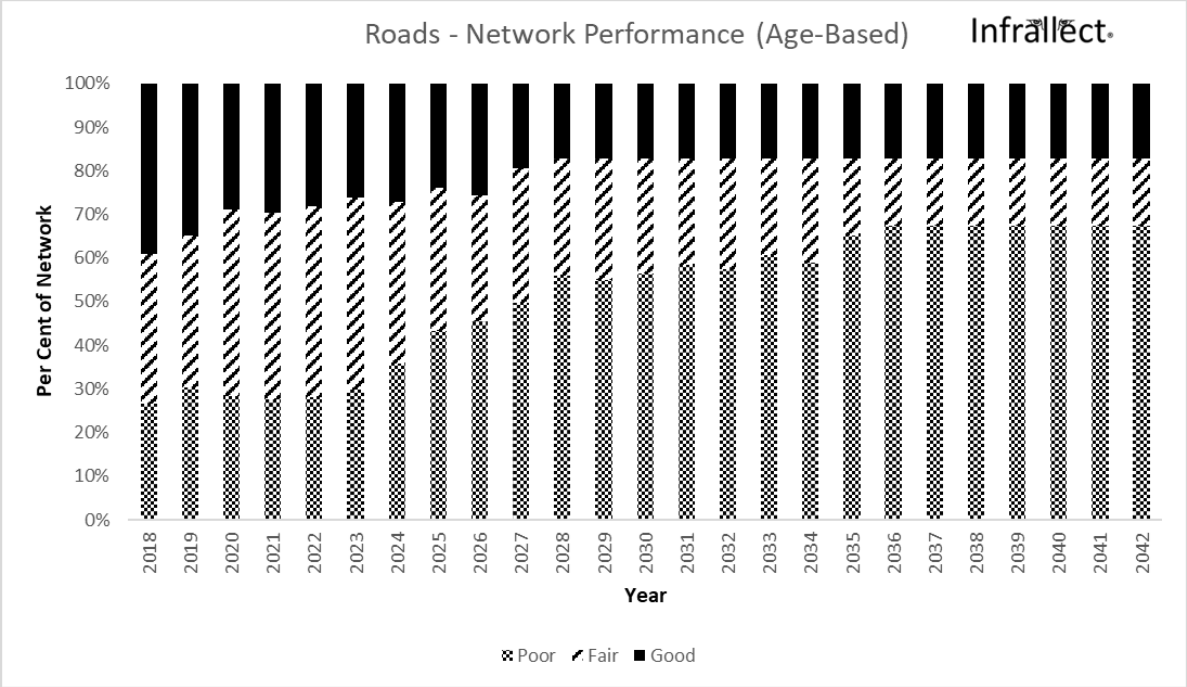


Figure 24: Roads – Age - Based Performance Forecast

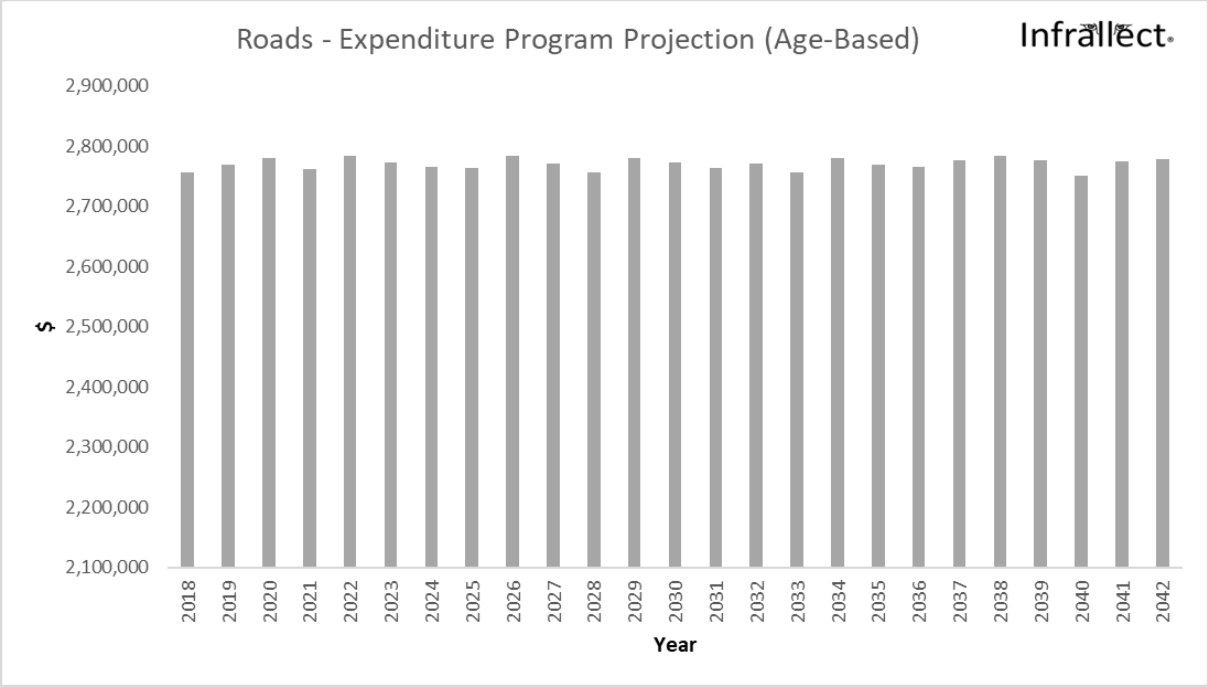


Figure 25: Roads – Age - Based Expenditure Forecast

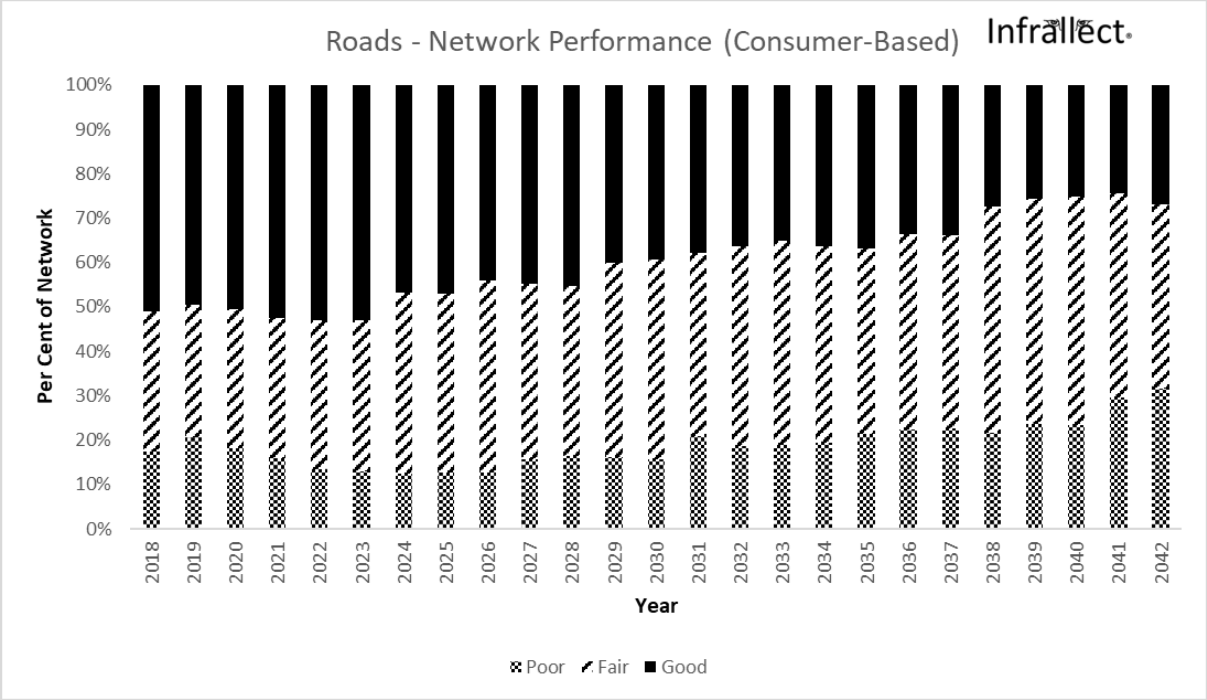


Figure 26: Roads – Consumer - Based Performance Forecast

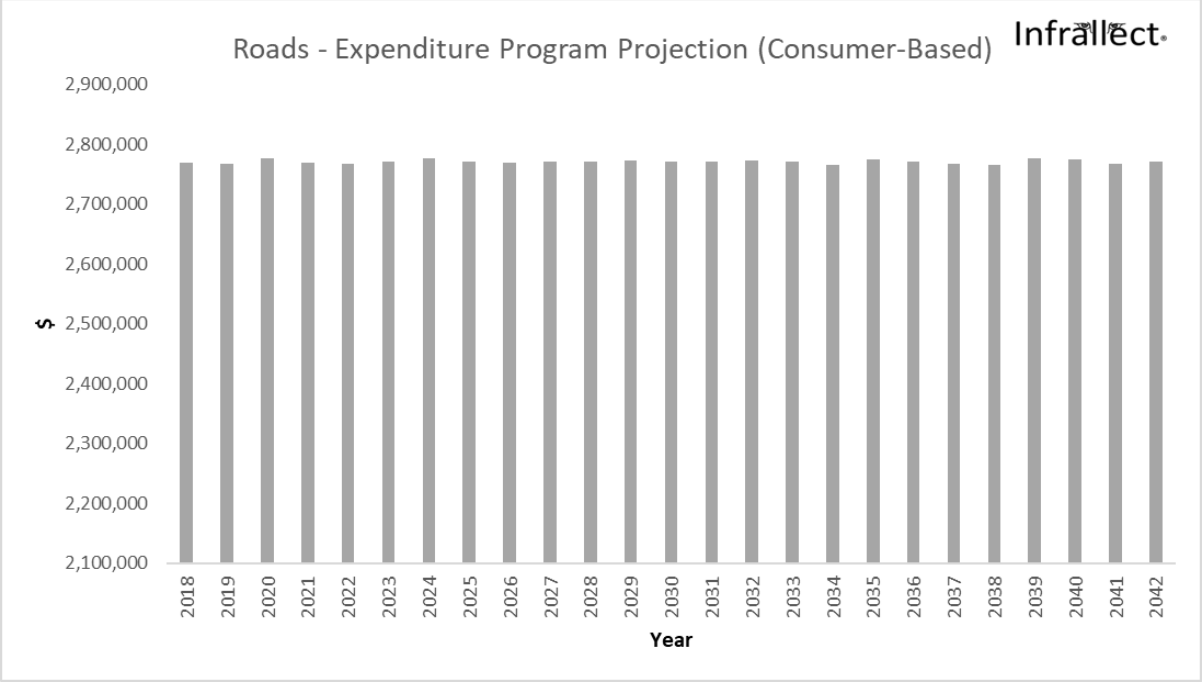


Figure 27: Roads – Consumer - Based Expenditure Forecast

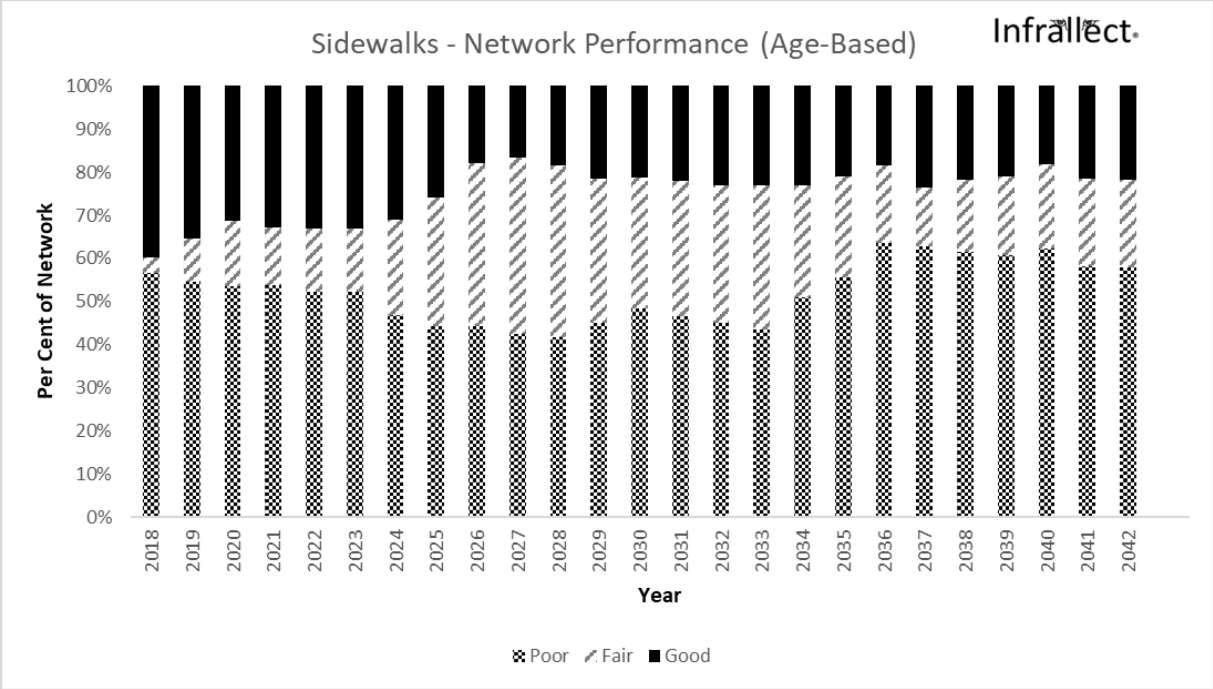


Figure 28: Sidewalks – Age - Based Performance Forecast

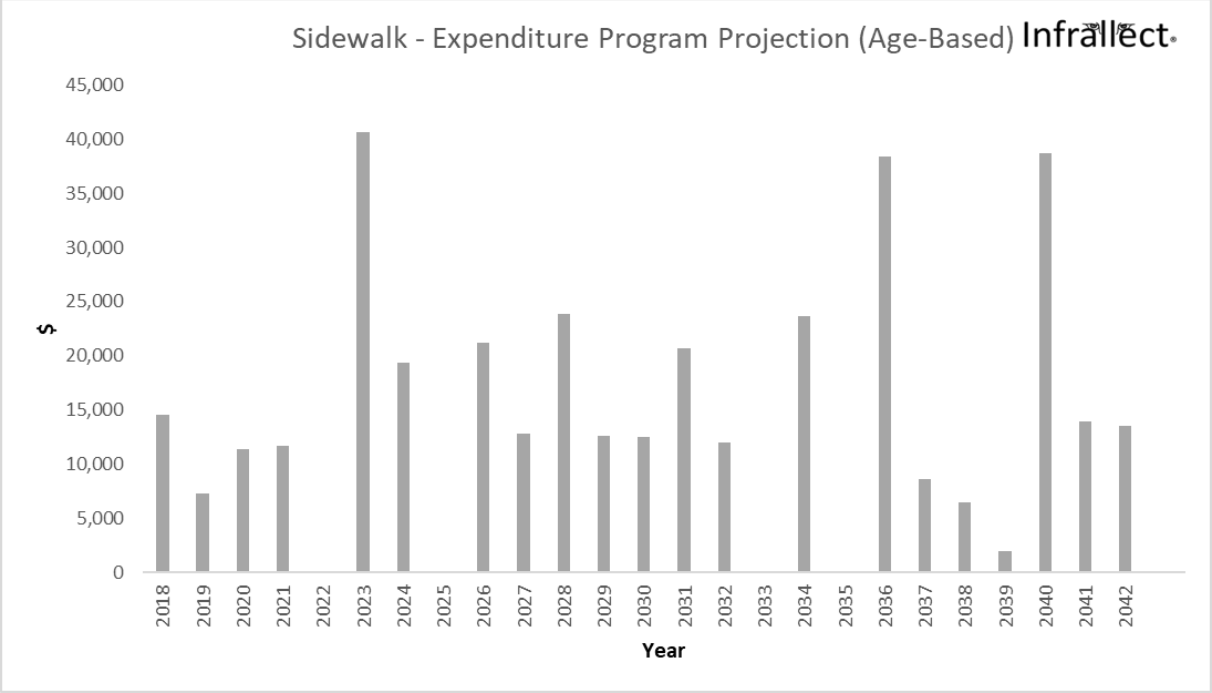


Figure 29: Sidewalks – Age - Based Expenditure Forecast

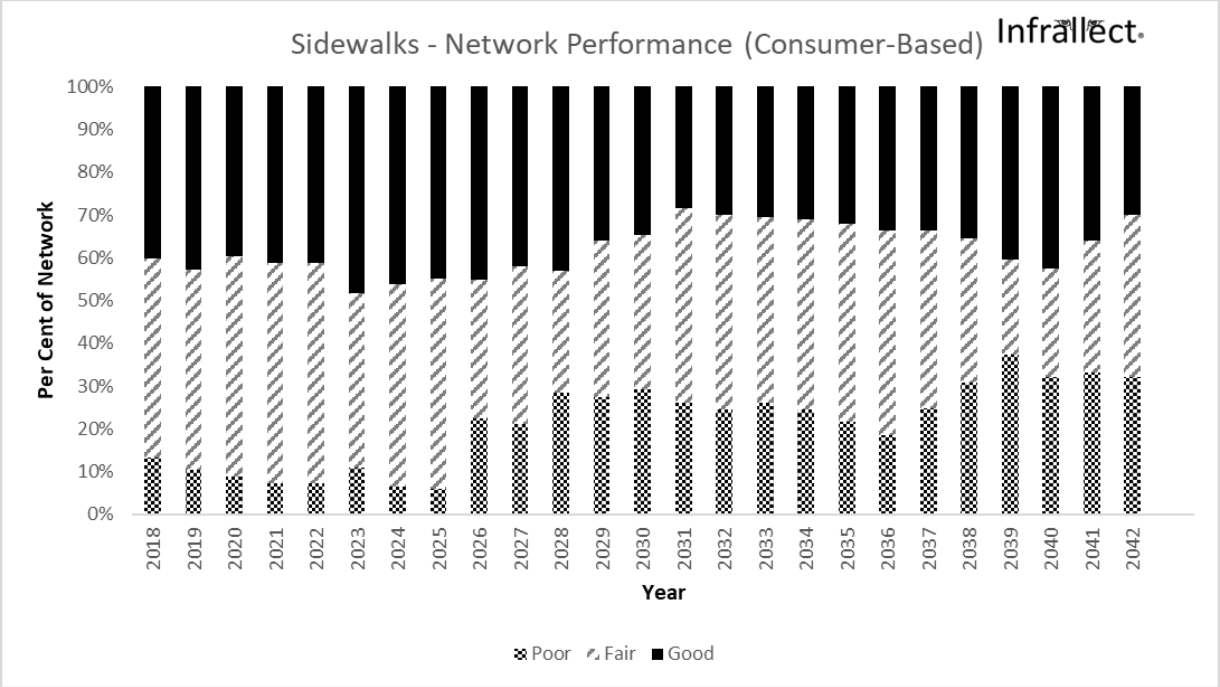


Figure 30: Sidewalks – Consumer - Based Performance Forecast

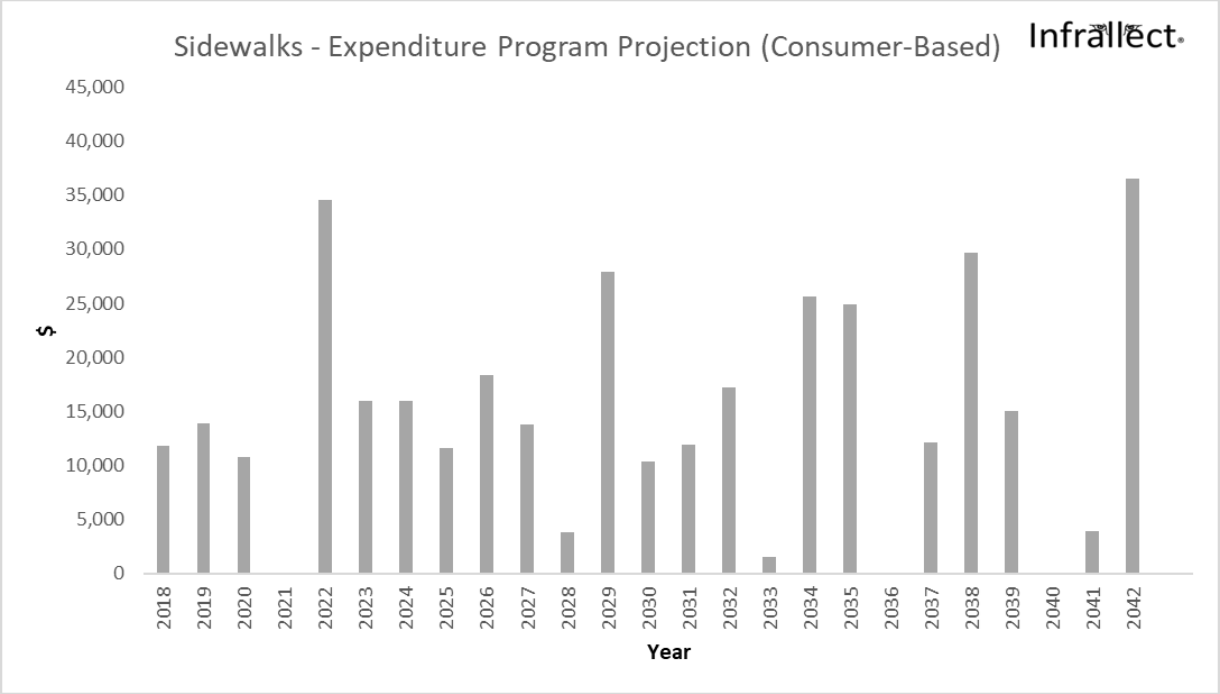


Figure 31: Sidewalks – Consumer - Based Expenditure Forecast

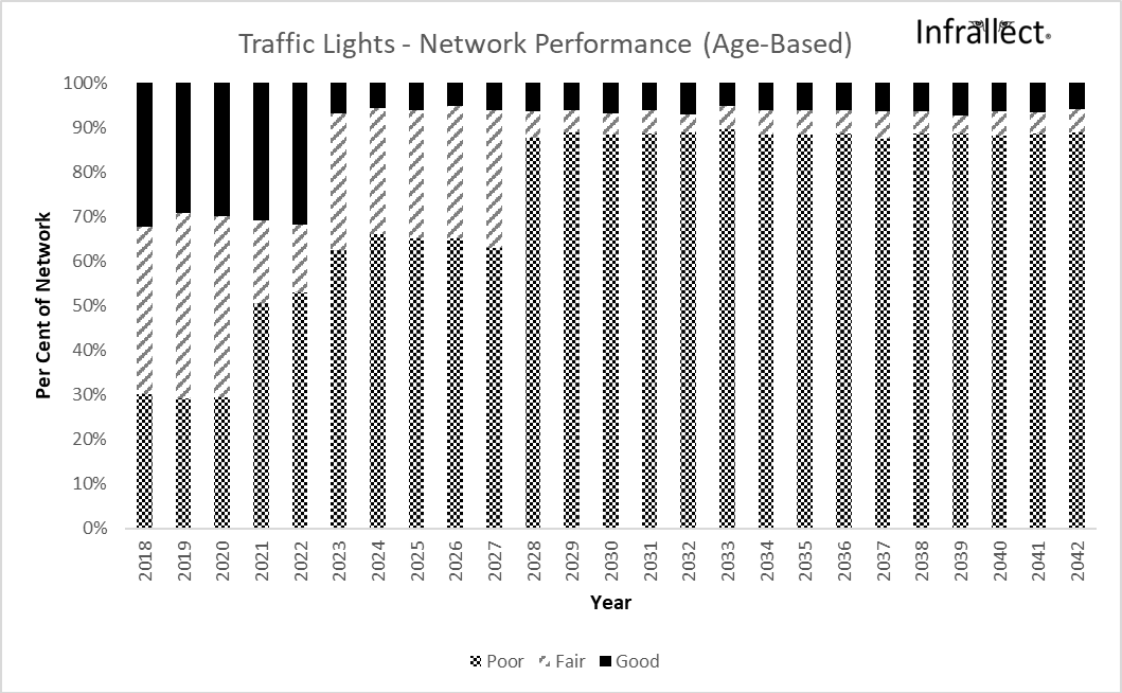


Figure 32: Traffic Lights – Age - Based Performance Forecast

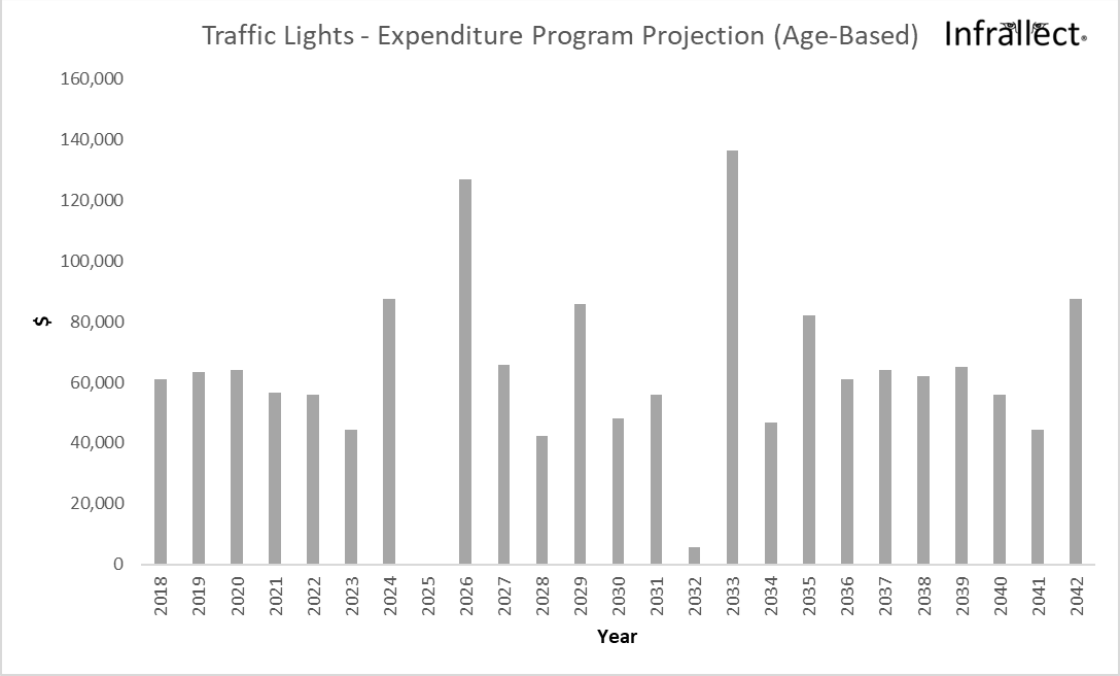


Figure 33: Traffic Lights – Age - Based Expenditure Forecast

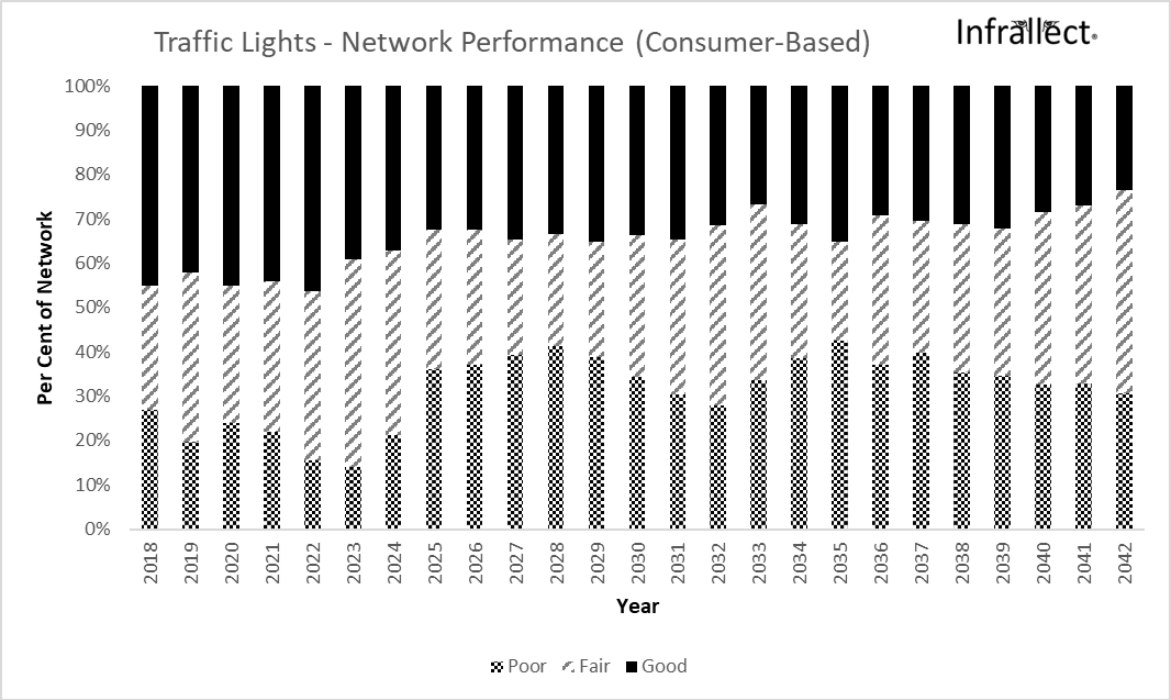


Figure 34: Traffic Lights – Consumer - Based Performance Forecast

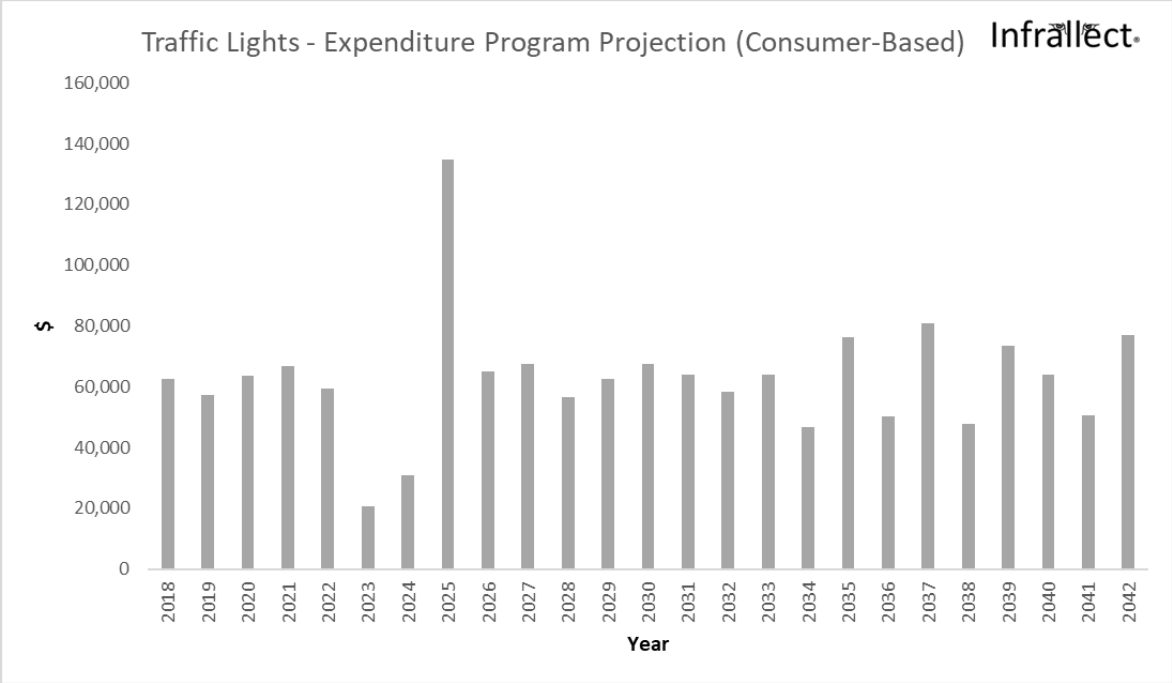


Figure 35: Traffic Lights Consumer - Based Expenditure Forecast

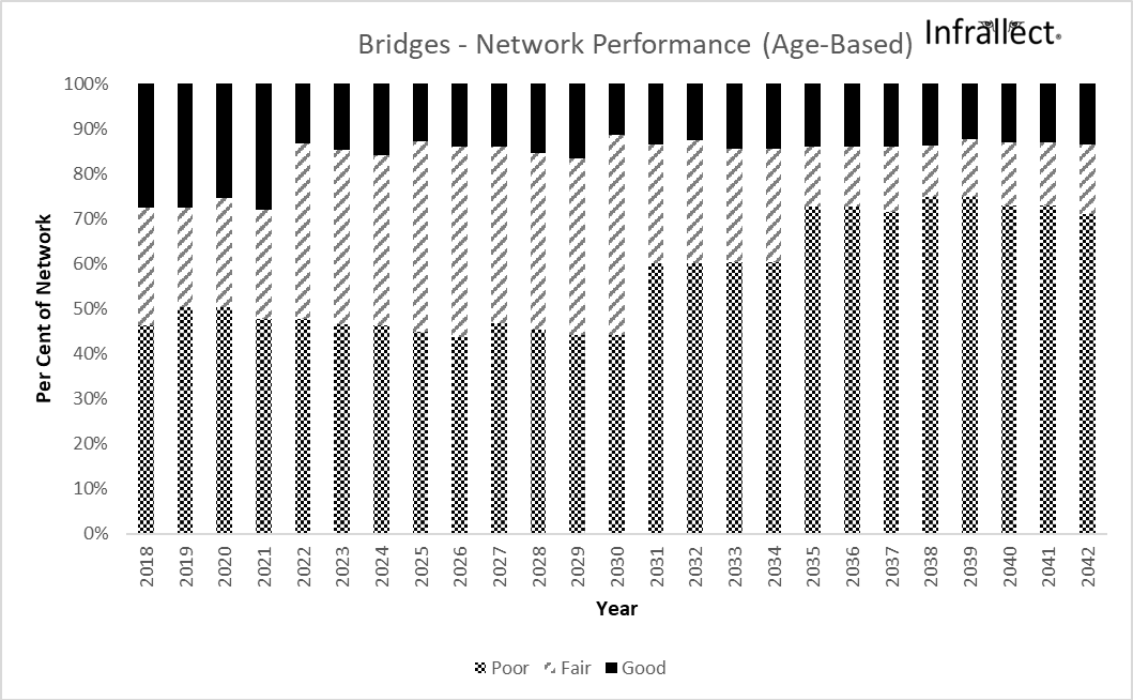


Figure 36: Bridges – Age - Based Performance Forecast

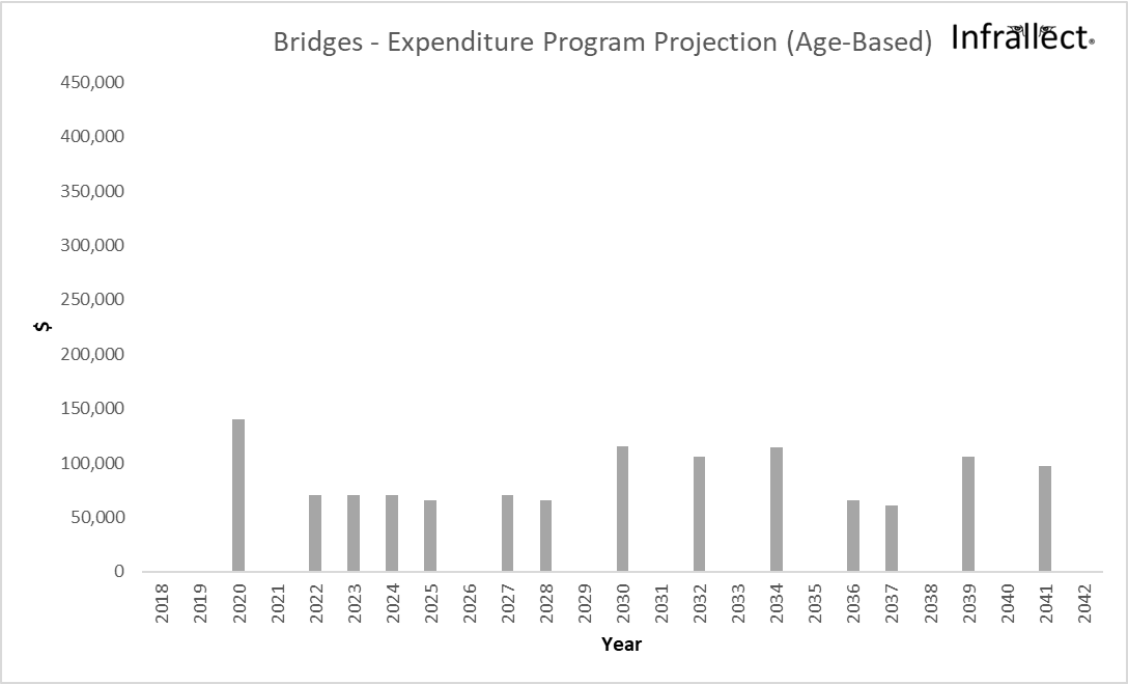


Figure 37: Bridges – Age - Based Expenditure Forecast

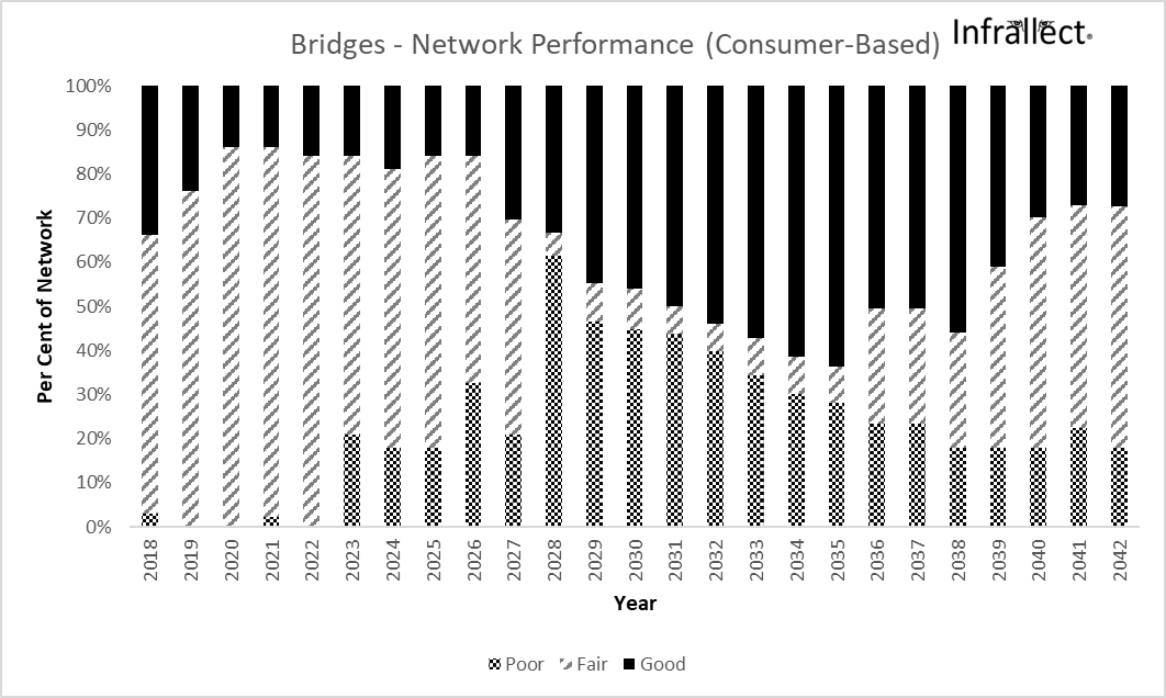


Figure 38: Bridges – Consumer - Based Performance Forecast

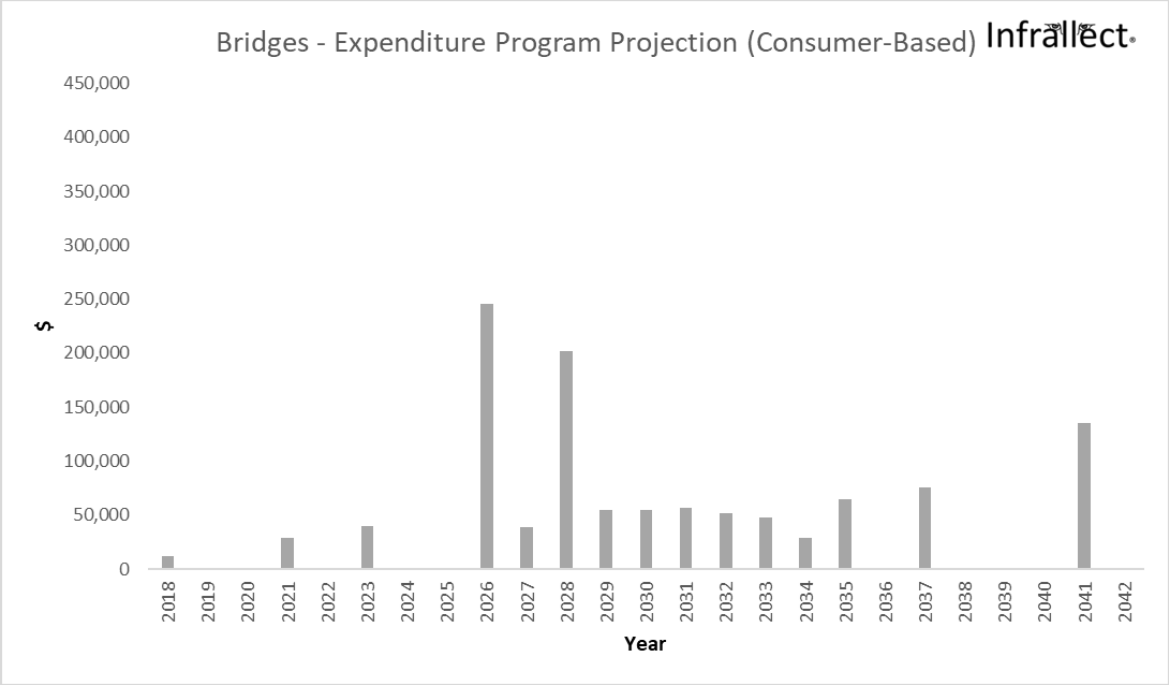


Figure 39: Bridges – Consumer - Based Expenditure Forecast

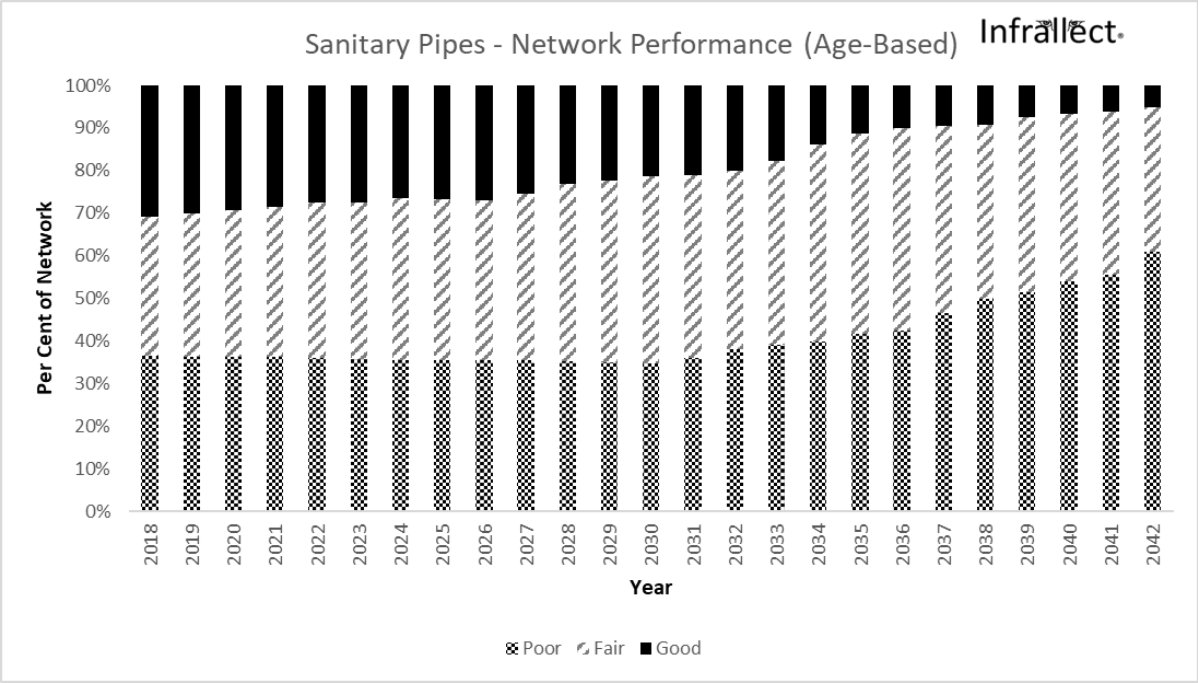


Figure 40: Sanitary – Age - Based Performance Forecast

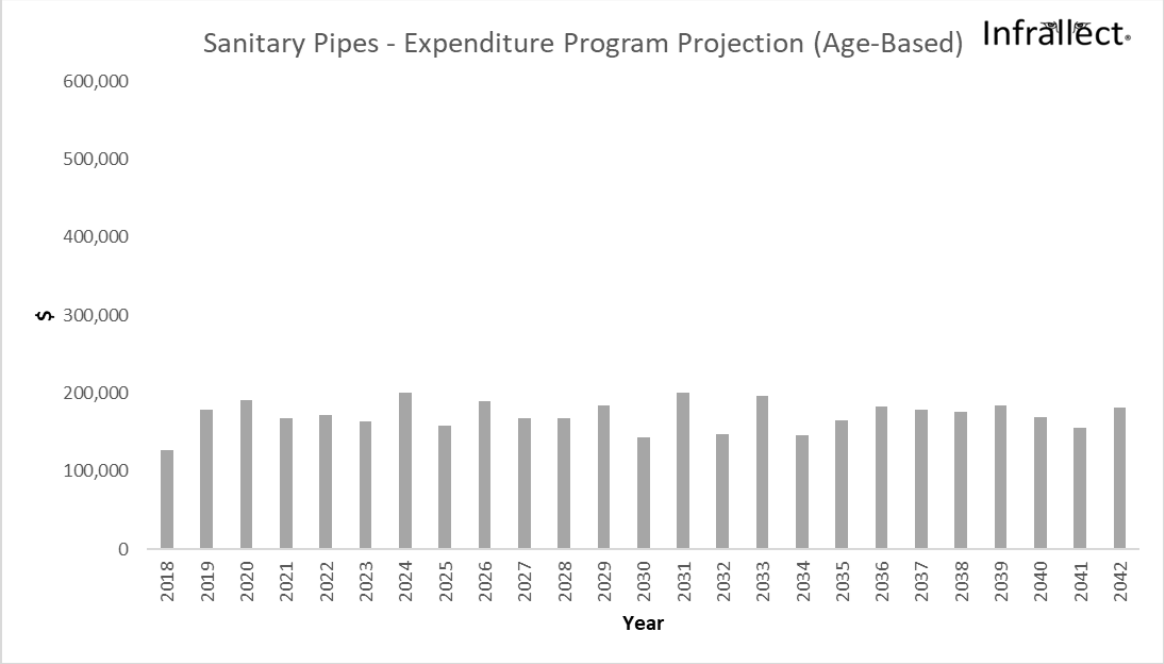


Figure 41: Sanitary – Age - Based Expenditure Forecast

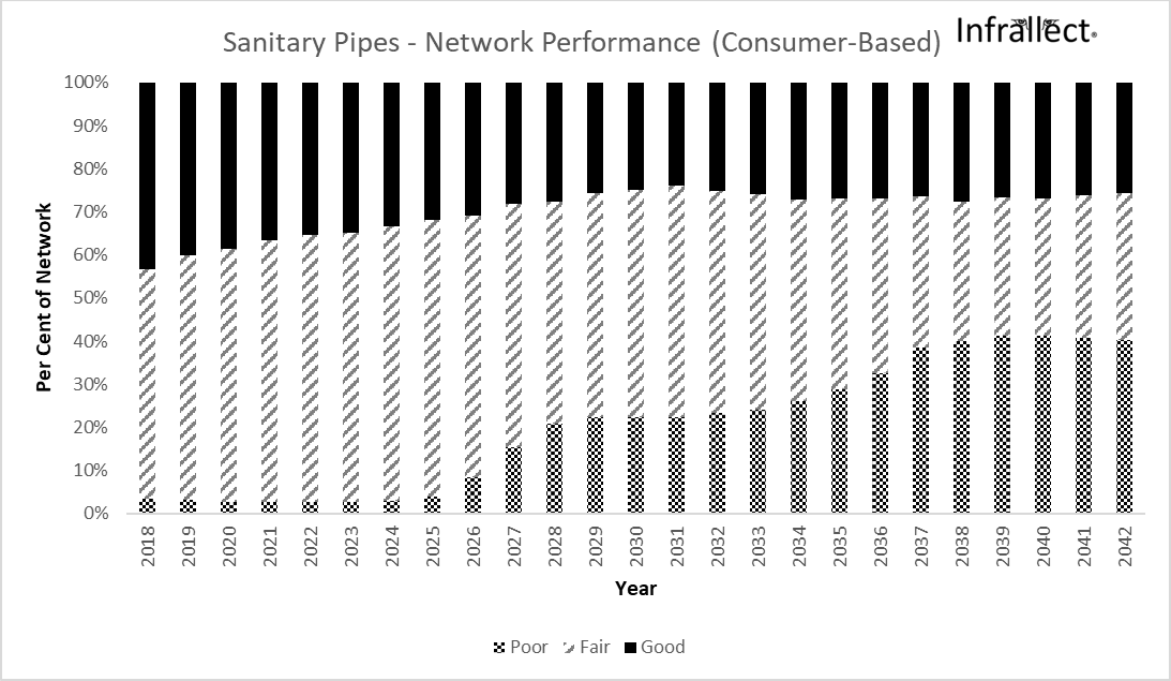


Figure 42: Sanitary – Consumer - Based Performance Forecast

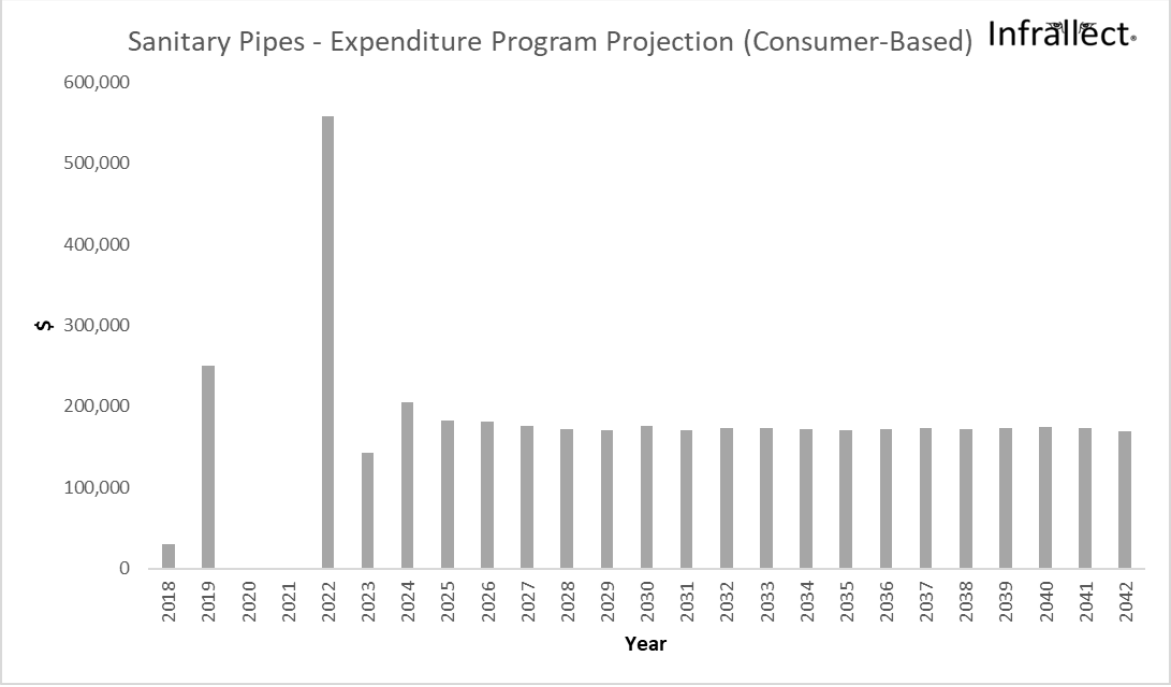


Figure 43: Sanitary – Consumer - Based Expenditure Forecast

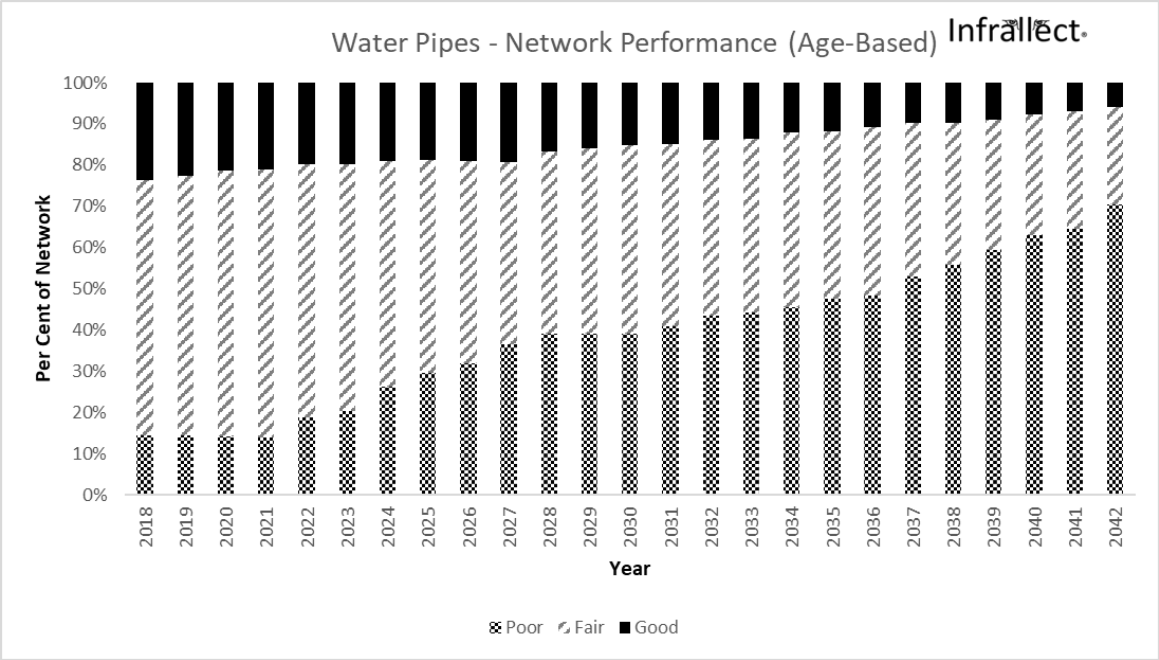


Figure 44: Water – Age - Based Performance Forecast

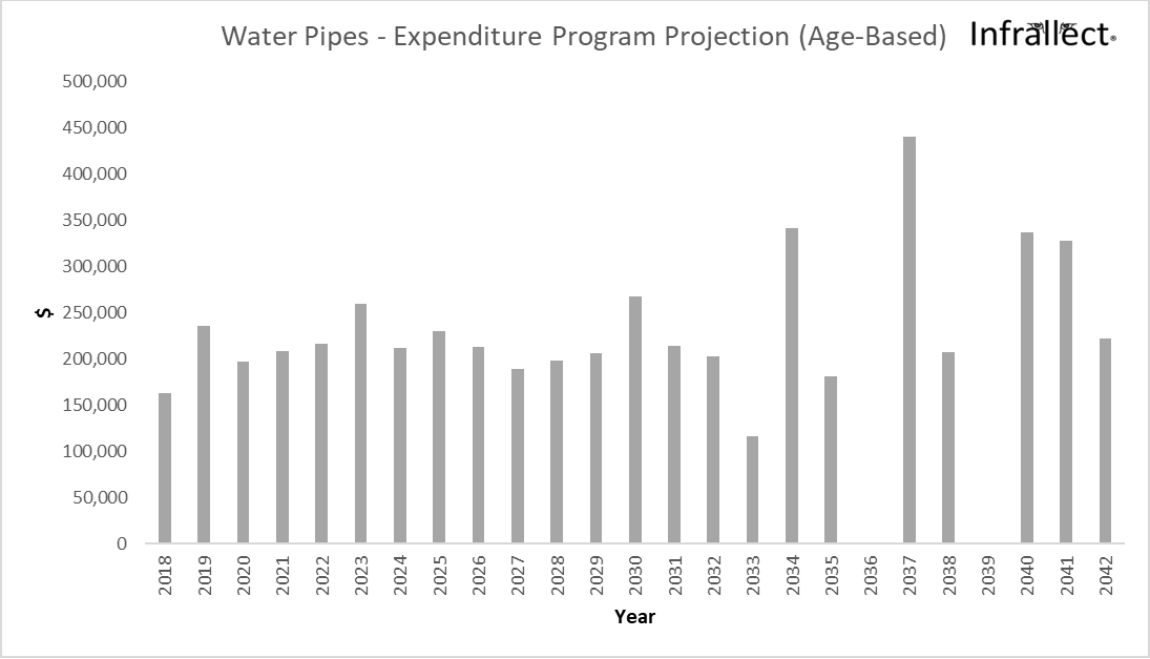


Figure 45: Water – Age - Based Expenditure Forecast

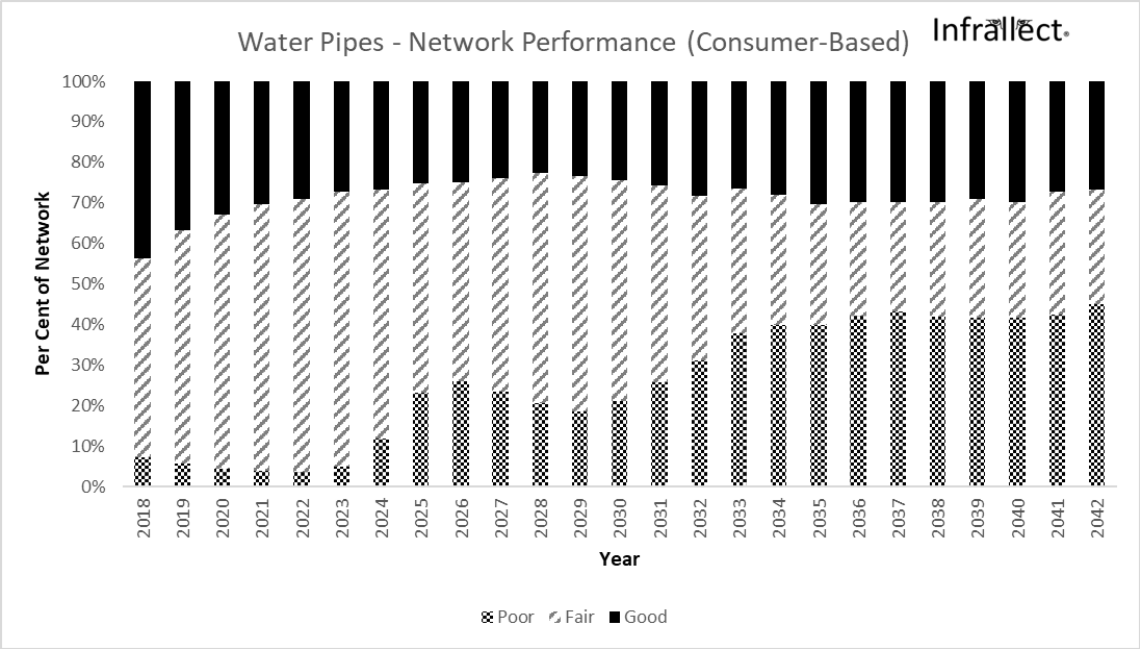


Figure 46: Water – Consumer - Based Performance Forecast

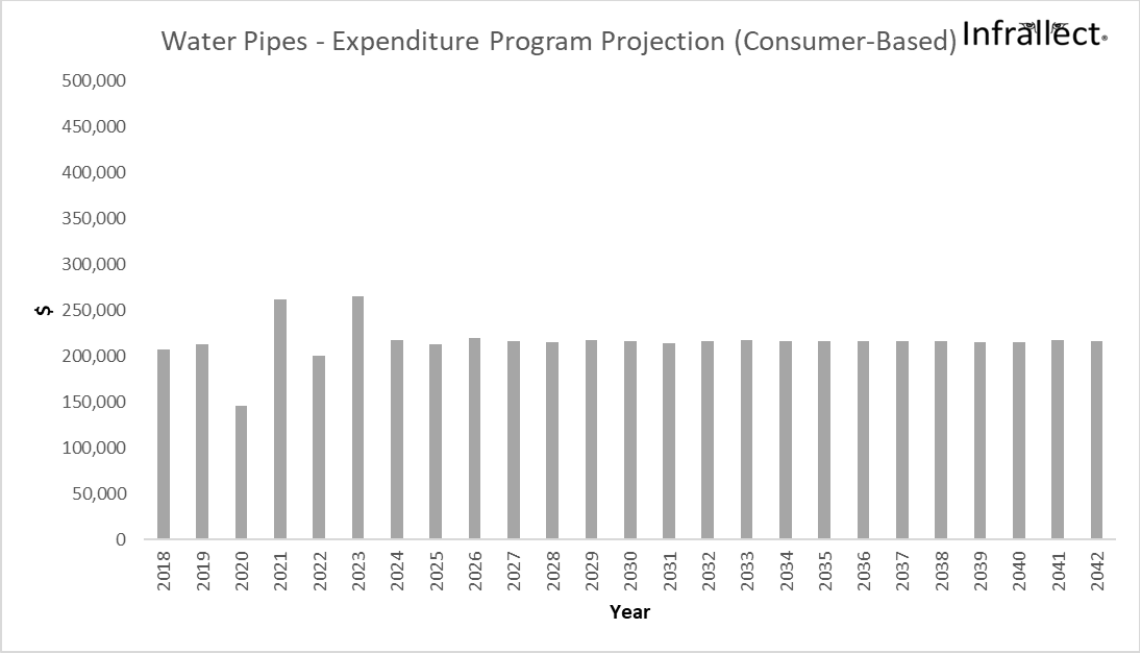


Figure 47: Water – Consumer - Based Expenditure Forecast

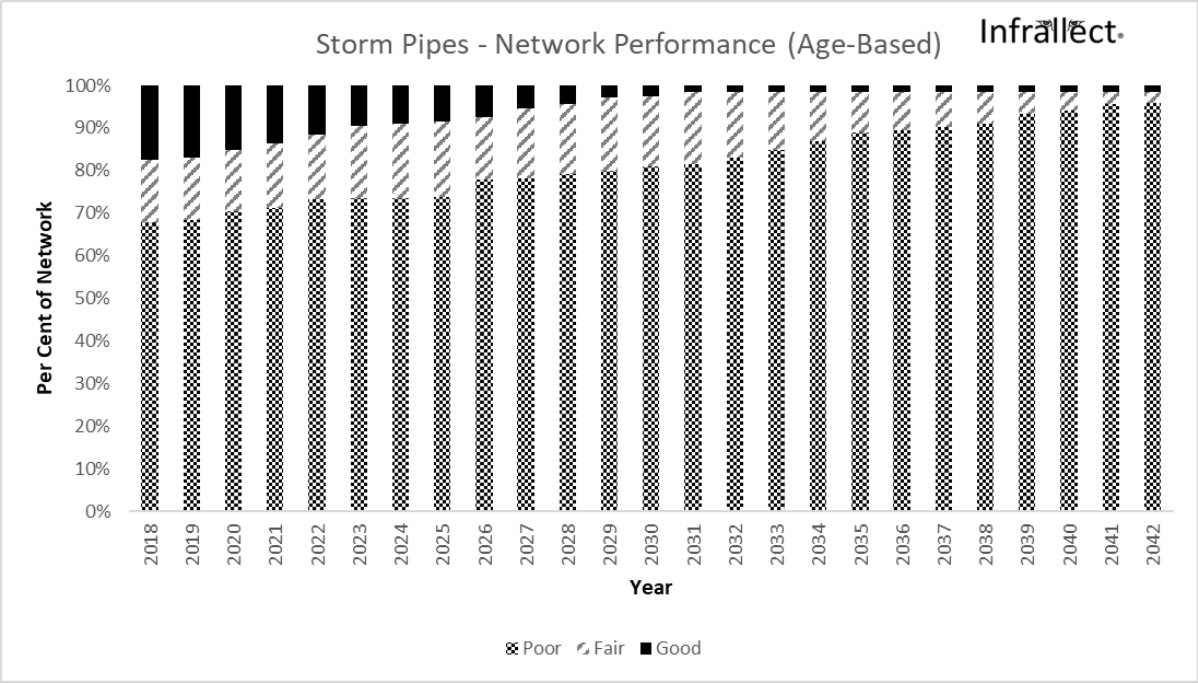


Figure 48: Storm – Age - Based Performance Forecast

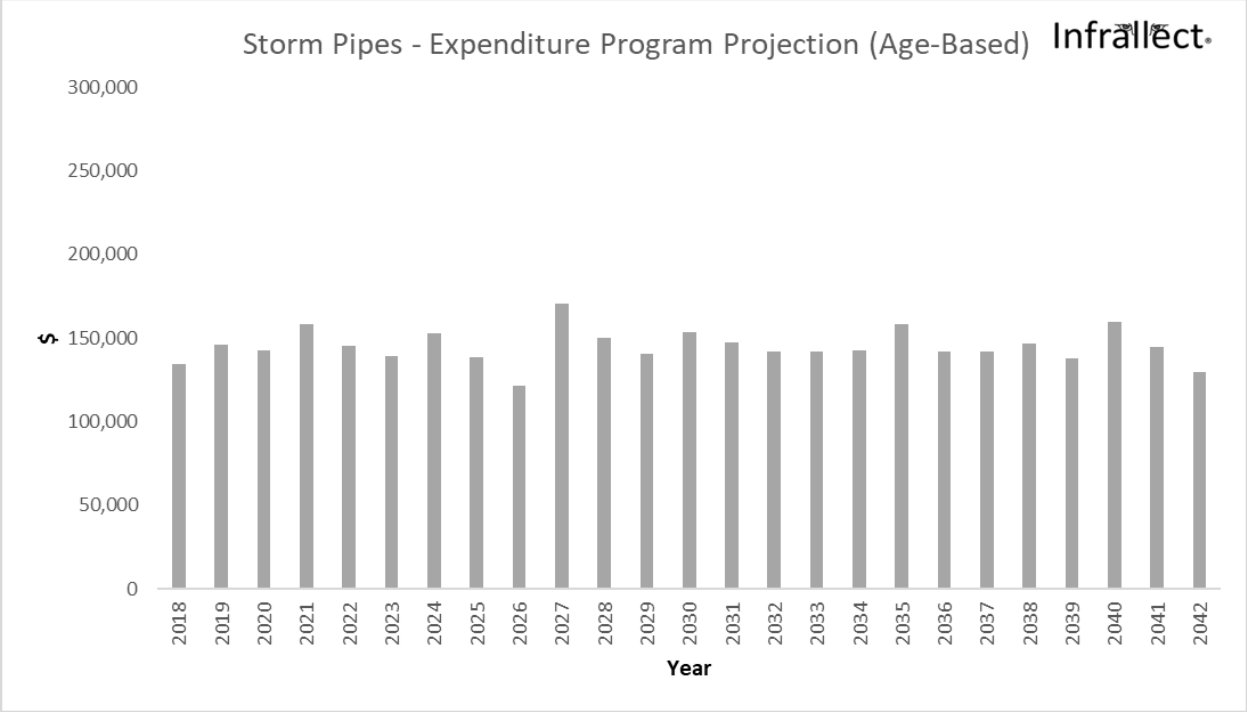


Figure 49: Storm – Age - Based Expenditure Forecast

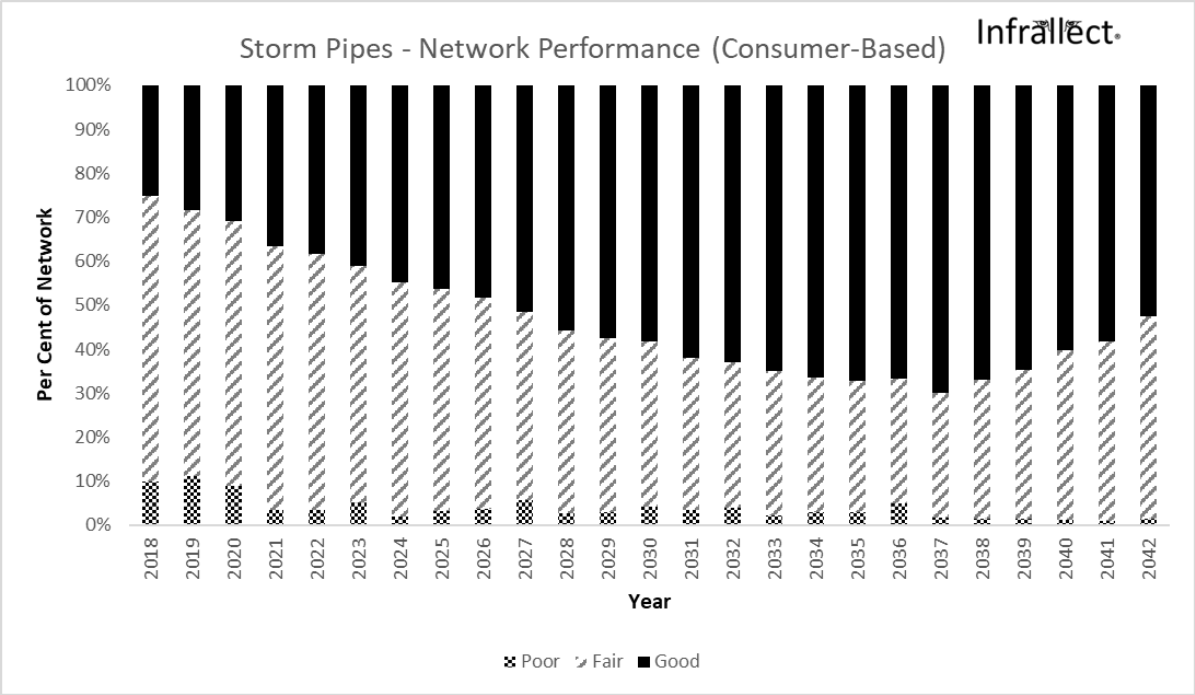


Figure 50: Storm – Consumer - Based Performance Forecast

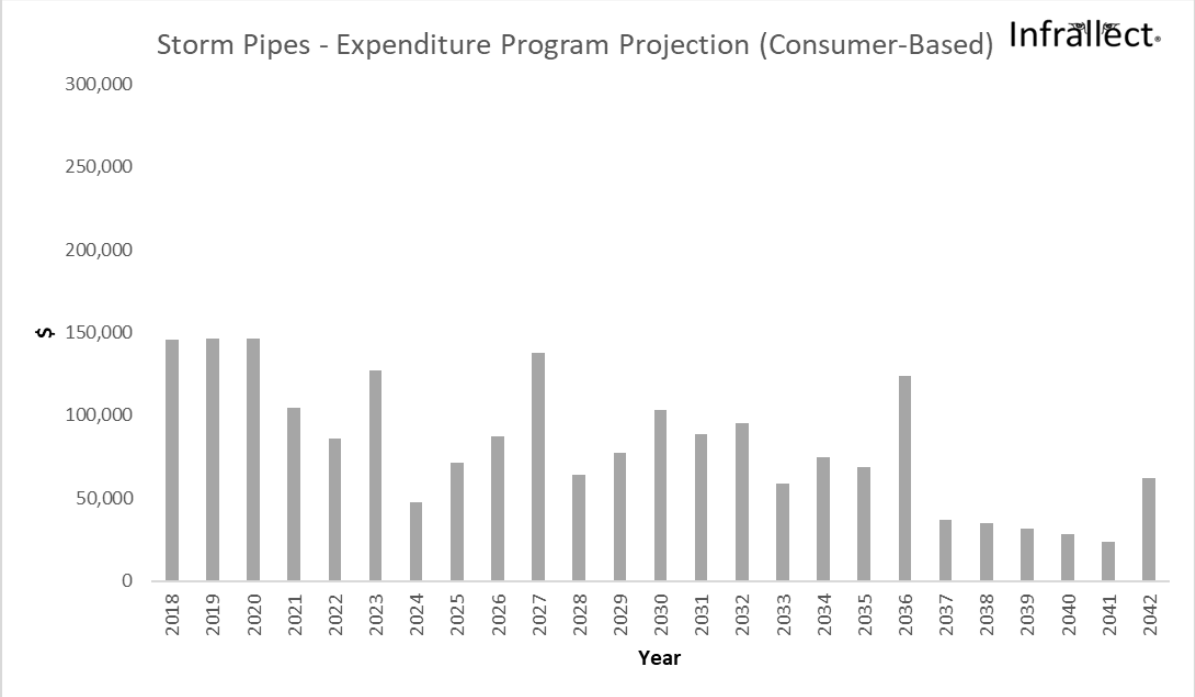


Figure 51: Storm – Consumer - Based Expenditure Forecast

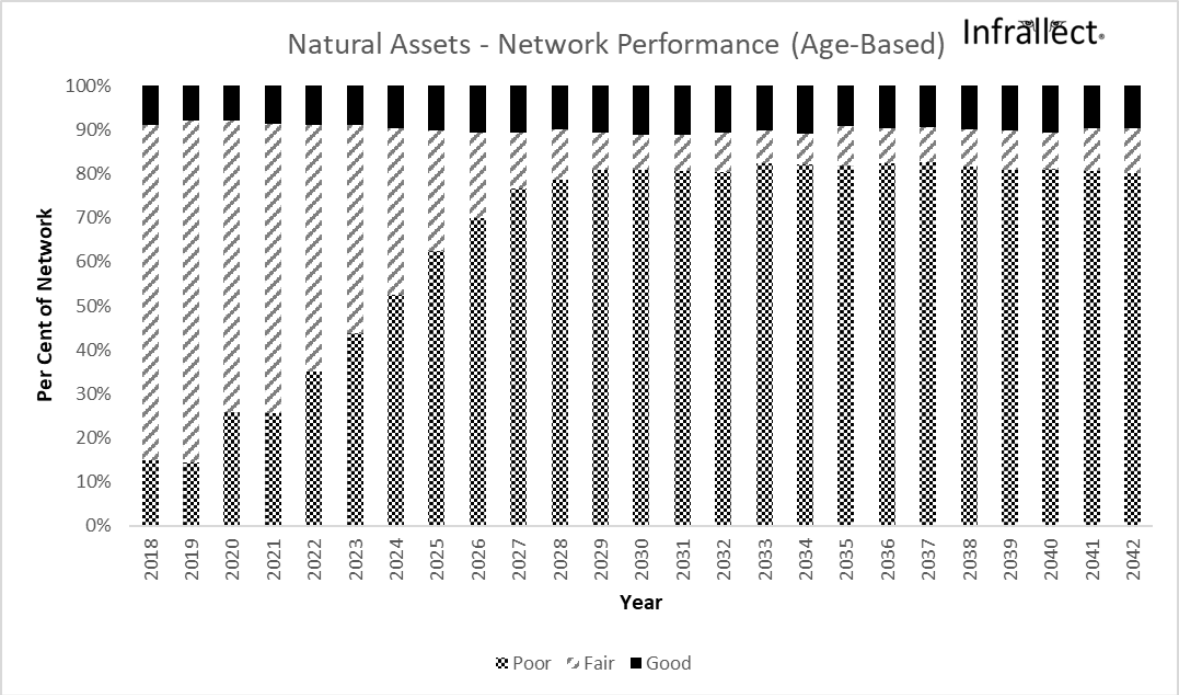


Figure 52: Natural Assets – Age - Based Performance Forecast

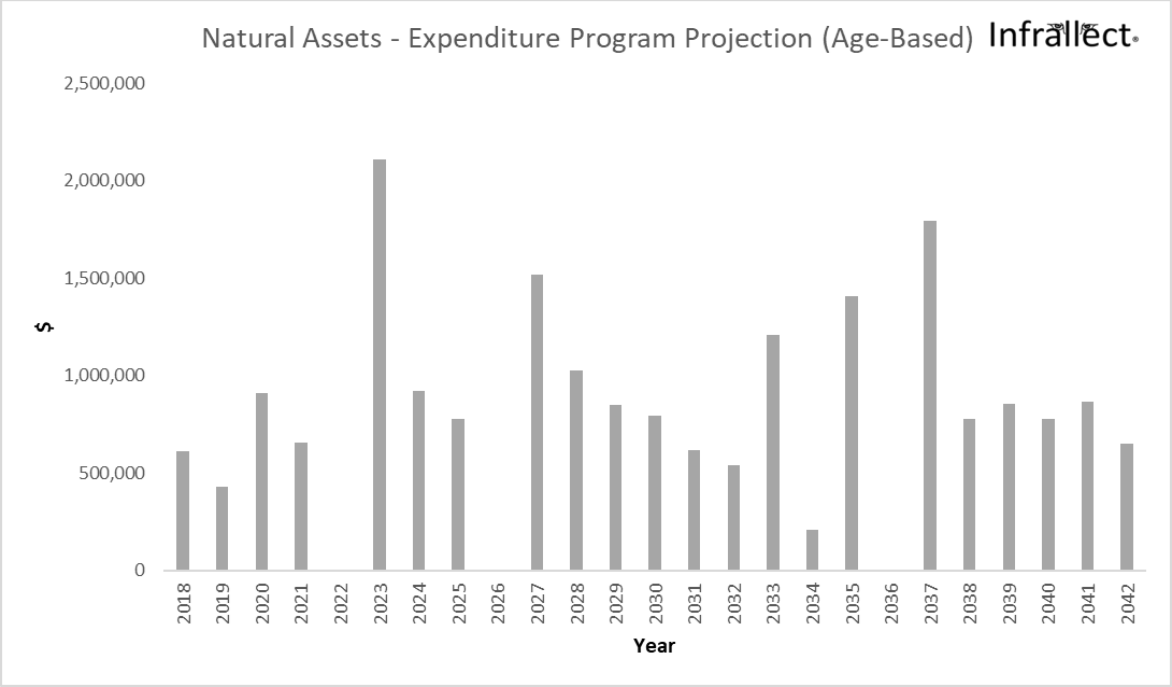


Figure 53: Natural Assets – Age - Based Expenditure Forecast

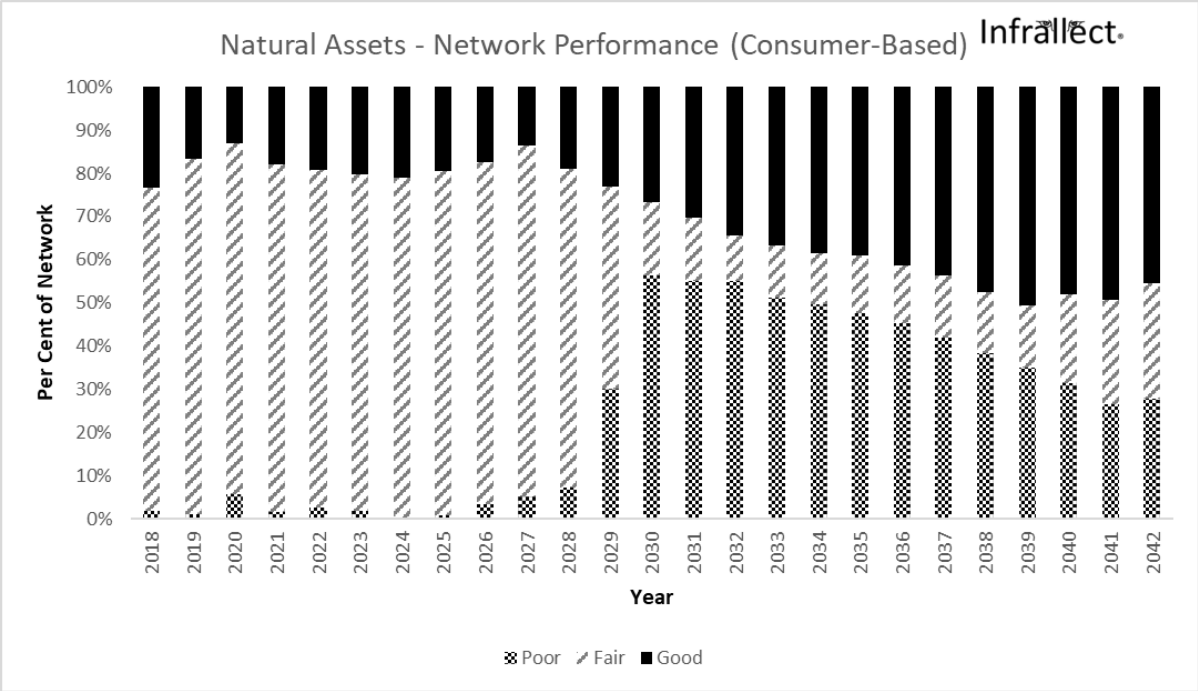


Figure 54: Natural Assets – Consumer - Based Performance Forecast

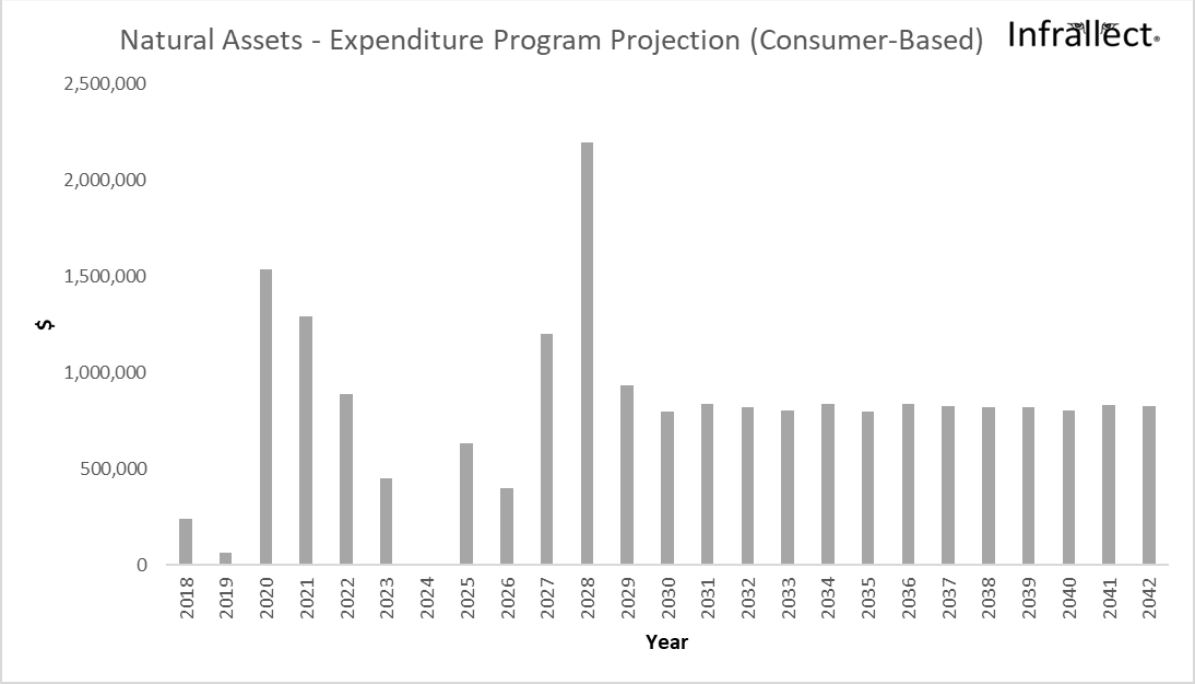


Figure 55: Natural Assets – Consumer - Based Expenditure Forecast

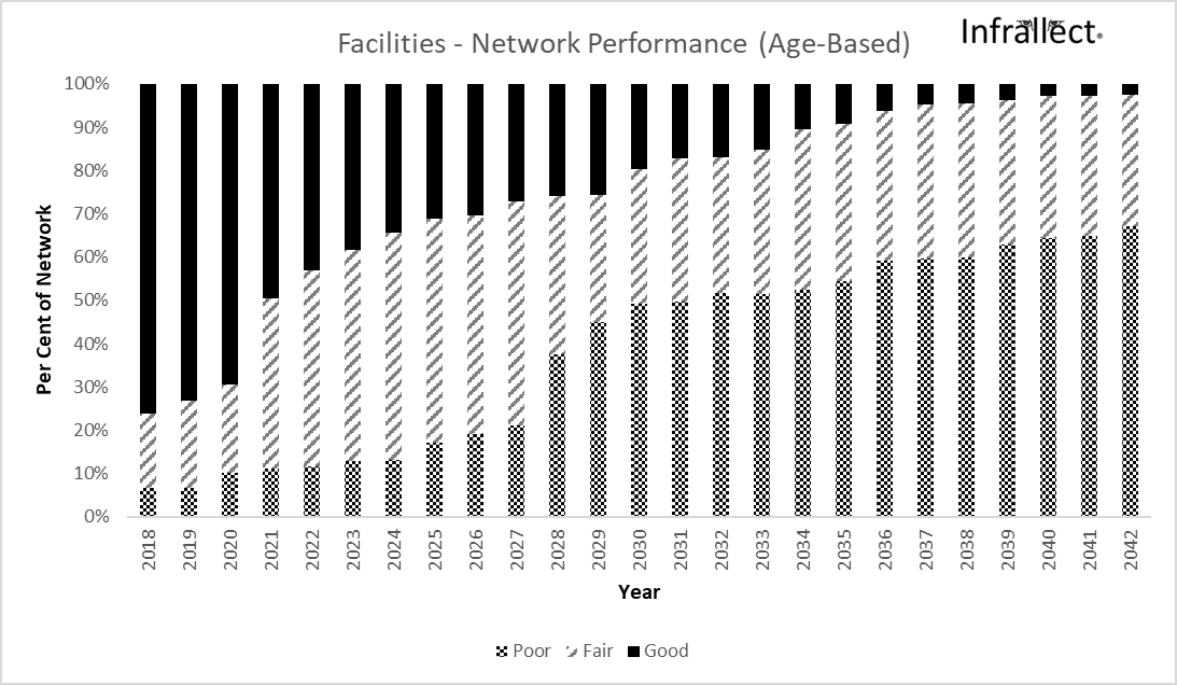


Figure 56: Facilities – Age - Based Performance Forecast

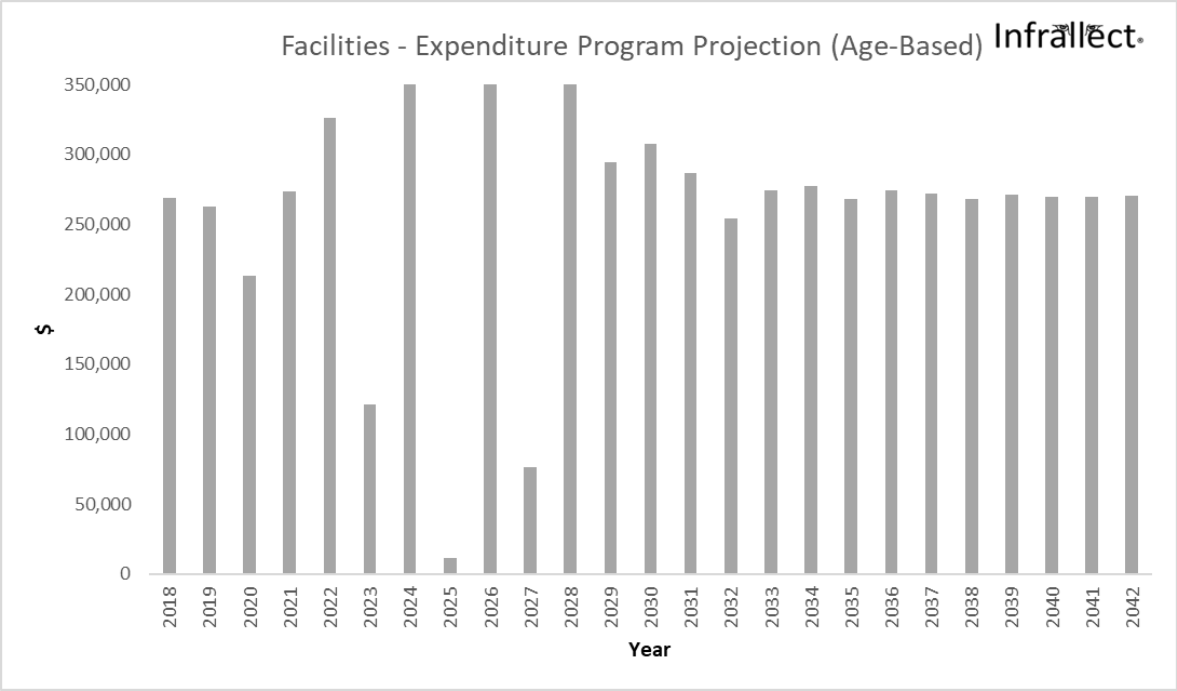


Figure 57: Facilities – Age - Based Expenditure Forecast

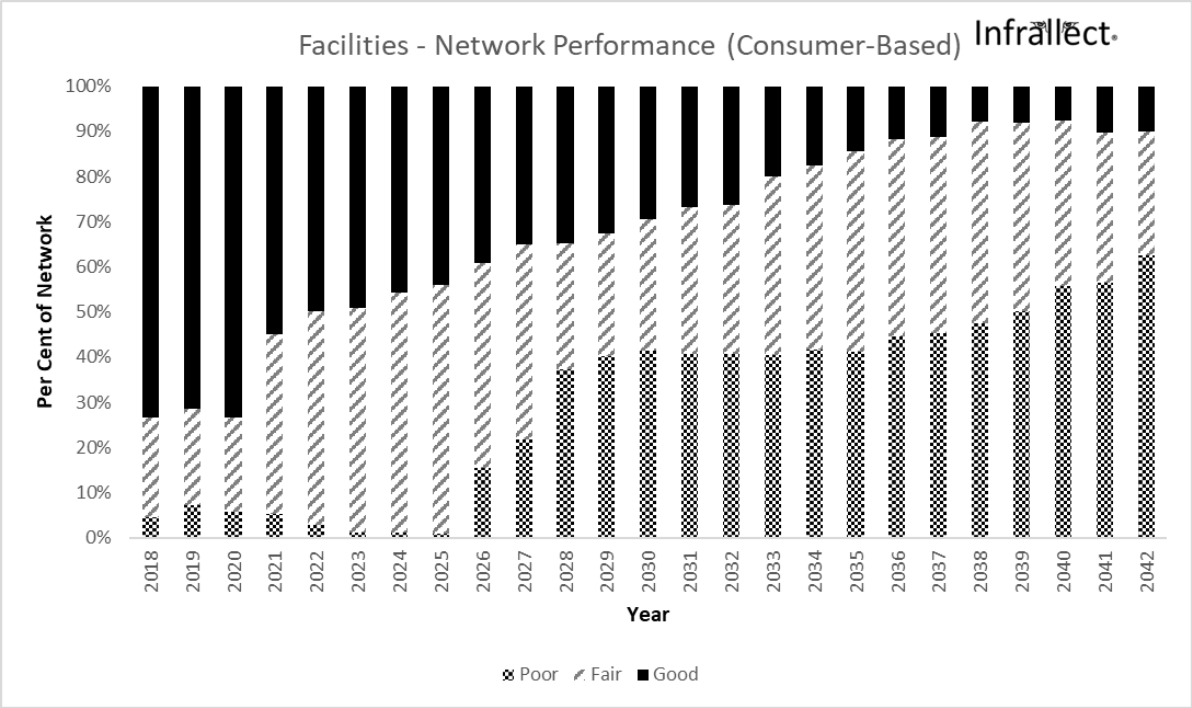


Figure 58: Facilities – Consumer - Based Performance Forecast

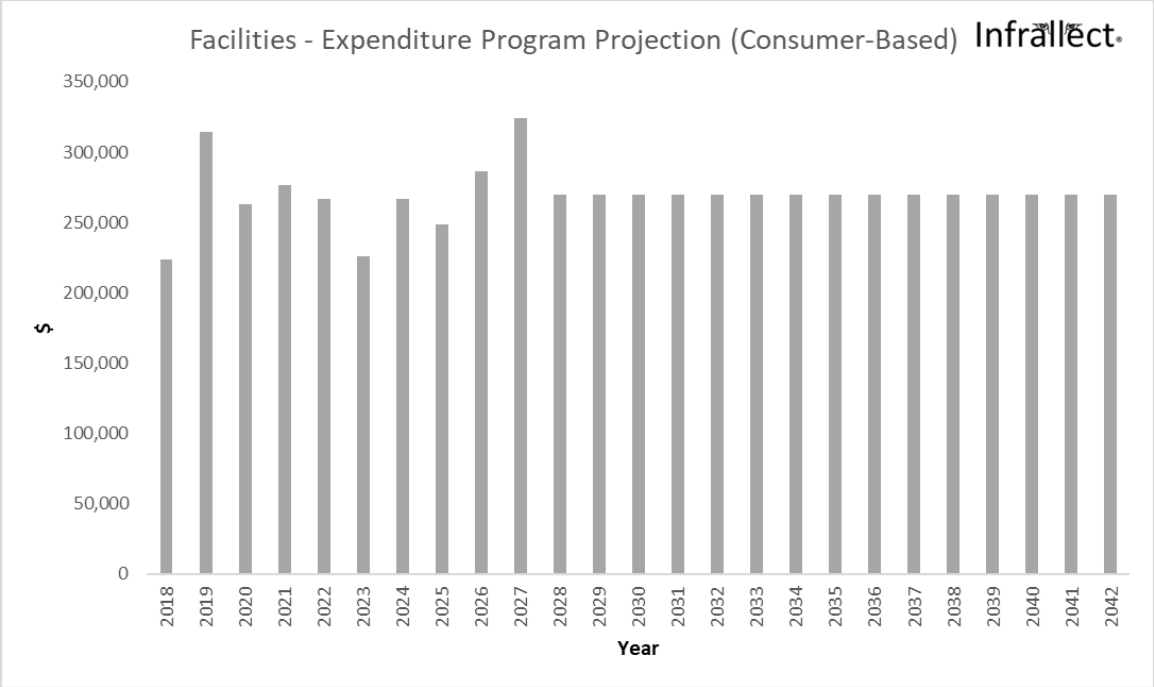


Figure 59: Facilities – Consumer - Based Expenditure Forecast

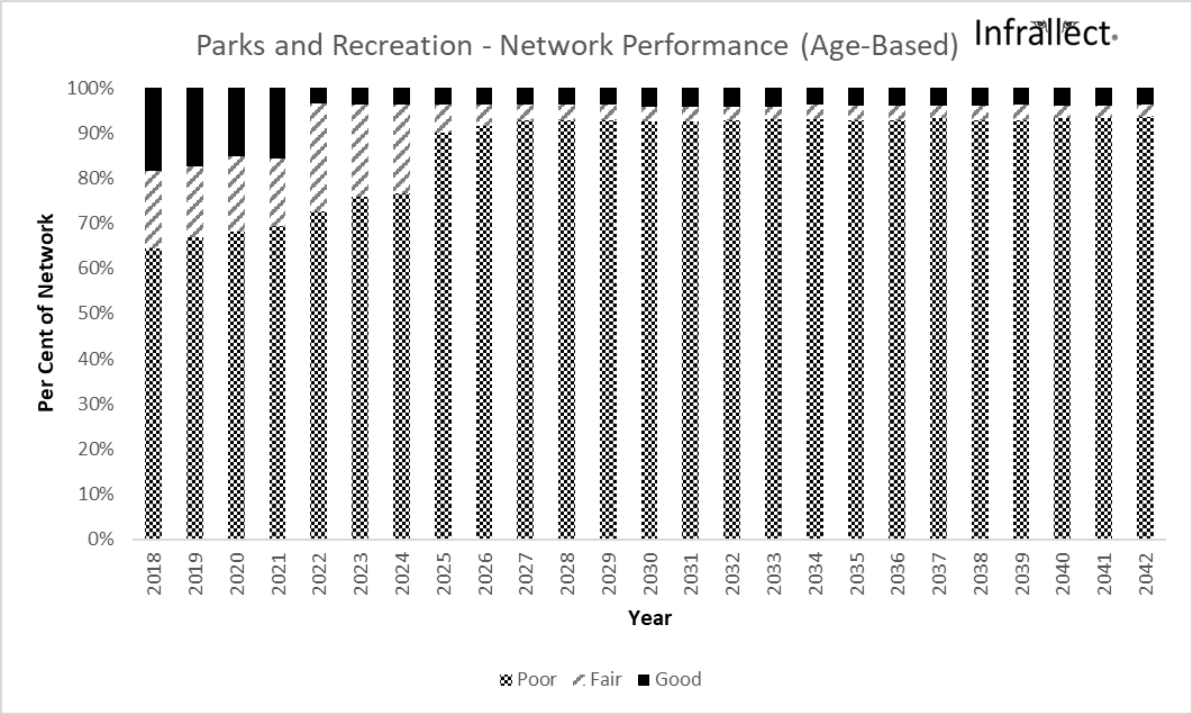


Figure 60: Parks– Age - Based Performance Forecast

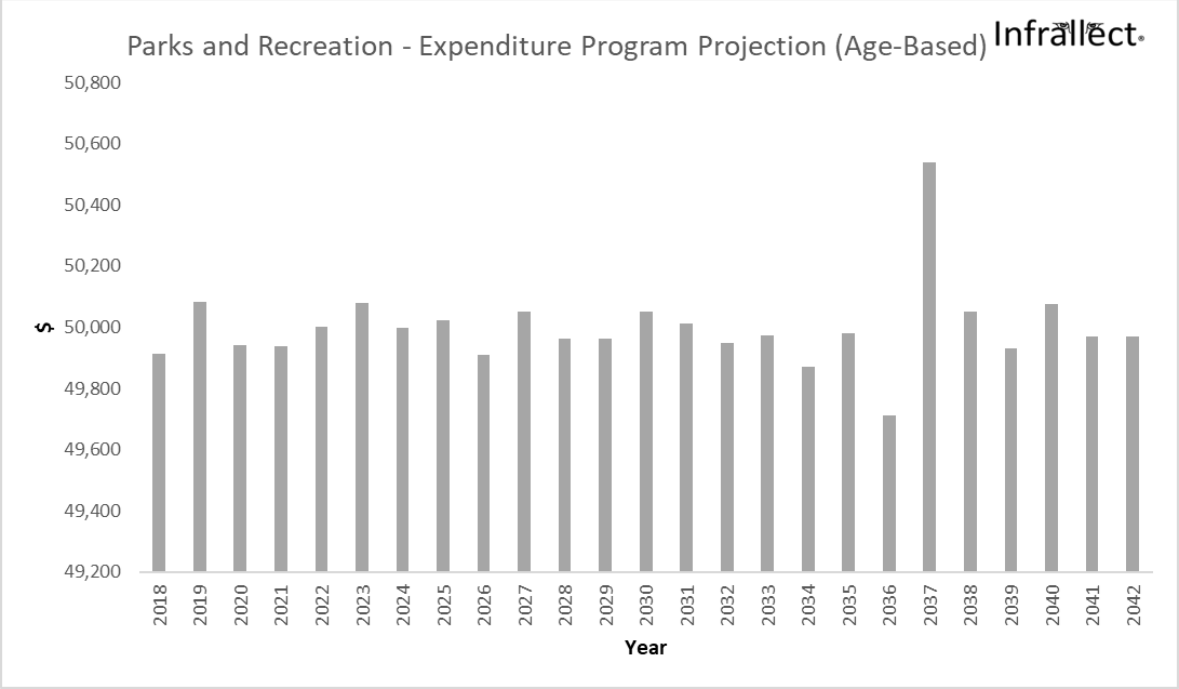


Figure 61: Parks – Age - Based Expenditure Forecast

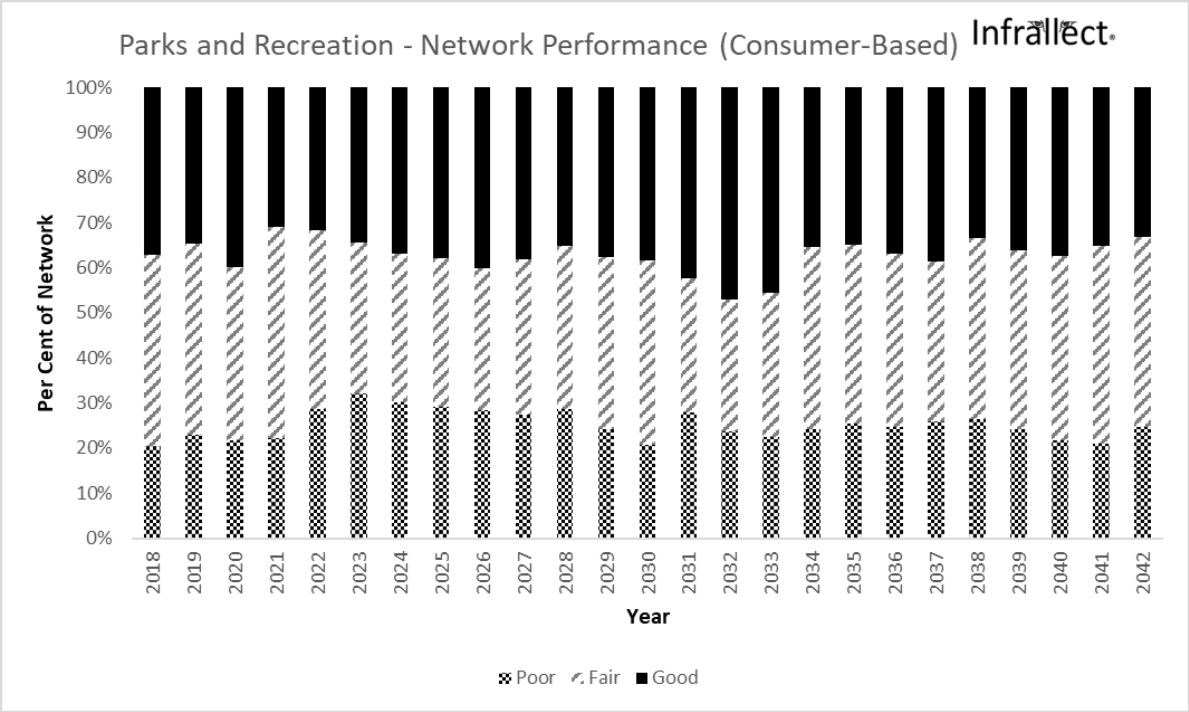


Figure 62: Parks – Consumer - Based Performance Forecast

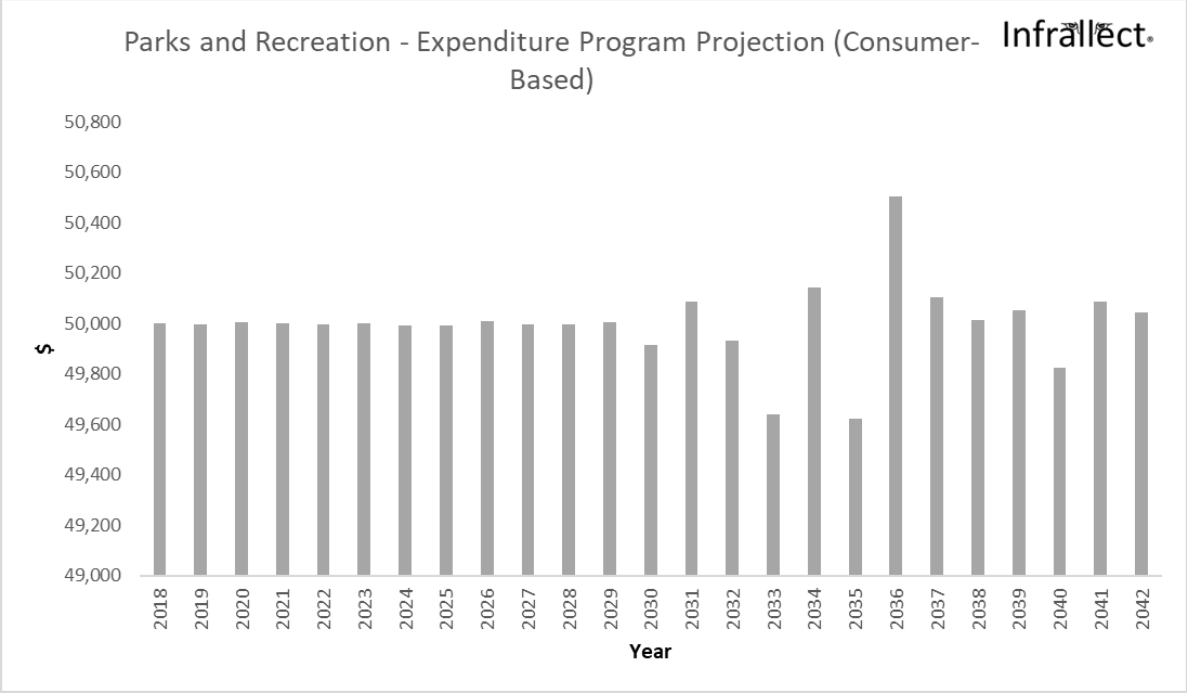


Figure 63: Parks – Consumer - Based Expenditure Forecast

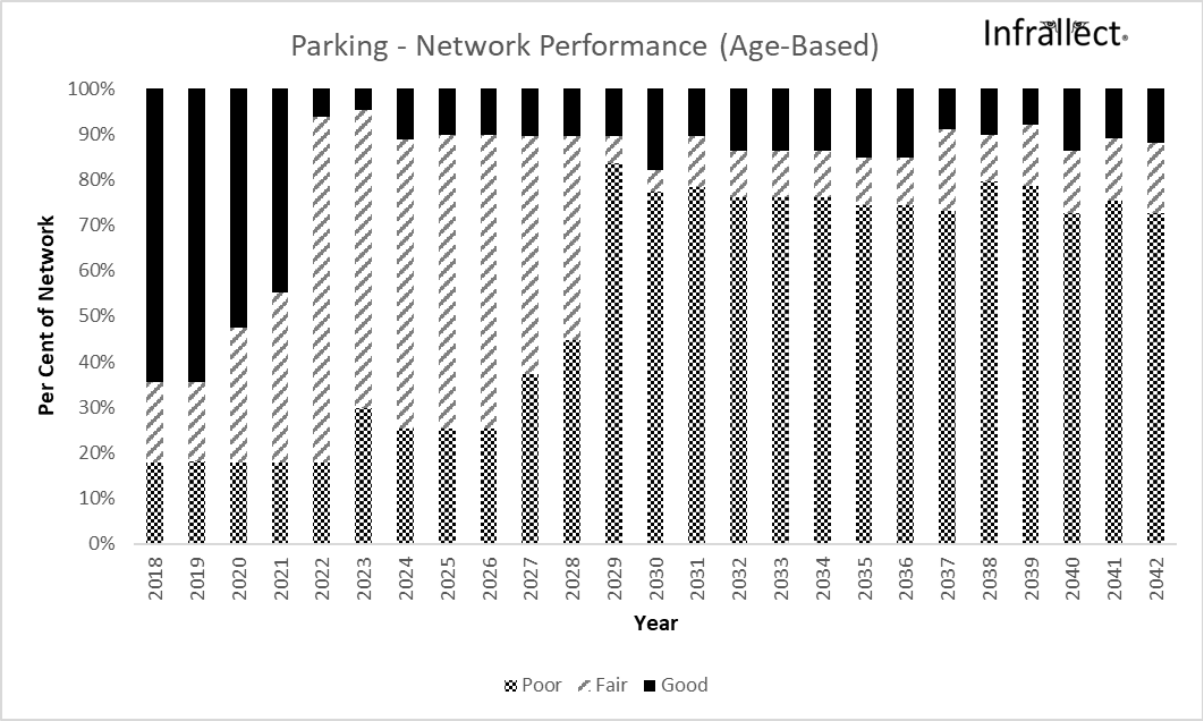


Figure 64: Parking – Age - Based Performance Forecast

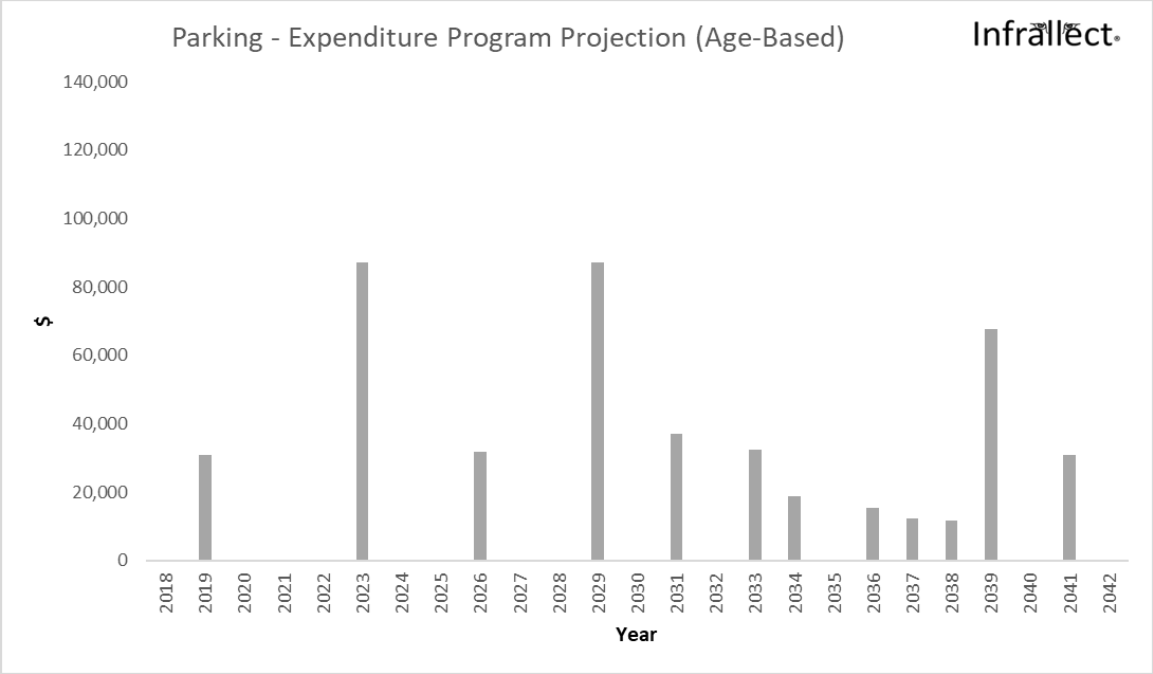


Figure 65: Parking – Age - Based Expenditure Forecast

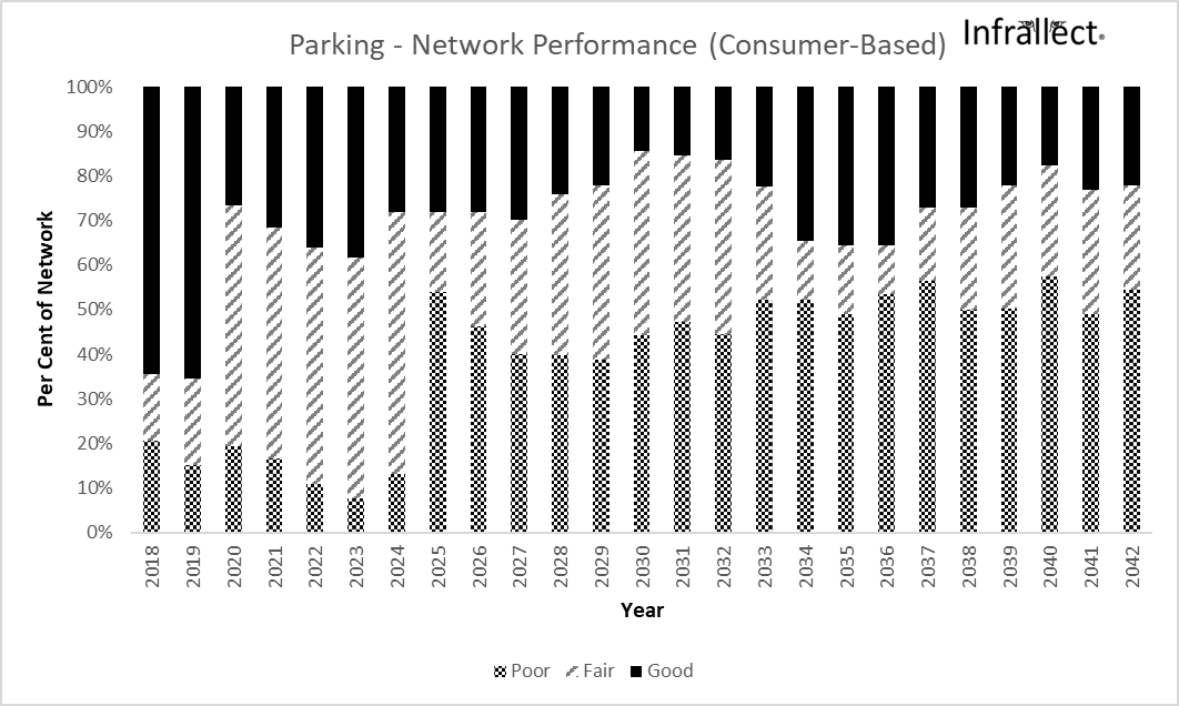


Figure 66: Parking – Consumer - Based Performance Forecast

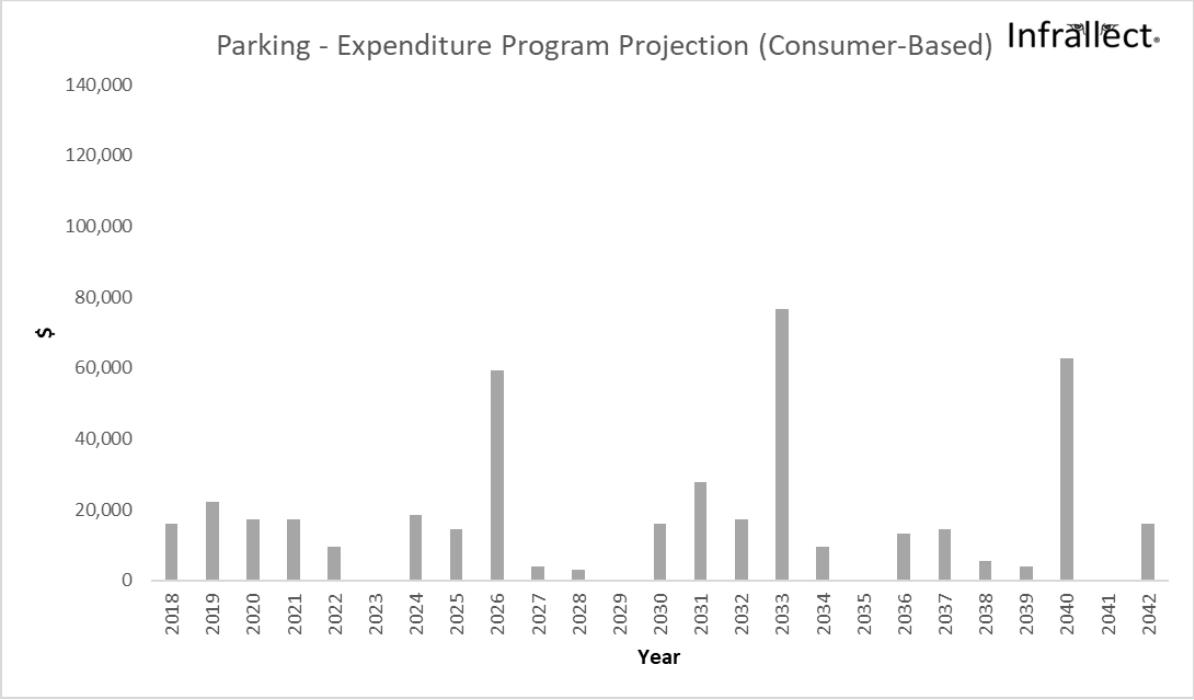


Figure 67: Parking – Consumer - Based Expenditure Forecast

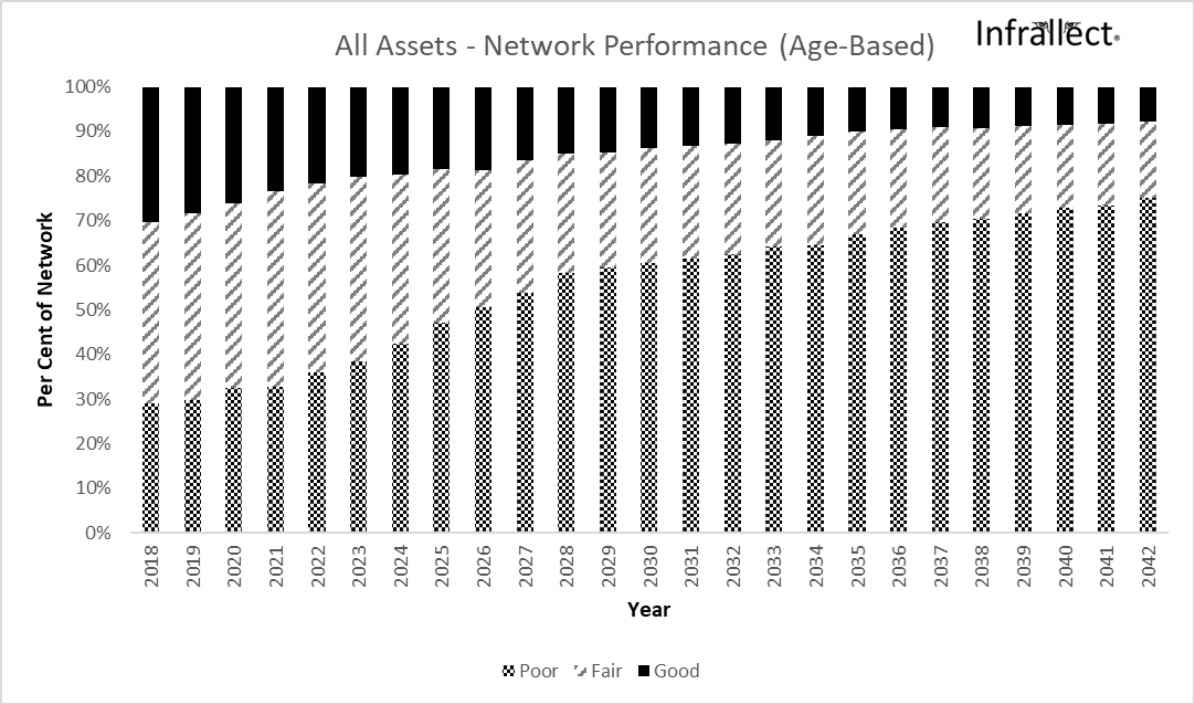


Figure 68: All Assets – Age - Based Performance Forecast

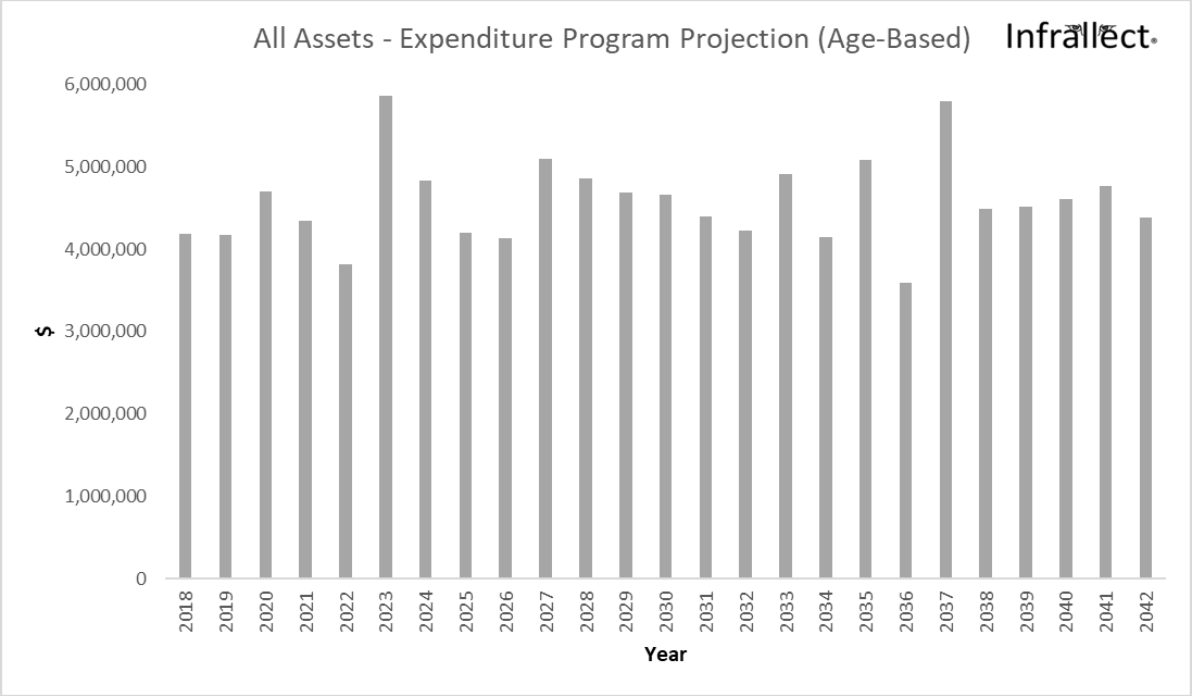


Figure 69: All Assets – Age - Based Expenditure Forecast

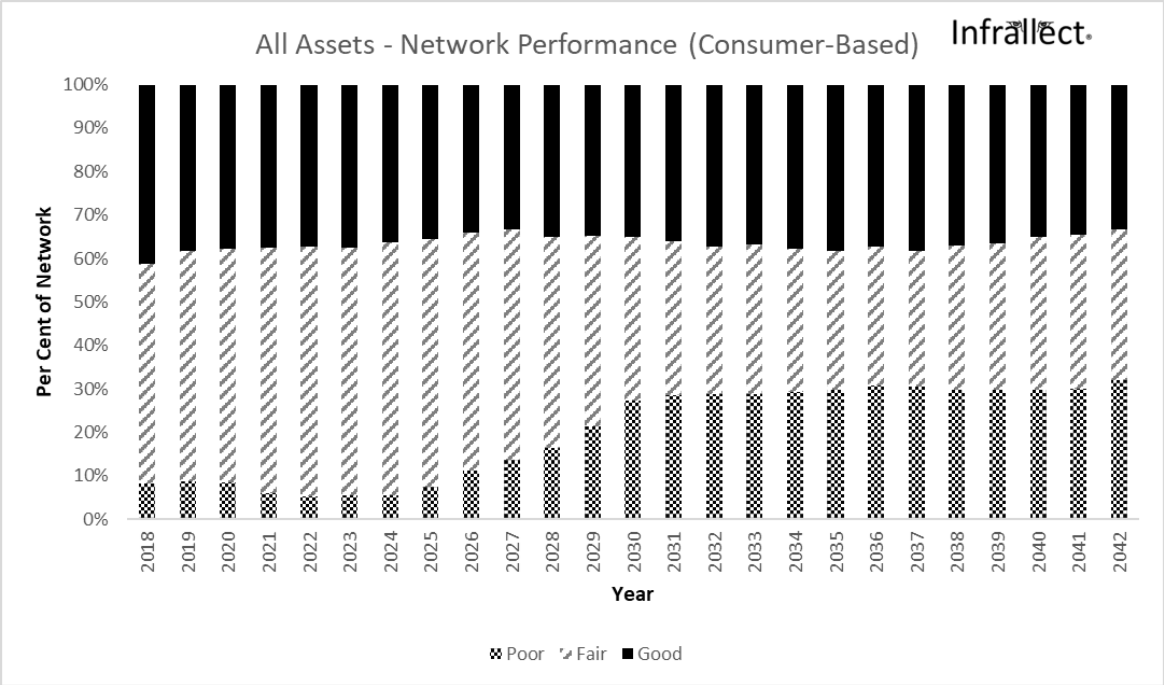


Figure 70: All Assets – Consumer - Based Performance Forecast

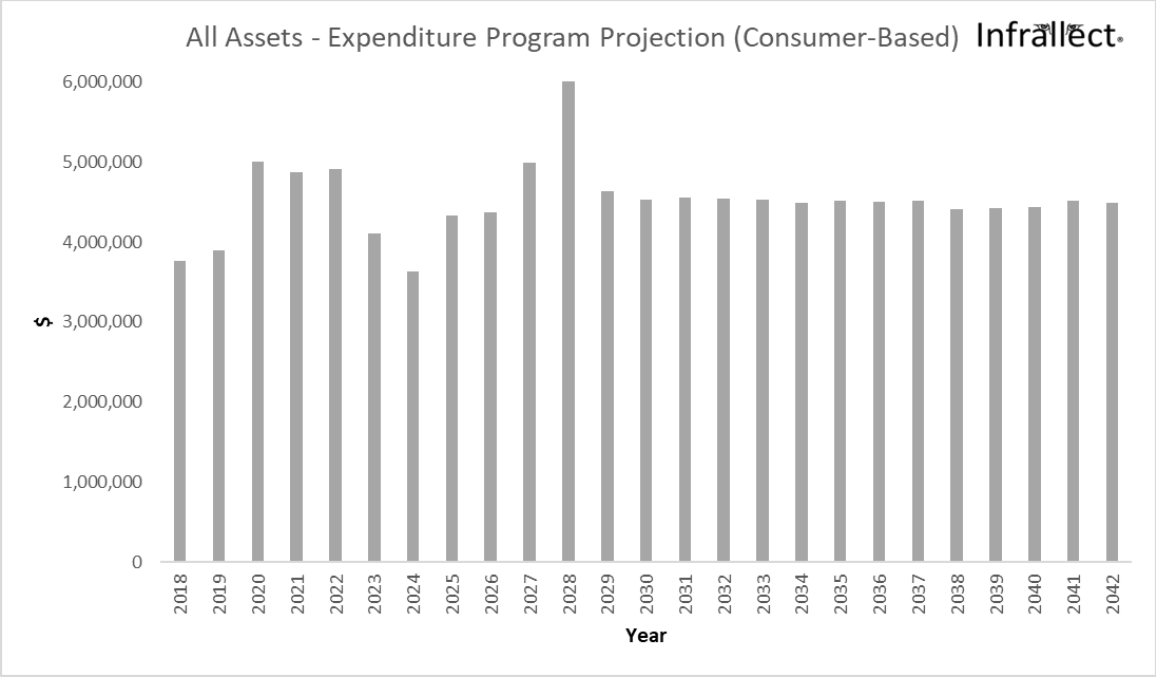


Figure 71: All Assets – Consumer - Based Expenditure Forecast

Appendix C contains the performance and expenditure data making up the graphs above. For each year the replacement value of each asset class in good, fair, and poor performance is shown, as well as the annual expenditure.

5.1.3 Forecast Analysis PSAB 3150 (Age-Based) versus Consumer-Based (Reliability-Risk Engineering)

Table 16 shows the portion of each asset class with initial (i.e. starting year of forecast) poor performance . On average for the entire portfolio Age-Based overestimates the initial poor performance by 192% (0.35 vs. 0.12) compared to Consumer-Based forecasting. This is important to note because infrastructure managing agencies could overestimate their needs by following strictly Age-Based forecasts. The main reason for this is shown in Figure 72. Typical Age-Based qualitative performance categories are spread evenly over the lifespan of the asset, such that the "poor" performance category is applied even though the asset can have up to 33% of its life span remaining. This approach inherently leads to an overestimation of the assets in the "poor" performance category. Another reason is that the Age-Based forecast ignores treatments performed on the assets since their initial construction. In the case of the Parking asset class - or for that matter - any asset class where Consumer-Based may have a greater initial poor performance, it is because Age-Based forecasting ignores any pre-mature defects which may have occurred to the asset class due to additional anticipated stresses imposed on the asset class by the community (e.g. nearby development).

Table 16: Portion of Each Asset Classes with Poor Performance in Initial Year

Asset Class	Age Based Poor Initial Performance	Consumer Based Poor Initial Performance	Age Based Minus Consumer Based
Roads	0.27	0.18	0.09
Sidwewalks	0.57	0.13	0.43
Traffice Lights	0.30	0.27	0.03
Bridges	0.46	0.03	0.43
Sanitary	0.36	0.03	0.33
Water	0.15	0.07	0.07
Storm	0.68	0.10	0.58
Natural Assets	0.15	0.02	0.13
Facilities	0.07	0.05	0.02
Parks	0.64	0.20	0.44
Parking	0.18	0.21	-0.03
Average	0.35	0.12	0.23

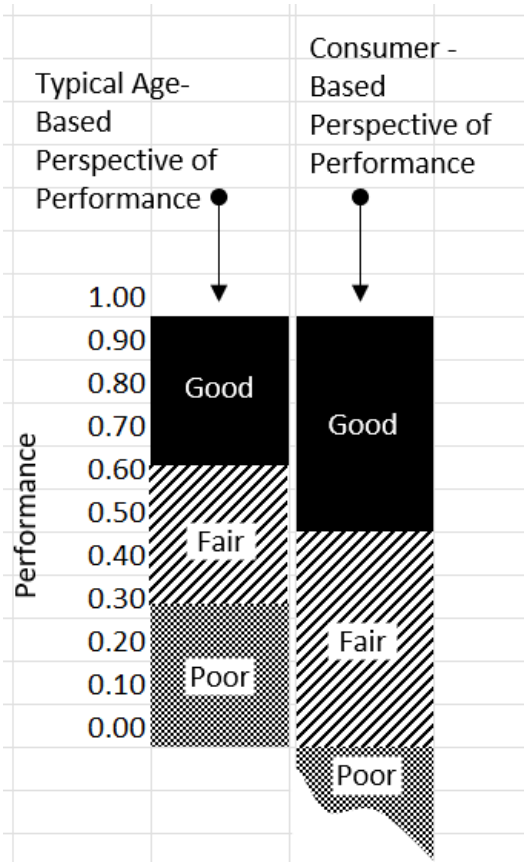


Figure 72: Typical Age-Based versus Consumer-Based Qualitative Performance

Table 17 shows the average deterioration rates for each asset class. The reciprocal of the deterioration rate is the estimated service life (ESL). The key item to note is the Consumer-Based method's average deterioration has a four times greater standard deviation than the Age-Based. This is because the former accounts for SEPMs and Corporate Decision Factors as discussed in Section 4.4, while the latter is constrained to prescribed (if any) variation of the deterioration rate. For example, if a municipality has different types of roads, pipes, or facilities. It is important to note that PSAB 3150 does not preclude municipalities from using their own Age-Based Estimated Service Lives, the main issue is that it encourages the use of Age-Based Estimate Service Lives (i.e. deterioration rates). It is important to note that while the averages have no physical meaning, the concept of the average deterioration is to provide a holistic perspective of the performance over time.

Table 17: Deterioration Rate Analysis (ESL-Estimated Service Life)

Asset Class	Age Based Average Deterioration Rate (1/ESL)	Age Based Average Deterioration's Standard Deviation	Age Based Average Coefficient of Variation (SD/Mean)	Consumer Based Average Deterioration Rate (1/ESL)	Consumer Based Average Deterioration's Standard Deviation	Consumer Based Average Coefficient of Variation (SD/Mean)
Roads	0.040	0.000	0%	0.049	0.028	57%
Sidwewalks	0.033	0.000	0%	0.038	0.009	24%
Traffice Lights	0.067	0.000	0%	0.082	0.024	30%
Bridges	0.025	0.000	0%	0.052	0.012	23%
Sanitary	0.016	0.005	28%	0.026	0.006	24%
Water	0.014	0.002	15%	0.037	0.007	20%
Storm	0.017	0.000	0%	0.028	0.004	14%
Natural Assets	0.020	0.000	0%	0.051	0.016	32%
Facilities	0.031	0.014	44%	0.056	0.020	36%
Parks	0.082	0.028	34%	0.057	0.013	23%
Parking	0.050	0.000	0%	0.106	0.033	31%
Average	0.036	0.004	11%	0.053	0.016	28%

Table 18 demonstrates the greatest deficiency of the Age-Based method of forecasting, as prescribed by PSAB 3150. Full asset cost replacement is assumed for any forecast treatment at the end of the Estimated Service Life. This is the case at the most granular asset inventory available, extending out to full asset class replacement, and subsequently the entire asset portfolio replacement. Whereas the Consumer-Based method accounts for three types of asset treatments: maintenance, rehabilitation/repair, and reconstruction/replacement. Specifically, average treatment costs are derived from a variety of corporate information, hence the average 84% standard deviation, compared no deviation for Age-Based costs.

Table 19 summarizes the cost comparison of the Age-Based versus Consumer-Based forecasting method.

The second column contains each of the asset classes' replacement values, totaling to $684,909,287 for the entire infrastructure model portfolio. The third and fourth columns contain the 25-Year expenditure totals. The reason they are very close is because they were both constrained to the same annual spending limits, shown in the fifth and sixth columns. The limit was set by what were assumed to be acceptable levels of service (i.e. asset class performance forecast) under the Consumer-Based method. The reason Consumer-Based spending is projected slightly higher is that its average treatment costs vary, while Age-Based is always projected at full asset replacement cost.

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Seventh and eight columns contain the average annual spending. Finally, the ninth column shows by what percent Age-Based forecasting would increase its expenditure projections, from those shown in third or seventh columns, in order to have the same amount of poor performance projected as the Consumer-Based method. This is a straight average increase of 447%.

Table 18: Treatment Cost Analysis

Asset Class	Age Based Average Treatment Cost as Portion of Replacement Cost	Age Based Average Treatment Cost's Standard Deviation	Age Based Average Treatment Cost's Coefficient of Variation	Consumer Based Average Treatment Cost as Portion of Replacement Cost	Consumer Based Average Treatment Cost's Standard Deviation	Consumer Based Average Treatment Cost's Coefficient of Variation
Roads	1.00	0.00	0.00	0.51	0.38	74%
Sidwewalks	1.00	0.00	0.00	0.81	0.36	44%
Traffice Lights	1.00	0.00	0.00	0.32	0.28	88%
Bridges	1.00	0.00	0.00	0.27	0.15	56%
Sanitary	1.00	0.00	0.00	0.16	0.18	113%
Water	1.00	0.00	0.00	0.13	0.21	155%
Storm	1.00	0.00	0.00	0.02	0.00	17%
Natural Assets	1.00	0.00	0.00	0.17	0.14	83%
Facilities	1.00	0.00	0.00	0.26	0.28	109%
Parks	1.00	0.00	0.00	0.19	0.23	118%
Parking	1.00	0.00	0.00	0.38	0.27	70%
Average	1.00	0.00	0.00	0.29	0.23	84%

This however is not the practical increase that a community would see, as tax increase approvals are based upon entire infrastructure portfolios as one whole. The practical increase - if a municipal administration was to follow Age-Based forecasting – would be the weighted average of annual expenditure of the fourth or eight column, equaling to 335% above what the Consumer-Based method is forecasting. This is important to note, because infrastructure managing agencies could overestimate their needs by following strictly Age-Based forecasts.

It should be noted that there is a general awareness of municipalities and consulting industry regarding PSAB 3150's limitation in practice. The researcher is aware of only a handful of large municipalities that have increased taxes following the Age-Based approach. Provided there was administrative will, of which the research has not found evidence-off, the majority of municipalities would not be able to do the same. This is simply because the community's economic base is not able to support the projected tax increases.

Table 19: Age-Based Future Infrastructure Cost Overestimation

Asset Class	Replacement Value ($)	Age Based 25-Year Expenditure Value ($)	Consumer Based 25-Year Expenditure Value ($)	Age Based Annual Expenditure Limit ($)	Consumer Based Annual Expenditure Limit ($)	Age Based Average Annual Expenditure ($)	Consumer Based Average Annual Expenditure ($)	Additional Necessary Average Annual Expenditure Required In Order for Age-Based Forecasting to Equal Poor Performance Projection as Forecast by Consumer-Based Method (%)
Roads	144,254,257	66,493,659	69,263,036	2,770,672	2,770,672	2,659,746	2,770,521	175%
Sidewalks	757,771	355,223	367,051	15,000	15,000	14,209	14,682	234%
Traffice Lights	5,996,385	1,526,204	1,568,027	62,816	62,816	61,048	62,721	141%
Bridges	5,375,365	1,122,780	1,134,330	52,366	52,366	44,911	45,373	290%
Sanitary	80,931,318	4,456,914	4,311,883	172,612	172,612	178,277	172,475	402%
Water	87,933,352	5,405,764	5,396,940	215,884	215,884	216,231	215,878	96%
Storm	123,302,769	1,934,557	2,071,115	145,969	145,969	77,382	82,845	2271%
Natural Assets	144,510,768	21,067,991	20,488,408	819,711	819,711	842,720	819,536	823%
Facilities	85,364,114	6,790,167	6,744,373	269,775	269,775	271,607	269,775	195%
Parks	5,334,781	1,249,999	1,249,949	50,000	50,000	50,000	49,998	248%
Parking	1,148,407	1,526,204	1,568,027	20,000	20,000	61,048	62,721	45%
Total	684,909,287	111,929,464	114,163,138	4,594,804	4,594,804			
Average								447%

Finally, it is argued that the research is not aimed at discrediting PSAB 3150, but rather by providing asset managers with the latest scientific tools to bridge the gap between from the foundation provided by PSAB 3150 in 2008 to deliver tomorrow's sustainable public infrastructure.

It is recommended that current providers of asset management work with academia and all levels of government to refine PSAB 3150's mandate. This is necessary for the public infrastructure industry to have the same reliability and applicability of forecasts as the insurance, banking, and consumer goods industries have.

The following section speaks to the conclusions, limitations, and recommendations derived from the experimental design and its implementation.

5.2 Independent repetition of steps for scientific validation and / or field application

Formulas in Figures 9 to 13 can be applied to Appendix B information to derive Consumer-Based deterioration rates and average treatment costs. In order to replicate the exact forecast professional knowledge and experience gained through working with municipal information is necessary. However, it is claimed that even with less experience Age-Based method overestimates infrastructure needs.

Typical scientific assumptions are necessary when working with incomplete data sets. For example, model parameters derived from incomplete data are applied using probabilistic distributions to that part of the asset inventory which has not had a post-initial construction treatment.

5.3 Summary of Findings

It is argued that the number one limitation constraining researchers to date is significantly limited access to real corporate data. Number two is the limited access to the real corporate processes. The combination of these two limitations is detrimental to the advancement of the state of the art. In materials engineering it is the equivalent of not being able to obtain the minimum variety of raw materials to create a representative sample for testing, and not being able to identify the minimum number of variables representing field conditions to create a representative lab testing environment. This research was not constrained by either, as full corporate access to information had been provided, and ten years of the author's public infrastructure asset management experience at various vertical and horizontal organizational levels – covering the full corporate cross section - unbound the existing traditional research limitations.

The experimental design covered all of the organizational and technical aspects necessary for complete COAM. The precise relationships between the organizational structure and information nature, format, and flow were mapped (i.e. documented) to the most granular level possible. In a traditional engineering sense, this is the equivalent of reaching bedrock. The end result is an org-technical asset management system that rests on top of the existing org-technical agency capacities. Arguably, it provides cross-asset funding allocation capabilities that advance the current state of the practice as perceived in a state of the practice scan (Caltrans et al. 2012). However, it is argued that cross-asset funding allocation is different than cross-asset trade-off analysis.

In the former (funding allocation) the practitioner is allocating funds due to the ability to see the current performance of multiple asset classes at the time of contemplation and decision-making. The focus is on achieving relative asset-centric performance equilibrium between intrinsically different assets through mutually exclusive performance measures. Equilibrium is not necessarily equal performance of all asset classes; but rather a perceived best-case achievable infrastructure performance scenario according to existing corporate constraints (e.g. funding, external uncertainties, etc.).

The latter (trade-off) involves a direct or intrinsic "trade-off" step between the assets themselves through a "common unit of understating" (e.g. utility, index, etc.). Its general goal is to provide a more objective prioritized sequence of infrastructure treatments over time.

However, mid-way through the research effort it became apparent that the industry lacks a common-practical performance measure or indicator, which is inherently necessary in order for asset-centric performance measure interoperability, that allows for practical cross-asset trade-off analysis. As such, the research effort shifted solely to the introduction of a new common performance indicator "Infrastructure Asset Performance Stock" (iPS) as a decision-making tool to support existing asset-centric performance measures.

iPS now allows future research and industry practice to apply Corporate Decision Factors (Table 9) on top via analytical hierarchy processes, objective optimization etc., to perform cross-asset trade-off analysis. However, it is very important to note that the value yield of such analysis is realized only in scenarios where two or more assets are competing for limited funding at the same time.

It is argued that the final hypothesis is true:

5. *In order to implement Consumer-Based (reliability-risk engineering) forecasting to support decision-making, resonance of the Consumer-Based mechanism with existing corporate knowledge and processes is necessary.*

This was demonstrated through the application of Goldratt's Theory of Constraints to the problem of implementing a new asset management system into existing business processes or COAM. The entire process of identifying to exploiting the problem's constraints was presented. Through the process, the bottleneck of proper forecasting was identified and subsequently solved.

Compared to the Consumer-Based approach, the Age-Based approach was found to overestimate infrastructure needs by a factor of 335%.

Chapter 6

Conclusions, Limitations, and Recommendations

The research proposed the following hypotheses:

1. Stakeholder surveys and interviews are the dominant modes of empirical research in the field of organizational behaviour theory as it applies to infrastructure asset management. The method of accessing the "corporate conscience" provides additional efficiencies in the effort of continuous organizational improvement, in this case being the application of asset management processes in public organizations.

The reviewed literature material supports the first half of the statement being true. The research does demonstrate the efficiencies of accessing the "corporate conscience" (i.e. all past and current existing infrastructure relevant information) as the method has successfully been applied to multiple municipalities in their effort to manage public infrastructure.

2. Existing organizational information provides sufficient value to develop corporate data-driven asset performance measures, without new data collection efforts. Research in new data analysis methods could greatly advance technical and economic benefits.

This statement is true as demonstrated in Section 4.4 and the derivation of a Consumer-Based (i.e. reliability-risk engineering) performance measure coined as "Infrastructure Asset Performance Stock" or iPS, as published in the Institute of Civil Engineers' Journal of Infrastructure Asset Management.

3. Objective decision-making is already occurring within managing agencies to the highest degree possible according to the existing body of knowledge; it is just a matter of communicating it in a systematic manner.

This statement is true. as discussed in Section 4.4, based on the general argument that developed societies' perceived standard of living is the highest to date. It is difficult to imagine such progress occurring without access to top-performing public infrastructure, with which the public interacts on a daily basis. The millions of decisions made by public infrastructure managing agencies over the past decades (i.e. post-WWII) have yielded such infrastructure and provided an environment for society to thrive.

4. Corporate operationalization of asset management processes requires building on top of existing processes rather than altering them or developing systems independent of them.

This statement is true as demonstrated in Chapter 5, where the entire active in-the-field research effort depended on this strategic statement.

5. In order to implement Consumer-Based (reliability-risk engineering) forecasting to support decision-making, the resonance of the Consumer-Based mechanism with existing corporate knowledge and processes is necessary.

All research was conducted in-the-field, parallel, and "in step" (i.e., resonating) with existing business processes, and a Consumer-Based performance measure was developed; it is therefore argued that the above hypothesis is true.

For the next "quantum" leap to occur in the provision of infrastructure, academia requires full exposure to the industry's "in-field" processes as they occur. However, in order to minimize the effects of "inherit friction", there is a need to recognize what the "global standard" of related asset management practice is. According to professional knowledge, skills, experience, and academic curiosity, the research presented argues that there exists only one such standard: the existing processes of municipalities managing infrastructure.

The following are three research findings supporting the argument above:

1. There appears to be no dominant global standard that is practically accepted or practiced by North American municipalities – research and experience-based conclusion
2. The majority of existing efforts for domination are attempts to transpose private sector approaches to the public sector – experience-based conclusion
3. The inability to successfully apply a global standard of asset management is the result of the inherent incompatibility of a private sector foundation and a public sector superstructure. – research and experience-based conclusion

Perhaps the most effective aid in explaining the incompatibility is the Product-Process Matrix (Table 15). Assuming it still represents the general categorical breakdown of manufacturing processes, in an attempt to provide the "standard framework", the municipalities' variety and volume of "product" fits in an area of the matrix not recognized before. This is the "high variety, high volume", field (top right corner of matrix).

If there was a private organization attempting to manufacture or procure everything modern society is used to (the popular term being "cradle to grave"), it would require subject matter experts spanning the extremes of the "division of labour" dominated industry. Other than municipalities, which are public entities, the course of research has not encountered a path of potential existence of any such private organization. The largest private sector holders of private infrastructure appear to be dominated by a relationship reflecting that of a "typical land/property owner" rather than a "societal infrastructure provider".

The research supports the following forecasting-related conclusions:

1. Applying Age-Based Estimated Service Lives overestimates existing infrastructure needs by an average factor of 335%;
2. The Age-Based method has been applied to forecasting public infrastructure expenditure due to lack of academic and industry capacity to implement reliability engineering forecasting;

3. Other than the presented research, there appears to be zero evidence of any effort attempting to implement reliability engineering forecasting for entire municipal portfolios; and,
4. PSAB 3150 mandate should remain in place but municipalities should explicitly be allowed to apply their unique asset deterioration rates (i.e. Estimated Service Lives) and treatment costs based on the Consumer-Based method or reliability (risk) engineering.

With respect to limitations, the City of Waterloo and subsequent municipalities helped push the limits of the art beyond their existing corporate practice, rather than attempting to constrain them.

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Appendix A

Related Reviewed Infrastructure Asset Management Publications (excluding theses and dissertations)

The following entries can be found in the References section of the thesis. Using the first column (Publication as Cataloged), the year of publication is represented by the first four digits and the first author's name appears in the text. The references are organized alphabetically by first author's name and then year.

Publication as catalogued	Publication Title
19990101_fhwa	Asset Management Primer
20000101_vanier	Asset Management 101:A Primer
20010101_falls_et_al	Asset Management and Pavement Management: Using Common Elements to Maximize Overall Benefits
20010101_vanier	Why Industry Needs Asset Management Tools
20011201_howard	Infrastructure asset management under Australian Accounting Standard 27 (AAS27)
20020101_amekudzi_et_al	multipurpose asset valuation for civil infrastructure
20020101_garvin_et_al	Decision Support Systems for Infrastructure Asset Management: Prospects and Challenges
20030101_hassanain_et_al	Framework Model for Asset Maintenance Management
20030101_piyatrapoomi_et_al	Investment Decision-Making under Risk (Reliability) and Uncertainty for Infrastructure Asset Management
20030425_beauvais_et_al	Asset management for Virginia highways and roads
20040101_lipton_et_al	On Approximately Fair Allocations of Indivisible Goods
20040101_marler_et_al	Survey of Multi-Objective Optimization Methods for Engineering
20040101_vanier	[PDF] Geographic information systems (GIS) as an integrated decision support tool for municipal infrastructure asset management
20060101_falls_et_al	Asset Service Index as Integration Mechanism for Civil Infrastructure
20060101_gharaibeh_et_al	Decision Methodology for Allocating Funds across Transportation Infrastructure Assets
20060101_halfawy_et_al	Review of Commercial Municipal Infrastructure Asset Management Systems
20060101_too_et_al	A Strategic Approach to Infrastructure Asset Management
20060101_woodhouse	Asset Management: concepts & practices
20060501_flintsch_et_al	Asset Management Data Collection for Supporting Decision Processes
20070101_lin_et_al	Developing a data quality framework for asset management in engineering organisations
20070303_halfawy_et_al	Standard data models for interoperability of municipal infrastructure asset management systems

Publication as catalogued	Publication Title
20090101_hooper_et_all	Whole-life infrastructure asset management: good practice guide for civil infrastructure
20090101_mrawira_et_al	Cross-Assets Trade-off Analysis: Why Are We Still Talking About It?
20090101_pantelias_et_al	Asset Management Data Practices for Supporting Project Selection Decisions
20090801_Lethanh	Stochastic Optimization Methods for Infrastructure Management with Incomplete Monitoring Data
20100101_amadi-echendu_et_	Definitions, Concepts and Scope of Engineering Asset Management
20100101_chris_lloyd_book	Asset management whole-life management of physical assets
20100101_dehghanisanij_et_al	A Flexible Framework for Sustainable Multi-Objective Cross-Asset Infrastructure Management
20100101_kellick	Leadership, the essential ingredient in asset management
20100101_Too_org	A Framework for Strategic Infrastructure Asset Management
20110101_javed	Integrated Prioritization and Optimization Approach For Pavement Management
20110101_schraven_et_al	Effectiveness of infrastructure asset management: challenges for public agencies
20110101_valencia_et_al	Asset Management: A System Perspective
20111130_herder_et_al	A Systems View on Infrastructure Asset Management
20120101_haider_et_al	Information Systems for Engineering and Infrastructure Asset Management
20120101_too	Capability model to improve infrastructure asset performance
20120102_too	Infrastructure asset: developing maintenance management capability In: Facilities
20120301_kobayashi_et_al	A Bayesian Estimation Method to Improve Deterioration Prediction for Infrastructure System with Markov Chain Model
20120601_alyami_et_al	A Methodology for Integrating Asset Valuation in Transportation Asset Management
20120601_bai_et_al	Trade-Off Analysis for Multiobjective Optimization in Transportation Asset Management by Generating Pareto Frontiers...
20120613_lloyd	International Case Studies in Asset Management
20121001_fwa_et_al	Optimal Multiasset Maintenance Budget Allocation in Highway Asset Management
20121201_wu_et_al	Framework for Multiobjective Optimization of Physical Highway Assets Investments
20121210_osman_org_tech	Agent Based Simulation of Urban Infrastructure Asset Management Activities

Publication as catalogued	Publication Title
20130101_dehghani_et_al	Cross-Asset Resource Allocation Framework for Achieving Performance Sustainability
20130101_ice	Realising a World Class Infrastructure: ICE's Guiding Principles of Asset Management
20130101_woodhouse	How asset management can be a massive victory for IT
20130101_yusof_org_tech	The Effectiveness of Public Sector Asset Management in Malaysia
20130102_woodhouse	Why Asset Management Should Be This Year's Obsession for CEOs
20131222_posavljak_et_al	Strategic Total Highway Asset Management Integration
20140101_ford_et_al	Methodology and Benefits of a Performance-Based, Cross-Asset Resource Allocation Towards Systematic Transportation Infrastructure…
20140201_woodhouse	ISO 55000 - What, Why and How: An Introduction to the First International Standard for Asset Management
20140301_bai_et_al	A Hybrid Pareto Frontier Generation Method for Trade-Off Analysis in Transportation Asset Management
20140301_holt	Infrastructure and assets: what role history?
20140521_ibm	TUC White Paper: Asset Management PAS 55/ISO 55000-The Sustainable Business Strategy for Operational Excellence
20140601_moodley	Editorial – Is ISO 55000:2014 the new dawn in asset management?
20140610_zeb_et_al	Tangible capital asset ontology in infrastructure management
20140626_shoghli	A Decision Support System for Multi-Objective Multi-Asset Roadway Asset Management (DSRAM)
20140701_iam	The Self-Assessment Methodology - Guidance
20140901_woodhouse	Briefing: Standards in asset management: PAS 55 to ISO 55000
20141018_han_et_al	Application of Bayesian estimation method with Markov hazard model to improve deterioration forecasts for infrastructure asset…
20141208_alvarado_et_al	A Fair Division Approach to Performance -based Cross-Asset Resource Allocation
20150101_shuo_et_al	Integrated Optimization Model for Network-Level Transportation Cross Asset Preservation
20150112_hegazy	Enhanced benefit–cost analysis for infrastructure fund allocation
20150301_eldiraby_et_al	Analyzing Approaches Used by Ontario Municipalities to Develop Road Asset Management Plans: Initial Insights
20150701_bc_auditor	Asset Management for Local Governments
20151113_spypond	Advancing Performance Management Under A National Framework
20161004_langdon_et_al	The Case for Internalising Externalities in a Sustainable Rail Asset Base
20161904_obrien_et_al	Guide For Civil Integrated Management (CIM) at Departments of Transportation (DOTs)
20170301_dixon	Asset management: making the ‘unreasonable’ reasonable?

Appendix B – Raw Information

Columns A to F – Year(s) of Treatment(s)

Columns G to K – Value(s) of Treatment(s)

Asset ID	Road Section Name	A	B	C	D	E	F	G	H	I	J	K
1	anonymized information	1991	2010					199,937.02	775,461.40			
2	anonymized information	1991						-				
3	anonymized information	1998						-				
4	anonymized information	2008	2015					418,545.75	510,928.02			
5	anonymized information	1979						37,780.73				
6	anonymized information	1994						82,983.15				
7	anonymized information	2017						-				
8	anonymized information	1977	1989	2014				51,819.95	29,505.18	72,874.60		
9	anonymized information	2005						-				
10	anonymized information	2005						-				
11	anonymized information	2008						-				
12	anonymized information	2013						-				
13	anonymized information	1972	1999	2002				199,307.50	36,339.48	144,419.14		
14	anonymized information	1973	2004					107,626.05	69,058.17			
15	anonymized information	1973						-				
16	anonymized information	1977	2012					544,221.09	604,695.37			
17	anonymized information	1984	2012					436,371.81	484,861.79			
18	anonymized information	1977						-				
19	anonymized information	1981	2003	2010				131,542.95	91,145.25	482,834.45		
20	anonymized information	1981						-				
21	anonymized information	1989						159,446.00				
22	anonymized information	1989						-				
23	anonymized information	2012	2018					258,143.07	388,564.71			
24	anonymized information	1990	2013					199,307.50	419,536.18			
25	anonymized information	1975						42,981.17				
26	anonymized information	1975						-				
27	anonymized information	1993						220,954.05				
28	anonymized information	2008						161,071.58				
29	anonymized information	1969	1999					300,587.60	97,666.52			
30	anonymized information	1969	1999	2008				125,571.70	40,800.59	62,885.15		
31	anonymized information	1973	2002	2020				418,545.75	303,280.20	21,244.22		
32	anonymized information	1978						-				
33	anonymized information	1972	2009					99,653.75	47,170.31			
34	anonymized information	2015						729,527.36				
35	anonymized information	1989	2007	2010				55,806.10	31,886.29	204,838.86		
36	anonymized information	2003						71,811.41				
37	anonymized information	1962	1982	2008				191,335.20	297,955.87	95,818.91		
38	anonymized information	1967						156,464.36				
39	anonymized information	1943	1987	2020	2010			639,777.08	559,579.14	3,944,301.67	2,348,331.21	
40	anonymized information	1943	1987	2001				360,347.96	315,177.28	400,523.62		
41	anonymized information	2006						340,343.29				
42	anonymized information	2004						23,019.39				
43	anonymized information	1973	2012					111,612.20	124,014.64			
44	anonymized information	1993						162,984.40				
45	anonymized information	1993						-				
46	anonymized information	1964	2012					215,252.10	239,171.08			
47	anonymized information	1964						-				
48	anonymized information	1983	2013					71,750.70	151,033.02			
49	anonymized information	1973	1997					97,262.06	89,496.36			
50	anonymized information	1973	1989	2004				238,778.36	215,387.82	341,389.51		
51	anonymized information	1973						-				
52	anonymized information	2017						160,809.26				
53	anonymized information	2019						143,843.07				
54	anonymized information											
55	anonymized information	1978						83,709.15				
56	anonymized information	2010						489,905.54				
57	anonymized information	1952	2007					59,792.25	34,163.88			
58	anonymized information	1973	2003					374,698.10	30,381.75			
59	anonymized information	1973	2009					203,293.65	96,227.44			
60	anonymized information	1967	2004					330,850.45	473,028.10			
61	anonymized information	1991						101,462.38				
62	anonymized information	2017						-				
63	anonymized information	2012	2018					76,175.33	69,968.50			
64	anonymized information	1976						354,767.35				
65	anonymized information	1978	2002					306,933.55	63,544.42			
66	anonymized information	1978						-				
67	anonymized information	1973	2008					71,750.70	35,932.09			
68	anonymized information	2003						309,341.46				
69	anonymized information	1995						517,142.69				
70	anonymized information	1991						66,960.04				
71	anonymized information	2005						25,936.44				
72	anonymized information	1970	1999	2008				449,269.10	46,626.28	71,864.18		

73	anonymized information	2008					51,303.04				
74	anonymized information	2002					-				
75	anonymized information	2017					106,727.45				
76	anonymized information	1993	2007				166,621.08	9,635.40			
77	anonymized information	1991					88,802.22				
78	anonymized information	1967	2001				294,975.10	254,177.69			
79	anonymized information	1983	2007				59,792.25	34,163.88			
80	anonymized information	1997	2004				163,587.60	114,073.87			
81	anonymized information	1973	1997				940,731.40	865,620.50			
82	anonymized information	1975	2016				141,348.88	131,416.74			
83	anonymized information	1975	1997				134,173.81	123,460.96			
84	anonymized information	1977	1997				512,300.00	471,396.39			
85	anonymized information	2004					37,040.76				
86	anonymized information	1973					-				
87	anonymized information	2006					-				
88	anonymized information	2004					40,923.36				
89	anonymized information	2004					603,355.88				
90	anonymized information	1973	2007				63,084.81	36,045.17			
91	anonymized information	2004					184,155.13				
92	anonymized information	1943	1973	1990	2001		733,650.91	48,463.83	1,552,286.24	815,446.60	
93	anonymized information	1943					2,818,994.92				
94	anonymized information	1943	2011				931,304.16	1,478,322.63			
95	anonymized information	1943	1990				897,680.98	1,176,227.67			
96	anonymized information	1993					441,908.09				
97	anonymized information	2009	2012				199,247.41	11,043.59			
98	anonymized information	2010					130,437.47				
99	anonymized information	1975	1997	2016			68,982.99	93,897.82	94,875.03		
100	anonymized information	1978	2008				139,523.22	69,871.95			
101	anonymized information	2004	2013				30,692.52	100,688.68			
102	anonymized information	1994					59,273.68				
103	anonymized information	1991	2009				103,831.44	41,632.56			
104	anonymized information	1976	2013				287,002.80	604,132.10			
105	anonymized information	1973	2002				215,252.10	259,625.87			
106	anonymized information	1988					87,440.04				
107	anonymized information	1988	2006				131,515.51	159,805.86			
108	anonymized information	1962	1989				183,362.90	279,311.00			
109	anonymized information	2003					73,800.03				
110	anonymized information	1975					67,541.83				
111	anonymized information	1990	2009				66,967.32	31,698.45			
112	anonymized information	1973	1997	2013			83,382.02	37,115.19	630,608.01		
113	anonymized information	1986	2003				303,744.04	271,778.57			
114	anonymized information	1986	2003				233,364.32	208,805.49			
115	anonymized information	2003					66,287.46				
116	anonymized information	1962	2002				79,723.00	168,103.88			
117	anonymized information	1971	1992				175,757.36	231,690.02			
118	anonymized information	2015					319,218.10				
119	anonymized information	1984	2003				184,008.66	318,179.79			
120	anonymized information	1964	1987	2013			215,252.10	188,269.62	453,099.07		
121	anonymized information	1964					-				
122	anonymized information	1984	2012				162,634.92	180,707.04			
123	anonymized information	1992	2016				245,380.79	172,702.20			
124	anonymized information	1982					103,639.90				
125	anonymized information	1994	2008	2008			185,463.39	33,660.42			
126	anonymized information	1995	2008	2008			204,457.18	30,207.89			
127	anonymized information	1994	2008	2008			271,378.62	49,253.49			
128	anonymized information	2010					272,541.63				
129	anonymized information	1993					98,885.99				
130	anonymized information	1979	2002				231,993.93	95,316.63			
131	anonymized information	1996					71,341.71				
132	anonymized information	1975					267,072.05				
133	anonymized information	1977	2013				763,746.34	1,177,626.66			
134	anonymized information	1977	2003	2013	2018		141,109.71	9,398.66	217,578.20	82,424.39	
135	anonymized information	1977					-				
136	anonymized information	2016					279,436.60				
137	anonymized information	2010					191,257.29				
138	anonymized information	1967	1987	2007			255,113.60	223,134.36	145,765.89		
139	anonymized information	1964	1971	2009			407,647.62	40,971.54	192,956.77		
140	anonymized information	1968					-				
141	anonymized information	1964					-				
142	anonymized information	1953					163,216.90				
143	anonymized information	1988					184,832.60				
144	anonymized information	1962	1971	1980	1989		326,864.30	28,955.08	75,433.05	497,902.22	
145	anonymized information	1986	2008				65,811.21	42,559.56			
146	anonymized information	1973	1980	1989	1998	2021	528,332.29	88,307.39	132,773.32	624,672.63	3,621,076.74
147	anonymized information	2008					19,435.27				
148	anonymized information	1996	2012				272,128.18	327,752.97			
149	anonymized information	1993	2011				470,885.67	822,573.43			

150	anonymized information	2004				112,539.24				
151	anonymized information	1979	1993	2016		119,584.50	331,704.87	111,181.67		
152	anonymized information	1998				75,408.26				
153	anonymized information	1988				88,861.83				
154	anonymized information	2007				156,110.72				
155	anonymized information	1975	2013			135,573.46	243,330.98			
156	anonymized information	1978				234,449.40				
157	anonymized information	1975	1999			81,317.46	3,163.01			
158	anonymized information	1975				110,488.11				
159	anonymized information	1973	1996			471,960.16	181,132.24			
160	anonymized information	1978				727,073.76				
161	anonymized information	1978				165,823.84				
162	anonymized information	1986				185,209.78				
163	anonymized information	2007	2014			342,909.71	843,988.80			
164	anonymized information	2004	2014			143,231.76	313,921.36			
165	anonymized information	1983	1999	2014		271,855.43	75,367.12	382,311.38		
166	anonymized information	1973	2008			410,573.45	205,611.41			
167	anonymized information	1973	2007			306,933.55	175,374.59			
168	anonymized information	1975	1998			73,137.88	86,474.43			
169	anonymized information	1995				100,966.51				
170	anonymized information	2004				268,892.06				
171	anonymized information	1987	2008			90,648.33	46,150.55			
172	anonymized information	1978	2013			159,446.00	335,628.94			
173	anonymized information	1995				300,957.86				
174	anonymized information	1979				-				
175	anonymized information	1974	1989	2008		304,055.55	265,546.63			
176	anonymized information	1985								
177	anonymized information	1976	2004			51,022.72				
178	anonymized information	1975				163,737.77				
179	anonymized information	1987	2008			27,891.80	14,200.17			
180	anonymized information	1978				117,360.23				
181	anonymized information	1973	2017			83,709.15	84,212.36			
182	anonymized information	1978	2002			87,695.30	155,972.67			
183	anonymized information	2004				176,482.00				
184	anonymized information	1976	1999			308,528.01	85,533.94			
185	anonymized information	1976	2009			354,767.35	167,926.32			
186	anonymized information									
187	anonymized information	1994				359,593.66				
188	anonymized information	1992	2016			284,346.84	200,127.01			
189	anonymized information	2003				127,498.40				
190	anonymized information	1979	1987	2006		426,518.05	373,052.76	462,141.27		
191	anonymized information	2011				-				
192	anonymized information	2011				-				
193	anonymized information	1978				171,404.45				
194	anonymized information	1988	2018			124,406.56	128,147.44			
195	anonymized information	1975	2017			96,195.94	188,475.27			
196	anonymized information	1991				185,601.91				
197	anonymized information	1979	2002			131,542.95	65,855.13			
198	anonymized information	1979				-				
199	anonymized information	1979				-				
200	anonymized information	1973	2004			599,461.15	384,643.79			
201	anonymized information	1989	2007			77,921.26	44,522.37			
202	anonymized information	1967	1980	2003		68,226.94	11,403.70	47,274.00		
203	anonymized information	1975	2012			321,335.38	695,367.78			
204	anonymized information	1975	2017			40,934.44	80,202.24			
205	anonymized information	1967	1973	1988	2000	358,753.50	255,081.29	1,058,325.51	45,038.32	
206	anonymized information	1977	1998			127,556.80	150,816.53			
207	anonymized information	1973	2009			150,724.30	71,344.16			
208	anonymized information	2011				85,303.61				
209	anonymized information	1967	1980	2003		191,335.20	31,980.47	132,574.91		
210	anonymized information	1974	2013			91,681.45	141,364.37			
211	anonymized information	1986	2003			325,969.21	291,664.81			
212	anonymized information	2004				99,750.69				
213	anonymized information	1978	2013			279,030.50	587,350.65			
214	anonymized information	2012				439,879.62				
215	anonymized information	1998				209,201.38				
216	anonymized information	1986	2016			37,146.91	44,598.67			
217	anonymized information	1974	2019			81,317.46	72,466.79			
218	anonymized information	1985	2007			106,889.16	111,602.01			
219	anonymized information	1985				-				
220	anonymized information	1988	2016			298,575.75	311,308.68			
221	anonymized information	1975	2007			462,393.40	264,200.68			
222	anonymized information	1999				-				
223	anonymized information	1980	2004	2018		157,851.54	101,285.32	144,989.68		
224	anonymized information	2004				-				
225	anonymized information	1979	2002			90,884.22	222,405.48			
226	anonymized information	1983	2009			287,313.72	135,997.67			

227	anonymized information	2001						-				
228	anonymized information	1996	2007					223,439.30	4,025.42			
229	anonymized information	1991	2016					83,520.86	82,052.07			
230	anonymized information	1980	1993	2012				218,305.32	248,633.10	199,309.24		
231	anonymized information	1962	1991					191,335.20	181,075.04			
232	anonymized information	1975						63,291.89				
233	anonymized information	2006	2018					156,350.60	132,541.07			
234	anonymized information	1982	2010					951,119.31	1,140,878.41			
235	anonymized information	1976	2007					289,290.85	165,293.97			
236	anonymized information	1998	2003					61,269.21	35,905.71			
237	anonymized information	1976	2013					243,155.15	511,834.14			
238	anonymized information	1989	2007					306,933.55	175,374.59			
239	anonymized information	1977						80,687.65				
240	anonymized information	1985						110,379.41				
241	anonymized information	2007						224,652.57				
242	anonymized information	1986	2008					363,171.68	234,860.13			
243	anonymized information	1985	2007					101,448.72	105,921.70			
244	anonymized information	1985	2007					124,357.90	129,840.97			
245	anonymized information	1980	2004					65,372.86	41,946.45			
246	anonymized information	1976	1996					256,660.23	200,982.35			
247	anonymized information	1988	2011					331,547.04	590,202.76			
248	anonymized information	1989	2011					125,165.11	198,683.12			
249	anonymized information	1993						123,444.49				
250	anonymized information	1993						-				
251	anonymized information	2013						65,189.50				
252	anonymized information	2016						187,526.42				
253	anonymized information	1992	2012					431,785.95	363,185.72			
254	anonymized information	1974	1997					114,801.12	105,635.04			
255	anonymized information	1976	1996	2012				177,782.29	109,175.60	197,537.60		
256	anonymized information	1983	2012					364,334.11	404,819.20			
257	anonymized information	1978	2016					637,784.00	592,968.92			
258	anonymized information	1998	2013					1,139,607.39	2,385,346.59			
259	anonymized information	1998	2013					1,528,431.24	3,199,205.54			
260	anonymized information	1968	1998					202,496.42	239,421.24			
261	anonymized information	1975	2007					290,634.55	323,418.07			
262	anonymized information	1973	1980	1989	1998			61,538.18	23,728.74	93,739.20	72,759.55	
263	anonymized information	1973	1989	1998				75,633.21	115,209.72	89,424.77		
264	anonymized information	1973	1989	2001	2016			131,542.95	200,375.28	146,208.84	122,299.84	
265	anonymized information	1973	1989	2001	2016			113,023.30	172,164.87	125,624.41	105,081.50	
266	anonymized information	1970	1989	2001	2017			145,042.51	67,653.98	49,365.42	173,872.97	
267	anonymized information	1973	1989	2001	2017			69,964.90	106,575.36	77,765.38	153,953.98	
268	anonymized information	1978	2013					133,528.05	281,072.46			
269	anonymized information	1997	2013					294,318.31	673,288.44			
270	anonymized information	1997						-				
271	anonymized information	1997						-				
272	anonymized information	1983	2007					78,128.54	44,640.80			
273	anonymized information	1979	1994	2009				243,155.15	241,046.30	115,095.57		
274	anonymized information	1979						-				
275	anonymized information	1973	2015					91,681.45	425,072.11			
276	anonymized information	1989	2008					548,494.24	98,684.84			
277	anonymized information	1975	2002					43,114.37	46,214.13			
278	anonymized information	1985						-				
279	anonymized information	1975						55,261.50				
280	anonymized information	1972	1983					207,279.80	905,989.40			
281	anonymized information	1972						-				
282	anonymized information	1991						499,880.27				
283	anonymized information	1962	1986	2017				159,446.00	123,473.19	160,404.49		
284	anonymized information	1967						-				
285	anonymized information	1983	2007	2011				1,043,494.35	596,228.05	309,056.56		
286	anonymized information	1988	2004					1,066,341.95	767,313.02			
287	anonymized information	1966	1996					2,808,643.22	2,408,702.12			
288	anonymized information	1983	1994	2012				748,379.73	741,889.14	831,540.28		
289	anonymized information	1989	2010					752,385.81	902,495.33			
290	anonymized information	1989	1997	2010				752,385.81	189,652.42	902,495.33		
291	anonymized information	1989	2012					462,393.40	58,647.23			
292	anonymized information	1994						44,202.36				
293	anonymized information	1967	1989	2012				139,515.25	212,519.24	155,018.29		
294	anonymized information	1967						-				
295	anonymized information	1990	2012					99,653.75	110,727.35			
296	anonymized information	1978	2015					271,058.20	1,256,734.93			
297	anonymized information	1978						-				
298	anonymized information	1984						-				
299	anonymized information	1988						81,041.99				
300	anonymized information	1993						399,890.60				
301	anonymized information	1943	1980	2010	1989			558,332.06	1,761,860.66	669,725.64	697,454.29	
302	anonymized information	1943	1980	1989	2002	2010		406,866.33	3,036,313.68	1,201,962.26	294,817.24	488,040.78
303	anonymized information	1943	1971	1980	1989	2010		159,446.00	326,806.39	835,630.01	330,794.46	191,257.29

304	anonymized information	1943	1980	1989	2010			464,777.12	2,492,146.59	986,547.00	557,505.43		
305	anonymized information	1943	1980	1989	2010			366,725.80	1,472,633.96	582,960.34	439,891.76		
306	anonymized information	1975	1987	2008				183,362.90	160,377.82	91,826.45			
307	anonymized information	1989	2012					103,639.90	115,156.45				
308	anonymized information	2017						305,567.77					
309	anonymized information	1967	1988	2001				203,197.98	952,232.84	225,852.79			
310	anonymized information	1988	2001					152,927.65	190,620.89				
311	anonymized information	1973						66,002.67					
312	anonymized information	1962	1989	2000	2001			215,252.10	327,886.83	6,435.78	239,250.84		
313	anonymized information	1990	2004					93,275.91	133,359.73				
314	anonymized information	2004						236,628.03					
315	anonymized information	1967	1991	2003				71,750.70	67,903.14	49,715.59			
316	anonymized information	1967	1989	2008				221,111.74	336,812.64	110,730.72			
317	anonymized information	2013						172,998.91					
318	anonymized information	2018						113,589.89					
319	anonymized information	2016						138,578.34					
320	anonymized information	2017						-					
321	anonymized information	1988						95,970.78					
322	anonymized information	2006						-					
323	anonymized information	1976	2018					267,072.05	1,226,628.79				
324	anonymized information	1976						-					
325	anonymized information	1975	1991	2018				98,242.66	181,075.04	878,778.84			
326	anonymized information	1975						-					
327	anonymized information	1991						77,100.24					
328	anonymized information	1998						60,571.69					
329	anonymized information	2000						207,869.75					
330	anonymized information	1975	2002					350,781.20	45,165.58				
331	anonymized information	1975	2003					459,204.48					
332	anonymized information	1975	2004					97,262.06	62,408.13				
333	anonymized information	1975	1995	2004				196,915.81	239,795.46	281,537.20			
334	anonymized information	1975	2004					164,229.38	234,804.31				
335	anonymized information	1975	2004					777,299.25	498,753.46				
336	anonymized information	1988						155,500.85					
337	anonymized information	1968	1983	2009				231,196.70	720,491.07	109,435.13			
338	anonymized information	1978	1988					123,570.65	110,188.67				
339	anonymized information	1991						67,903.14					
340	anonymized information	1975	2004	2020				199,307.50	284,956.68	589,724.61			
341	anonymized information	1974	1982	2004	2020			176,299.44	40,069.92	252,061.28	240,425.68		
342	anonymized information	1974	1981	1998	2020			195,544.57	34,525.71	231,201.74	661,912.36		
343	anonymized information	1982	1998	2020				42,957.01	225,989.14	418,448.66			
344	anonymized information	1975	2007					55,806.10	31,886.29				
345	anonymized information	1991	1998					105,627.10	131,964.46				
346	anonymized information	1978	2004					1,144,778.28	612,656.87				
347	anonymized information	1988	2002	2011				655,994.73	780,571.02	1,709,971.97			
348	anonymized information	1978	2003					1,011,664.53	262,387.85				
349	anonymized information	1975						-					
350	anonymized information	1962	1971	1980	1989	1998	2012	1,881,462.80	55,014.66	363,478.72	162,278.50	2,224,543.78	
351	anonymized information	1975	1986	2015				1,508,199.71	1,167,932.86				
352	anonymized information	1988	2012					170,614.71	212,596.52				
353	anonymized information	1991	1995					64,130.74	82,520.70				
354	anonymized information	1995						344,742.37					
355	anonymized information	1994	2008					525,559.96	265,498.22				
356	anonymized information	1975	1998					184,852.86	323,312.93				
357	anonymized information	1983	2012					233,987.01	259,987.83				
358	anonymized information	2004						136,779.21					
359	anonymized information	1974	2001					55,407.49	327,862.26				
360	anonymized information	1967	1997	2016				146,690.32	134,978.11	755,477.83			
361	anonymized information	1997	2016					275,091.26	2,139,890.97				
362	anonymized information	2016						67,872.70					
363	anonymized information	1993						-					
364	anonymized information	1989	2012					259,099.75	287,891.12				
365	anonymized information	2013						220,832.71					
366	anonymized information	1993						94,177.13					
367	anonymized information	1978	1989					2,451,482.25	657,152.68				
368	anonymized information	1968	1997					187,349.05	172,390.52				
369	anonymized information	1975						252,514.63					
370	anonymized information	1998						210,445.61					
371	anonymized information	1968	1995					318,892.00	388,332.72				
372	anonymized information	1970	1993					9,375.72	882,246.48				
373	anonymized information	1993						213,709.65					
374	anonymized information	1973	2004					40,005.00	25,669.18				
375	anonymized information	1973	1995	2004				203,484.99	247,795.11	130,565.98			
376	anonymized information	1983	2004					116,929.72	75,027.87				
377	anonymized information	1968	1985	2020				267,072.05	146,154.56	1,167,694.65			
378	anonymized information	1968	2009	2020				209,671.49	99,246.34	1,075,301.51			
379	anonymized information	1967						87,831.83					
380	anonymized information	1971	2018					33,855.18	132,562.85				

381	anonymized information	1973	1989	1998				143,501.40	29,505.18	169,668.59		
382	anonymized information	1998						56,735.29				
383	anonymized information	2002						-				
384	anonymized information	1996						345,676.33				
385	anonymized information	2015						103,158.80				
386	anonymized information	2014						236,562.17				
387	anonymized information	1962	1982	2004				900,072.67	1,401,634.06	577,530.93		
388	anonymized information	1962						-				
389	anonymized information	1989						-				
390	anonymized information	1998						108,399.38				
391	anonymized information	1982	1997	2007				102,045.44	93,897.82	58,306.36		
392	anonymized information	1990	1996					105,234.36	97,083.57			
393	anonymized information	1985	2009					21,377.83	18,490.76			
394	anonymized information	2009						-				
395	anonymized information	1964	2015					131,542.95	433,549.37			
396	anonymized information	1991						80,065.35				
397	anonymized information	1980	1999	2018				86,613.76	39,772.64	2,927,534.37		
398	anonymized information	2010						244,225.99				
399	anonymized information	1973	1999	2009				107,626.05	97,666.52	50,943.94		
400	anonymized information	2015						141,113.45				
401	anonymized information	1988						171,993.36				
402	anonymized information	1993	2009					78,674.13	40,981.57			
403	anonymized information	1943	1996	2009				2,796,284.23	1,488,758.17	2,818,633.81		
404	anonymized information	1943	1993	2009				1,583,318.71	1,203,063.38	2,383,162.84		
405	anonymized information	1990						-				
406	anonymized information	1943	1997	2009				1,357,284.08	864,108.86	2,876,374.97		
407	anonymized information	1943	2009	2020				725,479.30	677,311.37	812,521.68		
408	anonymized information	1943	2009	2020				601,111.42	3,287,937.34	3,944,301.67		
409	anonymized information	1943	1990	2009				2,185,805.35	1,551,055.48	2,028,396.74		
410	anonymized information	1998						127,251.45				
411	anonymized information	1999	2016					56,182.08	160,761.29			
412	anonymized information	1992						278,217.59				
413	anonymized information	1988	1995					363,978.05	497,065.89			
414	anonymized information											
415	anonymized information	2011						960,342.91				
416	anonymized information	1989	2013					98,856.52	208,089.95			
417	anonymized information	1976	1992	2003				436,084.81	576,065.64	302,160.32		
418	anonymized information	1962	1989	2008				240,763.46	366,747.49	120,572.12		
419	anonymized information	1988						298,575.75				
420	anonymized information	1986						175,949.29				
421	anonymized information	1984						-				
422	anonymized information	1983	2007					78,925.77	45,096.32			
423	anonymized information	1975	1991	2007				188,625.36	264,067.76	159,431.44		
424	anonymized information	1991						196,164.62				
425	anonymized information	1993						188,397.74				
426	anonymized information	1998						259,215.91				
427	anonymized information	1992	2018					311,654.67	216,700.99			
428	anonymized information	1992	2008					384,626.50	145,812.42			
429	anonymized information	1992	2008					198,147.62	75,118.03			
430	anonymized information	1992						179,085.85				
431	anonymized information	1975	2012					96,195.94	208,167.42			
432	anonymized information	1978						41,567.57				
433	anonymized information	1991						98,082.31				
434	anonymized information	1974	2012					581,977.90	646,647.74			
435	anonymized information	1990	2013					59,792.25	125,860.85			
436	anonymized information	1978	2018					151,473.70	1,589,232.94			
437	anonymized information	1978						-				
438	anonymized information	2017						100,137.87				
439	anonymized information	1993						253,553.82				
440	anonymized information	1973	2016					63,778.40	316,587.04			
441	anonymized information	1964	1973	1981				161,837.69	48,463.83	465,491.75		
442	anonymized information	1981						58,186.47				
443	anonymized information	1975	2013					47,074.61	192,986.64			
444	anonymized information	1975	2013					81,868.89	245,851.08			
445	anonymized information	1968	1980	2004	2018			135,529.10	99,350.85	193,770.55	124,486.09	
446	anonymized information	1979	2006					703,156.86	761,885.23			
447	anonymized information	1979						-				
448	anonymized information	1977						75,593.35				
449	anonymized information	1978	2008					319,800.84	160,153.32			

Asset ID	Bridge Name	A	B	C	D	E	F	G	H	I	J	K
1	anonymized information	1998	2020					57,578.50	14,196.33			
2	anonymized information	1968	1996	2006				1,102,610.04	223,313.73	687,525.50		
3	anonymized information	1994	2018					208,589.54	96,525.52			
4	anonymized information	1992	2010					893,778.04	279,183.76			
5	anonymized information	1987	1999					69,199.56	6,161.24			
6	anonymized information	1982	1994					120,604.95	6,993.08			

7	anonymized information	1991	2018					117,261.14	5,624.20			
8	anonymized information	1953						279,354.00				
9	anonymized information	1973						332,046.30	8,077.30			
10	anonymized information	1982						80,015.58				
11	anonymized information	1982						80,015.58				
12	anonymized information	1982						80,494.72				
13	anonymized information	1982						80,628.65				
14	anonymized information	1982						80,628.65				
15	anonymized information	1982						80,681.27				
16	anonymized information	1982						130,791.96				
17	anonymized information	1982						120,234.24				
18	anonymized information	1984						74,883.81				
19	anonymized information	1984						74,883.81				
20	anonymized information	1987						190,047.67				
21	anonymized information	1987						130,452.34				
22	anonymized information	1987						120,728.53				
23	anonymized information	1992						74,883.81				
24	anonymized information	1992						110,936.15				
25	anonymized information	1992						114,750.10				
26	anonymized information	1992						116,408.34				
27	anonymized information	1992						138,622.35				
28	anonymized information	1992						164,165.60				
29	anonymized information	1992						176,878.29				
30	anonymized information	1994						130,978.01				
31	anonymized information	2002						183,157.90				
32	anonymized information	2008						136,039.33				
33	anonymized information	2013						269,674.66				

Asset ID	Parking Lot Name	A	B	C	D	E	F	G	H	I	J	K
1	anonymized information											
2	anonymized information	1996						35,310.86				
3	anonymized information	1996	2002	2004				99,250.54	6,107.46	61,599.20		
4	anonymized information	1996	2007	2016				99,250.54	17,074.96	15,819.14		
5	anonymized information	2007						3,414.99				
6	anonymized information	2008	2017					28,432.57	506,162.57			
7	anonymized information	2008						32,697.45				
8	anonymized information	2012						42,338.29				
9	anonymized information	2015	2020					13,448.03	6,268.30			
10	anonymized information											
11	anonymized information	1996						99,250.54				
12	anonymized information	2015						36,772.33				
13	anonymized information	2015						21,507.84				
14	anonymized information	1994	2015					4,747.34	133,226.85			
15	anonymized information	2019						13,933.35				
16	anonymized information	2018						17,483.11				

Asset ID	Intersection Name	A	B	C	D	E	F	G	H	I	J	K
1	anonymized information	1991	2004	2011	2020			12,930.06	58,462.03	41,148.95	5,967.91	
2	anonymized information	1991	2002	2012	2019			226,309.35	7,113.82	35,869.96	16,290.09	
3	anonymized information	1984	2006	2012				222,206.53	20,186.53	130,257.31		
4	anonymized information	1991	2006	2012				1,985.74	6,382.85	55,561.16		
5	anonymized information	1971	1977	1982				6,949.22	4,335.91	24,669.31		
6	anonymized information	2007	2016					12,527.29	25,403.73			
7	anonymized information	2008	2019					128,553.12	23,787.31			
8	anonymized information	2003	2012					30,483.18	531,269.92			
9	anonymized information	2007	2019					230,722.53	17,563.47			
10	anonymized information	1992	2019					11,748.37	16,290.09			
11	anonymized information	1997	2004					176,118.89	10,008.13			
12	anonymized information	1990	2001					237,972.17	26,967.37			
13	anonymized information	1991	1999					226,309.35	1,702.13			
14	anonymized information	1991	2019					667,559.77	33,532.08			
15	anonymized information	1990	2012					28,807.37	41,050.74			
16	anonymized information	1988	1995					326,392.22	128,797.82			
17	anonymized information	1991										
18	anonymized information	1977										
19	anonymized information	1986										
20	anonymized information	1989										
21	anonymized information	1989										
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23	anonymized information	1991										
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29	anonymized information	1992										
30	anonymized information	1992										
31	anonymized information	1995										

32	anonymized information	1996
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64	anonymized information	

Asset ID	Water Section Name	A	B	C	D	E	F	G	H	I	J	K
1	anonymized information	1991						241,076.14				
2	anonymized information	1991						73,567.80				
3	anonymized information	1998						24,787.85				
4	anonymized information	2008						438,369.27				
5	anonymized information	1979						44,176.62				
6	anonymized information	1994						97,465.78				
7	anonymized information	2017						66,928.04				
8	anonymized information	1977						118,574.38				
9	anonymized information	2005						85,358.50				
10	anonymized information	2005						276,182.99				
11	anonymized information	1980	2008					119,746.61	7,277.67			
12	anonymized information	2013						131,340.51				
13	anonymized information	1972						215,415.55				
14	anonymized information	1973						114,082.28				
15	anonymized information	1973						103,557.93				
16	anonymized information	1977						573,389.02				
17	anonymized information	1984						447,293.58				
18	anonymized information	1977						98,201.63				
19	anonymized information	1981						150,027.65				
20	anonymized information	1989						147,375.17				
21	anonymized information	1989						165,018.44				
22	anonymized information	2012						285,928.71				
23	anonymized information	1990						224,125.95				
24	anonymized information	1975						100,571.75				
25	anonymized information	1975						63,111.89				
26	anonymized information	1993						263,878.91				
27	anonymized information	2008						351,196.82				
28	anonymized information	1969						327,777.99				
29	anonymized information	1969						138,485.09				
30	anonymized information	1973						368,301.03				
31	anonymized information	1978						104,370.78				
32	anonymized information	1972						102,360.03				
33	anonymized information	2012						667,894.29				
34	anonymized information	1989						55,180.13				
35	anonymized information	2000						118,240.68				
36	anonymized information	1981						206,696.59				
37	anonymized information	1964	1991					125,975.65	43,977.38			
38	anonymized information	1953	1994					417,123.76	5,996.01			
39	anonymized information	2006						340,030.73				
40	anonymized information	2004						40,018.21				
41	anonymized information	1973						183,183.64				
42	anonymized information	1993						203,351.04				
43	anonymized information	1993						47,385.26				

44	anonymized information	1964		185,237.18	
45	anonymized information	1964		71,950.64	
46	anonymized information	1983		74,226.64	
47	anonymized information	1973		104,387.90	
48	anonymized information	1973		235,360.48	
49	anonymized information	1973		158,874.95	
50	anonymized information	2017		182,785.77	
51	anonymized information	2019		158,904.29	
52	anonymized information	1978		100,066.92	
53	anonymized information	2010		448,782.39	
54	anonymized information	1973		205,147.88	
55	anonymized information	1973		235,582.94	
56	anonymized information	1964		389,067.38	
57	anonymized information	1991		195,410.72	
58	anonymized information	2017		29,947.35	
59	anonymized information	1976		382,846.88	
60	anonymized information	1978		297,462.72	
61	anonymized information	1978		147,828.66	
62	anonymized information	2003		52,638.88	
63	anonymized information	1995		452,957.90	
64	anonymized information	1991	2010	62,367.49	17,817.57
65	anonymized information	2006	2020	160,637.57	6,435.19
66	anonymized information	1974		118,283.46	
67	anonymized information	2008		119,678.16	
68	anonymized information	2002		12,834.58	
69	anonymized information	2018		137,075.01	
70	anonymized information	1993		208,433.54	
71	anonymized information	1991		96,789.83	
72	anonymized information	1964		383,274.70	
73	anonymized information	1983		59,039.06	
74	anonymized information	1969	1997	185,528.09	28,038.56
75	anonymized information	1973		990,273.20	
76	anonymized information	1975	2006	196,514.49	12,107.84
77	anonymized information	1975		145,869.25	
78	anonymized information	1977		551,091.08	
79	anonymized information	2004		65,636.03	
80	anonymized information	2004		79,608.60	
81	anonymized information	2000		557,816.40	
82	anonymized information	1973		71,017.99	
83	anonymized information	2004		331,465.79	
84	anonymized information	1967	1969	1,647,104.09	93,316.24
85	anonymized information	1993		534,748.38	
86	anonymized information	2009		461,172.03	
87	anonymized information	2010		119,190.44	
88	anonymized information	1975		106,954.81	
89	anonymized information	1978		136,046.52	
90	anonymized information	2004		24,103.34	
91	anonymized information	1993		72,190.22	
92	anonymized information	1963	1991	320,222.70	328,997.10
93	anonymized information	1976		321,814.19	
94	anonymized information	1973		343,667.20	
95	anonymized information	1960	1988	128,345.77	129,941.87
96	anonymized information	1988		176,749.24	
97	anonymized information	1988		203,505.06	
98	anonymized information	2000		110,163.46	
99	anonymized information	1975		153,578.55	
100	anonymized information	1990		72,729.27	
101	anonymized information	1974		444,932.01	
102	anonymized information	1983		426,775.36	
103	anonymized information	2004		325,433.54	
104	anonymized information	1977	2005	466,964.70	63,119.76
105	anonymized information	1973		291,772.72	
106	anonymized information	2015		282,292.25	
107	anonymized information	1984		212,061.44	
108	anonymized information	1964		163,726.42	
109	anonymized information	1984		274,659.95	
110	anonymized information	1992		200,185.18	
111	anonymized information	1982	1993	184,407.21	11,637.74
112	anonymized information	1996		250,428.27	
113	anonymized information	1995		164,248.36	
114	anonymized information	1993		319,461.19	
115	anonymized information	2010		237,396.90	
116	anonymized information	1993		117,727.30	
117	anonymized information	1979		227,214.80	
118	anonymized information	1996		86,248.36	
119	anonymized information	1975		301,663.90	
120	anonymized information	1977		817,990.39	
121	anonymized information	1977		148,889.65	

122	anonymized information	2016		319,846.22	
123	anonymized information	2010		171,127.70	
124	anonymized information	1964		295,246.62	
125	anonymized information	1964		500,925.00	
126	anonymized information	1964		186,152.71	
127	anonymized information	1988		348,287.65	
128	anonymized information	1935	1963	337,335.47	82,547.38
129	anonymized information	1986		99,853.01	
130	anonymized information	1973		577,384.85	
131	anonymized information	2008		48,275.12	
132	anonymized information	1993		315,473.91	
133	anonymized information	1993		563,523.51	
134	anonymized information	2004		248,990.80	
135	anonymized information	1979		135,028.31	
136	anonymized information	1970	1998	80,566.92	88,555.45
137	anonymized information	1988		121,124.18	
138	anonymized information	1975		117,427.83	
139	anonymized information	1978		273,427.83	
140	anonymized information	1975		146,442.53	
141	anonymized information	1975		116,734.76	
142	anonymized information	1973		383,770.97	
143	anonymized information	1978		788,008.82	
144	anonymized information	1978		176,757.80	
145	anonymized information	1986		180,060.56	
146	anonymized information	2007		649,087.36	
147	anonymized information	1983	2013	233,418.18	112,889.47
148	anonymized information	1983		276,970.18	
149	anonymized information	1973		453,009.24	
150	anonymized information	1973		322,746.84	
151	anonymized information	1975		133,137.35	
152	anonymized information	1995		49,053.75	
153	anonymized information	2004		467,007.49	
154	anonymized information	1987		117,299.48	
155	anonymized information	1978		255,716.12	
156	anonymized information	1995		275,729.50	
157	anonymized information	1974		426,766.81	
158	anonymized information	1985		125,778.86	
159	anonymized information	1976	2017	57,764.15	1,179.08
160	anonymized information	1975		343,016.91	
161	anonymized information	1987		39,941.20	
162	anonymized information	1978		166,849.50	
163	anonymized information	1973		98,578.11	
164	anonymized information	1978		102,206.02	
165	anonymized information	2004		309,013.84	
166	anonymized information	1976	2019	342,683.21	107,882.86
167	anonymized information	1976		404,862.46	
168	anonymized information	1993		399,583.17	
169	anonymized information	1992		236,087.77	
170	anonymized information	2000		118,642.83	
171	anonymized information	1979		484,898.89	
172	anonymized information	1978		194,358.28	
173	anonymized information	1988		156,196.81	
174	anonymized information	1975		210,367.28	
175	anonymized information	1990		223,064.95	
176	anonymized information	1979		169,835.68	
177	anonymized information	1973		681,019.78	
178	anonymized information	1989		142,258.45	
179	anonymized information	1964		82,201.19	
180	anonymized information	1975		691,347.34	
181	anonymized information	1975		105,431.77	
182	anonymized information	1964	1988	397,067.60	28,882.17
183	anonymized information	1977		136,902.16	
184	anonymized information	1973		163,255.82	
185	anonymized information	2011		93,264.60	
186	anonymized information	1964		223,655.34	
187	anonymized information	1974		112,944.28	
188	anonymized information	1986		463,627.71	
189	anonymized information	2004		162,408.74	
190	anonymized information	1978		309,338.98	
191	anonymized information	2012		484,009.02	
192	anonymized information	1998		258,864.87	
193	anonymized information	1986		46,230.15	
194	anonymized information	1974		93,949.11	
195	anonymized information	1985		227,428.71	
196	anonymized information	1988		372,527.88	
197	anonymized information	1975		506,666.33	
198	anonymized information	2004		91,912.69	
199	anonymized information	2004		119,199.00	

200	anonymized information	1979		103,352.57	
201	anonymized information	1983		321,720.07	
202	anonymized information	1996		271,964.69	
203	anonymized information	1991		98,355.64	
204	anonymized information	1993		202,315.72	
205	anonymized information	1988		139,101.15	
206	anonymized information	1975		130,570.43	
207	anonymized information	2006		164,231.25	
208	anonymized information	1982		1,950,445.04	
209	anonymized information	1976		323,431.35	
210	anonymized information	1998		62,341.82	
211	anonymized information	1976		277,783.03	
212	anonymized information	1989		323,294.45	
213	anonymized information	1977		83,168.06	
214	anonymized information	1985		219,770.75	
215	anonymized information	1989		497,228.64	
216	anonymized information	1985		199,423.66	
217	anonymized information	1985		248,554.42	
218	anonymized information	1980		70,162.36	
219	anonymized information	1976		279,810.90	
220	anonymized information	1988		398,701.87	
221	anonymized information	1989		135,302.11	
222	anonymized information	1993		136,936.38	
223	anonymized information	2013		65,884.16	
224	anonymized information	2016		216,476.54	
225	anonymized information	1992		350,358.29	
226	anonymized information	1974		131,768.33	
227	anonymized information	1976		199,166.97	
228	anonymized information	1983		381,221.17	
229	anonymized information	1978		753,663.49	
230	anonymized information	1998		225,777.33	
231	anonymized information	1998		607,451.99	
232	anonymized information	1998		253,063.64	
233	anonymized information	1975		809,784.82	
234	anonymized information	1973		73,182.76	
235	anonymized information	1973		81,319.88	
236	anonymized information	1973	2018	62,196.36	58,027.12
237	anonymized information	1973		132,153.36	
238	anonymized information	1973	2018	53,451.74	49,868.67
239	anonymized information	1978		250,462.50	
240	anonymized information	1969	1997	355,637.58	99,995.67
241	anonymized information	1997		73,627.69	
242	anonymized information	1983		87,275.13	
243	anonymized information	1979		270,535.78	
244	anonymized information	1973		96,875.39	
245	anonymized information	1989		644,021.98	
246	anonymized information	1975		70,590.18	
247	anonymized information	1985		250,060.35	
248	anonymized information	1975		127,105.10	
249	anonymized information	1972		225,888.56	
250	anonymized information	1991		499,179.49	
251	anonymized information	1986		196,702.73	
252	anonymized information	1983		410,398.44	
253	anonymized information	1983		679,539.53	
254	anonymized information	1983		318,614.10	
255	anonymized information	1983		118,728.40	
256	anonymized information	1989		108,477.85	
257	anonymized information	1989		159,610.80	
258	anonymized information	1989		527,073.31	
259	anonymized information	1993		52,707.33	
260	anonymized information	1964	1988	172,274.25	155,879.79
261	anonymized information	1990		99,382.41	
262	anonymized information	1978		302,570.88	
263	anonymized information	1984		66,868.15	
264	anonymized information	1988		181,395.36	
265	anonymized information	1993		485,275.37	
266	anonymized information	1964		628,902.84	
267	anonymized information	1964		455,251.01	
268	anonymized information	1964	2001	193,964.69	5,066.67
269	anonymized information	1964		530,068.04	
270	anonymized information	1964		417,534.47	
271	anonymized information	1987		208,544.77	
272	anonymized information	1989		146,143.05	
273	anonymized information	2018		433,808.71	
274	anonymized information	1964		237,713.48	
275	anonymized information	1988		188,796.63	
276	anonymized information	1973		75,724.01	
277	anonymized information	1988		233,366.84	

278	anonymized information	1990		106,295.97	
279	anonymized information	2005		197,284.57	
280	anonymized information	1964		83,108.17	
281	anonymized information	1964	1988	252,644.38	228,601.50
282	anonymized information	2013		185,673.55	
283	anonymized information	2018		132,726.64	
284	anonymized information	2016		162,115.26	
285	anonymized information	2017		56,266.35	
286	anonymized information	1988		149,856.52	
287	anonymized information	2006		116,854.55	
288	anonymized information	1976		328,984.44	
289	anonymized information	1975		174,421.91	
290	anonymized information	1975		38,503.73	
291	anonymized information	1991		84,417.29	
292	anonymized information	1998		71,668.28	
293	anonymized information	2000		225,092.82	
294	anonymized information	1988		118,933.75	
295	anonymized information	1968		262,355.87	
296	anonymized information	1978		139,212.38	
297	anonymized information	1991		84,579.86	
298	anonymized information	1991	2019	243,856.97	4,907.50
299	anonymized information	1974		186,657.54	
300	anonymized information	1974	1998	237,670.70	10,391.64
301	anonymized information	1991	2019	246,423.88	4,959.16
302	anonymized information	1975	2008	66,611.46	79,866.76
303	anonymized information	1991		220,215.68	
304	anonymized information	1989		418,450.00	
305	anonymized information	1975		249,546.96	
306	anonymized information	1975		504,706.92	
307	anonymized information	1986		834,256.08	
308	anonymized information	1988		215,193.08	
309	anonymized information	1991		99,365.30	
310	anonymized information	1995		347,021.30	
311	anonymized information	1990		575,237.20	
312	anonymized information	1975		287,751.22	
313	anonymized information	1983		259,258.46	
314	anonymized information	2005		131,768.33	
315	anonymized information	1974		74,012.73	
316	anonymized information	1964		162,571.31	
317	anonymized information	2016		325,707.35	
318	anonymized information	2016		50,919.05	
319	anonymized information	1993		33,857.61	
320	anonymized information	1989		278,938.15	
321	anonymized information	2013		246,423.88	
322	anonymized information	1993		117,222.47	
323	anonymized information	1968	1996	268,105.76	196,107.08
324	anonymized information	1993		323,576.81	
325	anonymized information	1973	2001	185,493.87	5,066.67
326	anonymized information	1968	1993	671,025.93	35,030.05
327	anonymized information	1964		818,187.19	
328	anonymized information	1993		268,054.43	
329	anonymized information	1939	1967	44,690.00	7,329.81
330	anonymized information	1973		243,309.36	
331	anonymized information	1968	1983	116,974.34	122,242.96
332	anonymized information	1968		290,369.48	
333	anonymized information	1968	2019	224,579.43	4,519.55
334	anonymized information	1964	2018	80,130.54	73,213.46
335	anonymized information	1964		138,613.43	
336	anonymized information	1973		149,206.24	
337	anonymized information	2002		51,338.31	
338	anonymized information	1996		420,204.06	
339	anonymized information	2015		120,046.08	
340	anonymized information	2014		168,047.40	
341	anonymized information	1962		501,352.81	
342	anonymized information	1962		474,075.06	
343	anonymized information	1989	2014	171,641.08	25,444.85
344	anonymized information	1998		104,559.02	
345	anonymized information	1982	2021	124,230.15	59,061.08
346	anonymized information	1990		115,083.38	
347	anonymized information	1981		43,834.36	
348	anonymized information	2009		337,720.51	
349	anonymized information	1964		165,557.49	
350	anonymized information	1991		130,647.44	
351	anonymized information	2018		596,251.68	
352	anonymized information	2010		232,109.05	
353	anonymized information	1973		106,681.01	
354	anonymized information	2015		171,127.70	
355	anonymized information	1960	1988	124,067.58	125,610.47

356	anonymized information	1993						165,557.49				
357	anonymized information	1977	1990					1,172,524.20	1,073,777.71			
358	anonymized information	1977	1990					690,816.84	632,638.31			
359	anonymized information	1977	1990					585,256.72	535,968.15			
360	anonymized information	1977	1990					325,142.62	297,760.08			
361	anonymized information	1977	1990					486,858.30	445,856.54			
362	anonymized information	1977	1990					436,709.33	399,930.97			
363	anonymized information	1998						126,831.29				
364	anonymized information	1999						197,139.11				
365	anonymized information	1992						220,155.78				
366	anonymized information	1988						438,591.73				
367	anonymized information	2011						203,128.58				
368	anonymized information	1989						110,206.24				
369	anonymized information	1976	2020					550,072.87	99,064.56			
370	anonymized information	1988						274,754.07				
371	anonymized information	1988						394,526.35				
372	anonymized information	1986						253,577.02				
373	anonymized information	1984						69,041.47				
374	anonymized information	1983						82,141.29				
375	anonymized information	1975						310,254.52				
376	anonymized information	1963	1991					708,896.49	728,320.90			
377	anonymized information	1993						269,209.54				
378	anonymized information	1998						209,468.86				
379	anonymized information	1964	1992					221,216.77	208,362.52			
380	anonymized information	1964	1992					330,122.44	310,940.00			
381	anonymized information	1992						161,655.78				
382	anonymized information	1964	1992					148,915.32	140,262.29			
383	anonymized information	1975						212,703.17				
384	anonymized information	1991						113,654.46				
385	anonymized information	1974						673,353.26				
386	anonymized information	1990						79,711.28				
387	anonymized information	1978	2018					399,600.29	277,457.38			
388	anonymized information	1990	2018					125,205.58	97,409.53			
389	anonymized information	1993						318,314.63				
390	anonymized information	1973						117,222.47				
391	anonymized information	1964						130,459.20				
392	anonymized information	1981						34,696.14				
393	anonymized information	1975						111,857.62				
394	anonymized information	1975						246,432.44				
395	anonymized information	1968						37,225.41				
396	anonymized information	1979						703,317.72				
397	anonymized information	1977						86,419.49				
398	anonymized information	1978						305,685.41				

Asset ID	Sanitary Section Name	A	B	C	D	E	F	G	H	I	J	K
1	anonymized information	1968						83,004.96				
2	anonymized information	1991						87,488.00				
3	anonymized information	1991						28,145.84				
4	anonymized information	1998						888.88				
5	anonymized information	2008						392,987.96				
6	anonymized information	1979						43,873.24				
7	anonymized information	1955	1994					20,474.89	97,368.47			
8	anonymized information	1977						60,568.95				
9	anonymized information	2005						81,908.07				
10	anonymized information	2008						6,245.85				
11	anonymized information	2013						122,213.48				
12	anonymized information	1972						222,804.87				
13	anonymized information	1973						118,988.24				
14	anonymized information	1973						101,682.59				
15	anonymized information	1977						552,354.01				
16	anonymized information	1984						427,151.90				
17	anonymized information	1977						83,763.50				
18	anonymized information	1981						124,362.23				
19	anonymized information	1981						98,615.43				
20	anonymized information	1989						154,349.42				
21	anonymized information	1989						157,518.68				
22	anonymized information	2012						211,724.48				
23	anonymized information	1990						220,288.05				
24	anonymized information	1975						95,038.53				
25	anonymized information	1975						62,215.68				
26	anonymized information	1993						255,338.72				
27	anonymized information	2008						337,369.95				
28	anonymized information	1969						331,304.31				
29	anonymized information	1969						136,466.69				
30	anonymized information	1973						376,058.82				
31	anonymized information	1978						106,469.07				
32	anonymized information	1972						99,704.06				
33	anonymized information	2012						565,301.98				

34	anonymized information	1989		61,521.37	
35	anonymized information	2000		112,434.76	
36	anonymized information	1981		191,347.12	
37	anonymized information	1967		116,655.47	
38	anonymized information	1953		524,323.32	
39	anonymized information	2006		340,793.74	
40	anonymized information	2004		31,487.31	
41	anonymized information	1973	2019	180,046.17	7,872.34
42	anonymized information	1993		199,195.24	
43	anonymized information	1993		48,335.29	
44	anonymized information	1964	2018	371,807.92	6,318.90
45	anonymized information	1983		63,836.73	
46	anonymized information	1973		168,477.39	
47	anonymized information	1973	2019	250,633.88	22,739.24
48	anonymized information	1973		164,166.10	
49	anonymized information	2017		165,236.56	
50	anonymized information	2019		148,023.81	
51	anonymized information	1978		97,725.53	
52	anonymized information	2010		537,788.56	
53	anonymized information	1973		205,343.70	
54	anonymized information	1973		231,228.74	
55	anonymized information	1967		363,548.29	
56	anonymized information	1991		83,414.39	
57	anonymized information	2017		24,631.54	
58	anonymized information	2012		51,364.97	
59	anonymized information	1976		396,215.63	
60	anonymized information	1978		299,665.12	
61	anonymized information	1978		139,274.64	
62	anonymized information	1973		84,650.38	
63	anonymized information	2003		43,351.51	
64	anonymized information	1995		206,445.12	
65	anonymized information	1991		24,416.43	
66	anonymized information	2006		114,922.54	
67	anonymized information	1974		118,478.49	
68	anonymized information	2008		110,480.65	
69	anonymized information	2002		12,315.77	
70	anonymized information	2018		18,577.32	
71	anonymized information	1993		194,589.14	
72	anonymized information	1991		37,868.84	
73	anonymized information	1967		392,008.01	
74	anonymized information	1983		47,620.97	
75	anonymized information	1997		18,273.26	
76	anonymized information	1973		1,011,857.93	
77	anonymized information	1975	2006	278,532.01	16,995.38
78	anonymized information	1977		516,664.00	
79	anonymized information	2004		55,749.38	
80	anonymized information	1973		782,357.17	
81	anonymized information	2006		314,832.10	
82	anonymized information	2004		52,227.07	
83	anonymized information	2000		561,623.67	
84	anonymized information	1973		64,513.88	
85	anonymized information	2004		288,131.51	
86	anonymized information	1967	2015	431,052.76	16,584.70
87	anonymized information	1993		330,596.28	
88	anonymized information	2009		462,990.79	
89	anonymized information	2010		110,661.29	
90	anonymized information	1975		99,790.46	
91	anonymized information	1978		144,570.88	
92	anonymized information	1993		57,703.48	
93	anonymized information	1991		119,176.95	
94	anonymized information	1976		322,966.84	
95	anonymized information	1973		345,249.05	
96	anonymized information	1988		7,897.01	
97	anonymized information	1949	1988	11,510.24	146,620.99
98	anonymized information	1991		74,629.27	
99	anonymized information	2000		103,616.67	
100	anonymized information	1975		247,497.61	
101	anonymized information	1990		64,042.00	
102	anonymized information	1974		387,066.01	
103	anonymized information	1983		412,783.51	
104	anonymized information	2004		312,656.31	
105	anonymized information	2003		454,279.44	
106	anonymized information	1962		74,223.03	
107	anonymized information	1973		133,477.29	
108	anonymized information	2015		274,132.59	
109	anonymized information	1984		212,212.39	
110	anonymized information	1964		159,431.29	
111	anonymized information	1964	2000	38,581.86	49,671.41

112	anonymized information	1984		161,747.09	
113	anonymized information	1992		67,467.76	
114	anonymized information	1982		131,351.89	
115	anonymized information	1996		136,938.25	
116	anonymized information	1995		191,477.36	
117	anonymized information	1993		233,745.08	
118	anonymized information	2010		247,481.26	
119	anonymized information	1979	2019	249,000.94	9,979.77
120	anonymized information	1996		61,334.32	
121	anonymized information	1975		307,060.85	
122	anonymized information	1977		659,169.95	
123	anonymized information	1977		139,758.48	
124	anonymized information	1977		154,290.73	
125	anonymized information	2016		316,104.72	
126	anonymized information	2010		164,210.25	
127	anonymized information	1967		238,183.83	
128	anonymized information	1964		632,918.96	
129	anonymized information	1964		238,182.39	
130	anonymized information	1988		19,447.44	
131	anonymized information	1962		316,841.17	
132	anonymized information	1986		126,441.89	
133	anonymized information	1973		566,170.43	
134	anonymized information	2008		8,202.30	
135	anonymized information	1993		269,304.80	
136	anonymized information	1993		506,588.61	
137	anonymized information	2004		219,425.94	
138	anonymized information	1979		58,275.90	
139	anonymized information	1998		3,201.25	
140	anonymized information	1988		9,783.98	
141	anonymized information	1975	2019	120,750.77	14,020.44
142	anonymized information	1978		262,228.58	
143	anonymized information	1975		187,217.26	
144	anonymized information	1975		212,177.83	
145	anonymized information	1973		302,499.00	
146	anonymized information	1978		983,588.29	
147	anonymized information	1978		210,812.74	
148	anonymized information	1986		172,420.76	
149	anonymized information	2007		421,174.65	
150	anonymized information	2004		193,029.14	
151	anonymized information	1983		157,641.84	
152	anonymized information	1973		427,517.86	
153	anonymized information	1973	2020	331,261.11	6,642.13
154	anonymized information	1975		127,006.03	
155	anonymized information	1995		60,125.58	
156	anonymized information	2004		412,167.72	
157	anonymized information	1987		110,234.34	
158	anonymized information	1978		260,379.65	
159	anonymized information	1995		248,064.21	
160	anonymized information	1974		376,905.52	
161	anonymized information	1985		119,668.22	
162	anonymized information	1976		42,456.30	
163	anonymized information	1975		357,094.31	
164	anonymized information	1987		39,279.09	
165	anonymized information	1978		141,953.00	
166	anonymized information	1973		129,295.60	
167	anonymized information	1978		103,531.52	
168	anonymized information	2004		360,244.44	
169	anonymized information	1976		409,961.65	
170	anonymized information	1976		370,563.86	
171	anonymized information	1993		387,536.18	
172	anonymized information	1953	1992	83,148.34	230,425.43
173	anonymized information	2000		113,305.07	
174	anonymized information	1979	2019	481,974.94	8,447.10
175	anonymized information	1949	1988	11,812.96	142,999.23
176	anonymized information	1975	2020	218,873.73	7,293.00
177	anonymized information	1990		175,294.44	
178	anonymized information	1979		140,380.55	
179	anonymized information	1979		62,112.00	
180	anonymized information	1979		62,941.43	
181	anonymized information	1973	2018	669,269.96	16,335.78
182	anonymized information	1989		141,828.39	
183	anonymized information	1967		77,274.96	
184	anonymized information	1975		592,833.06	
185	anonymized information	1975		89,362.14	
186	anonymized information	1964	2020	377,110.17	6,368.44
187	anonymized information	1977		171,484.76	
188	anonymized information	1973	2020	165,885.43	6,775.64
189	anonymized information	2011		144,505.02	

190	anonymized information	1967		130,735.99	
191	anonymized information	1974	2018	144,285.77	9,160.23
192	anonymized information	1986		450,757.13	
193	anonymized information	2004		153,117.84	
194	anonymized information	1978		311,812.77	
195	anonymized information	2012		426,339.06	
196	anonymized information	1998		11,179.89	
197	anonymized information	1986		123,223.37	
198	anonymized information	1974		88,126.64	
199	anonymized information	1985		92,606.37	
200	anonymized information	1985		66,276.41	
201	anonymized information	1988		28,678.63	
202	anonymized information	1975	2020	461,368.86	9,178.83
203	anonymized information	1969	2008	5,265.81	5,265.81
204	anonymized information	2004		118,182.11	
205	anonymized information	1979		96,766.50	
206	anonymized information	1983		295,988.97	
207	anonymized information	1957	1996	180,247.78	255,442.01
208	anonymized information	1991		31,262.63	
209	anonymized information	1973	1993	9,692.77	243,835.94
210	anonymized information	1952	1991	52,953.85	161,713.07
211	anonymized information	1975		109,726.30	
212	anonymized information	2006		129,931.36	
213	anonymized information	1982		1,271,512.78	
214	anonymized information	1976	2020	323,994.98	7,509.95
215	anonymized information	1959	1998	2,637.10	59,956.36
216	anonymized information	1976		275,326.62	
217	anonymized information	1989		307,894.21	
218	anonymized information	1977		88,480.87	
219	anonymized information	1985		214,089.11	
220	anonymized information	1989		441,315.04	
221	anonymized information	1985		174,670.44	
222	anonymized information	1985		257,933.24	
223	anonymized information	1980		80,350.76	
224	anonymized information	1976		264,656.38	
225	anonymized information	1988		32,678.40	
226	anonymized information	1989		130,070.94	
227	anonymized information	1993		127,550.31	
228	anonymized information	2013		90,219.50	
229	anonymized information	2016		204,679.86	
230	anonymized information	1953	1992	124,707.77	345,597.30
231	anonymized information	1974		108,862.31	
232	anonymized information	1976		174,508.02	
233	anonymized information	1983		362,050.75	
234	anonymized information	1978		703,527.03	
235	anonymized information	1992		96,456.20	
236	anonymized information	1998		556,319.68	
237	anonymized information	1998		8,847.69	
238	anonymized information	1975		719,787.26	
239	anonymized information	1973		74,311.49	
240	anonymized information	1973	2019	114,201.75	6,095.84
241	anonymized information	1973		125,191.66	
242	anonymized information	1973		49,765.63	
243	anonymized information	1973		75,123.64	
244	anonymized information	1978		266,358.44	
245	anonymized information	1997		29,902.33	
246	anonymized information	1958	1997	9,825.19	58,000.78
247	anonymized information	1983		85,389.33	
248	anonymized information	1979		288,519.69	
249	anonymized information	1979		50,197.62	
250	anonymized information	1973		93,025.44	
251	anonymized information	1989		620,788.63	
252	anonymized information	1975		50,975.21	
253	anonymized information	1985		144,710.28	
254	anonymized information	1975		123,360.01	
255	anonymized information	1972		207,399.99	
256	anonymized information	1952	1991	208,417.55	539,495.10
257	anonymized information	1964	2018	231,998.27	20,733.89
258	anonymized information	1983		359,694.33	
259	anonymized information	1983		332,689.96	
260	anonymized information	1983		115,973.49	
261	anonymized information	1989		443,269.14	
262	anonymized information	1993		49,263.07	
263	anonymized information	1967		151,698.77	
264	anonymized information	1990		98,361.94	
265	anonymized information	1978		291,136.56	
266	anonymized information	1984		63,812.10	
267	anonymized information	1988		11,476.30	

268	anonymized information	1993			303,008.96		
269	anonymized information	1964			767,909.61		
270	anonymized information	1964	2019		386,984.96	12,627.11	
271	anonymized information	1964			246,038.70	46,328.14	
272	anonymized information	1964			659,651.17		
273	anonymized information	1964			550,707.54		
274	anonymized information	1987			195,779.37		
275	anonymized information	1989			130,957.67		
276	anonymized information	2018			59,389.37		
277	anonymized information	1964	2018		290,532.47	26,272.00	
278	anonymized information	1988			187,053.10		
279	anonymized information	1973			73,179.67		
280	anonymized information	1991			34,129.95		
281	anonymized information	1990			95,849.52		
282	anonymized information	2005			256,833.04		
283	anonymized information	1967			163,423.07		
284	anonymized information	1967			167,095.01		
285	anonymized information	2013			192,618.62		
286	anonymized information	2018			131,310.72		
287	anonymized information	2016			172,858.37		
288	anonymized information	2017			53,836.02		
289	anonymized information	1988			11,194.36		
290	anonymized information	2006			117,697.69		
291	anonymized information	1976			65,671.62		
292	anonymized information	1976			283,829.20		
293	anonymized information	1975			207,931.22		
294	anonymized information	1991			32,039.46		
295	anonymized information	1998			2,559.28		
296	anonymized information	2000			215,985.74		
297	anonymized information	1988			9,178.55		
298	anonymized information	1968			166,706.22		
299	anonymized information	1978			139,957.19		
300	anonymized information	1991			28,215.32		
301	anonymized information	2020			220,041.73		
302	anonymized information	1974			202,060.55		
303	anonymized information	1974	1998	2020	208,998.59	9,522.95	18,624.67
304	anonymized information	2020			304,610.01		
305	anonymized information	1975			17,962.28		
306	anonymized information	1952	1991		78,598.68	203,455.05	
307	anonymized information	1989			89,051.22		
308	anonymized information	1975			596,651.88		
309	anonymized information	1986			893,960.58		
310	anonymized information	1988			17,484.27		
311	anonymized information	1991			32,064.72		
312	anonymized information	1995			307,073.16		
313	anonymized information	1990			552,813.79		
314	anonymized information	1975			265,675.89		
315	anonymized information	1983			251,857.47		
316	anonymized information	2005			98,402.99		
317	anonymized information	1967			167,613.40		
318	anonymized information	2016			304,002.43		
319	anonymized information	2016			45,264.55		
320	anonymized information	1989			281,210.05		
321	anonymized information	2013			227,513.30		
322	anonymized information	1993			106,736.66		
323	anonymized information	1973			205,066.62		
324	anonymized information	1968	1996	1996	212,668.69	162,110.35	597,984.53
325	anonymized information	1993			303,906.42		
326	anonymized information	1998			5,974.53		
327	anonymized information	1968	1996		306,679.06	233,771.36	
328	anonymized information	1964			703,325.35	69,733.50	
329	anonymized information	1993			253,918.30		
330	anonymized information	1928	1967		16,320.77	74,259.65	
331	anonymized information	1973			190,225.62		
332	anonymized information	1968			119,049.41		
333	anonymized information	1968			188,418.20		
334	anonymized information	1968			208,557.73		
335	anonymized information	1967			73,914.06		
336	anonymized information	1967			104,585.58		
337	anonymized information	1973			140,570.62		
338	anonymized information	2002			52,333.81		
339	anonymized information	1957	1996		295,030.57	418,108.91	
340	anonymized information	2015			225,789.09		
341	anonymized information	2014			168,972.34		
342	anonymized information	1962	2012		300,667.34	423,395.78	
343	anonymized information	1962	2012		487,288.46	686,193.16	
344	anonymized information	1989	2012		172,420.76	255,497.45	
345	anonymized information	1998			4,638.96		

346	anonymized information	1982						116,283.96		
347	anonymized information	1990						102,631.40		
348	anonymized information	1981						41,946.55		
349	anonymized information	1964						176,859.27		
350	anonymized information	1991						49,407.59		
351	anonymized information	2018						139,917.06	6,375.11	
352	anonymized information	2010						178,989.17		
353	anonymized information	1973	2019					114,815.18	8,760.60	
354	anonymized information	2015						170,228.55		
355	anonymized information	1988						10,411.59		
356	anonymized information	1993						151,878.06		
357	anonymized information	1977	1990					1,108,140.01	1,057,565.46	
358	anonymized information	1977	1990					666,159.92	635,756.96	
359	anonymized information	1990						244,711.77	1,676,790.12	
360	anonymized information	1977	1990					754,546.08	720,109.26	
361	anonymized information	1977	1990					298,862.65	285,222.82	
362	anonymized information	1977	1990	2020				325,957.34	311,080.93	398,723.92
363	anonymized information	1998						5,328.44		
364	anonymized information	1999						161,894.88		
365	anonymized information	1992						76,593.15		
366	anonymized information	1988						59,296.88		
367	anonymized information	2011						160,326.67		
368	anonymized information	1989						105,094.56		
369	anonymized information	1976	2020					514,884.19	6,758.96	
370	anonymized information	1989						270,488.29		
371	anonymized information	1988						48,769.60		
372	anonymized information	1986						250,313.89		
373	anonymized information	1984						45,921.40		
374	anonymized information	1983						75,741.98		
375	anonymized information	1975						236,948.33		
376	anonymized information	1952	1991					87,961.68	227,691.45	
377	anonymized information	1993						251,685.04		
378	anonymized information	1998						8,454.50		
379	anonymized information	1992						71,588.33		
380	anonymized information	1992						108,582.13		
381	anonymized information	1953	1992					55,318.26	153,301.11	
382	anonymized information	1992						45,461.89		
383	anonymized information	1975						222,649.35		
384	anonymized information	1991						42,163.50		
385	anonymized information	1974	2019					603,416.90	25,602.54	
386	anonymized information	1990						70,840.30		
387	anonymized information	1978	2018					213,440.48	59,156.29	
388	anonymized information	1978						117,018.35		
389	anonymized information	1979	2018					10,284.18	88,250.86	
390	anonymized information	1993						281,456.36		
391	anonymized information	1973						146,463.01		
392	anonymized information	1964						179,174.18		
393	anonymized information	1975						112,499.70		
394	anonymized information	1975						283,422.17		
395	anonymized information	1968						12,148.27		
396	anonymized information	1979						659,930.26		
397	anonymized information	1979						233,178.55		
398	anonymized information	1977						80,100.20		
399	anonymized information	1978						298,991.21		

Asset ID	Storm Section Name	A	B	C	D	E	F	G	H	I	J	K
1	anonymized information	1991						312,253.79				
2	anonymized information	1991						82,548.66				
3	anonymized information	2021						2,050.02				
4	anonymized information	2008						468,580.24				
5	anonymized information	1979						54,117.02				
6	anonymized information	1994						136,677.21				
7	anonymized information	2021						2,050.02				
8	anonymized information	2014						108,731.95				
9	anonymized information	2005						72,480.46				
10	anonymized information	2008						30,013.66				
11	anonymized information	2021						2,050.02				
12	anonymized information	1972						293,761.15				
13	anonymized information	1973						194,355.20				
14	anonymized information	1973						107,930.33				
15	anonymized information	1977						1,191,037.21				
16	anonymized information	1984						604,974.70				
17	anonymized information	1977						94,917.91				
18	anonymized information	1981						173,958.18				
19	anonymized information	1981						39,605.83				
20	anonymized information	1989						193,790.87				
21	anonymized information	1989						180,673.07				
22	anonymized information	2012						344,522.80				

23	anonymized information	1990		309,866.91	
24	anonymized information	1975		191,056.52	
25	anonymized information	1993		344,243.55	
26	anonymized information	2008		453,548.24	
27	anonymized information	1969		427,156.91	
28	anonymized information	1969		79,398.09	
29	anonymized information	1973		512,969.30	
30	anonymized information	1978		249,556.84	
31	anonymized information	1972		130,153.66	
32	anonymized information	2012		1,020,926.07	
33	anonymized information	1989		94,509.34	
34	anonymized information	2000		170,835.58	
35	anonymized information	1981		175,112.07	
36	anonymized information	1967		361,963.55	
37	anonymized information	2013		14,996.65	
38	anonymized information	2006		590,568.13	
39	anonymized information	2004		49,794.70	
40	anonymized information	1973		237,707.90	
41	anonymized information	1993		310,355.50	
42	anonymized information	1993		54,118.96	
43	anonymized information	1964		198,916.89	
44	anonymized information	1984		159,933.38	
45	anonymized information	1983		98,936.91	
46	anonymized information	1973		238,427.58	
47	anonymized information	1973		511,084.47	
48	anonymized information	1973		102,757.05	
49	anonymized information	2017		122,623.44	
50	anonymized information	2019		225,941.68	
51	anonymized information	1978		161,823.91	
52	anonymized information	2010		654,601.90	
53	anonymized information	1973		379,071.86	
54	anonymized information	1973		340,634.30	
55	anonymized information	1967		512,239.39	
56	anonymized information	1991		266,381.89	
57	anonymized information	1982	2017	147,633.03	78,612.19
58	anonymized information	1976		585,348.25	
59	anonymized information	1978		492,768.02	
60	anonymized information	2008		43,548.71	
61	anonymized information	2003		69,278.76	
62	anonymized information	1995		631,494.99	
63	anonymized information	1991		96,135.76	
64	anonymized information	2006		191,998.61	
65	anonymized information	1974		181,947.49	
66	anonymized information	2008		248,735.93	
67	anonymized information	2007		206,129.31	
68	anonymized information	1982	2017	235,007.56	232,988.00
69	anonymized information	1993		266,013.19	
70	anonymized information	1991		177,344.37	
71	anonymized information	1967		405,864.79	
72	anonymized information	1983		77,545.38	
73	anonymized information	1997		431,302.00	
74	anonymized information	1973		1,124,496.92	
75	anonymized information	1975		285,786.45	
76	anonymized information	2021		10,250.10	
77	anonymized information	1977		590,507.15	
78	anonymized information	2004		65,899.04	
79	anonymized information	2006		113,252.74	
80	anonymized information	2004		84,095.34	
81	anonymized information	2000		934,443.09	
82	anonymized information	1973		144,834.57	
83	anonymized information	2004		457,583.41	
84	anonymized information	1982		119,917.41	
85	anonymized information	2020		2,603,359.85	
86	anonymized information	1977	2012	430,975.61	125,728.91
87	anonymized information	1993		407,520.85	
88	anonymized information	2009		515,437.33	
89	anonymized information	2010		208,987.95	
90	anonymized information	1975		148,008.57	
91	anonymized information	1978		221,661.57	
92	anonymized information	2004		98,567.95	
93	anonymized information	1993		119,918.32	
94	anonymized information	1991		389,996.97	
95	anonymized information	1976		494,875.91	
96	anonymized information	1973		501,520.38	
97	anonymized information	1988		139,249.22	
98	anonymized information	1988		236,285.90	
99	anonymized information	1991		176,003.41	
100	anonymized information	2000		180,268.65	

101	anonymized information	1975		307,256.97	
102	anonymized information	1990		98,237.82	
103	anonymized information	1974		645,265.92	
104	anonymized information	1983		526,723.64	
105	anonymized information	2004		469,323.08	
106	anonymized information	2003		791,968.61	
107	anonymized information	1962		136,863.37	
108	anonymized information	1973		14,350.14	
109	anonymized information	2015		463,888.70	
110	anonymized information	1984		345,383.59	
111	anonymized information	1964		203,975.08	
112	anonymized information	1984		227,796.22	
113	anonymized information	1992		259,301.27	
114	anonymized information	1982		224,539.62	
115	anonymized information	1996		390,734.91	
116	anonymized information	1995		337,496.93	
117	anonymized information	1993		500,385.78	
118	anonymized information	2010		355,676.15	
119	anonymized information	1993		106,075.41	
120	anonymized information	1979		299,135.99	
121	anonymized information	1996		136,558.63	
122	anonymized information	1975		484,871.92	
123	anonymized information	1977		1,055,703.84	
124	anonymized information	2013		152,121.55	
125	anonymized information	1977		182,956.77	
126	anonymized information	2016		304,212.90	
127	anonymized information	2010		230,287.57	
128	anonymized information	1987		258,858.65	
129	anonymized information	1984		394,380.03	
130	anonymized information	1984		253,764.21	
131	anonymized information	1988		357,144.75	
132	anonymized information	1962		398,745.97	
133	anonymized information	1986		235,455.02	
134	anonymized information	1973		749,679.83	
135	anonymized information	2008		25,418.95	
136	anonymized information	1993		467,620.68	
137	anonymized information	1993		870,261.89	
138	anonymized information	2004		307,115.86	
139	anonymized information	1979		94,757.78	
140	anonymized information	1998		101,760.60	
141	anonymized information	1988		88,784.17	
142	anonymized information	1975		182,433.75	
143	anonymized information	1978		380,766.65	
144	anonymized information	1975		239,536.15	
145	anonymized information	1975		268,208.21	
146	anonymized information	1973		590,967.12	
147	anonymized information	1978		1,058,441.37	
148	anonymized information	1978		238,805.60	
149	anonymized information	1986		215,677.08	
150	anonymized information	2007		516,685.73	
151	anonymized information	2004		223,613.32	
152	anonymized information	1983		276,745.52	
153	anonymized information	1973		522,658.56	
154	anonymized information	1973		426,451.47	
155	anonymized information	1975		92,367.40	
156	anonymized information	1995		24,942.92	
157	anonymized information	2004		580,955.64	
158	anonymized information	1987		146,829.96	
159	anonymized information	1978		385,193.58	
160	anonymized information	1995		370,512.28	
161	anonymized information	1974		429,894.50	
162	anonymized information	1985		171,591.89	
163	anonymized information	1976		172,940.61	
164	anonymized information	1975		542,762.48	
165	anonymized information	1987		71,059.75	
166	anonymized information	1978		210,870.84	
167	anonymized information	1973		172,844.81	
168	anonymized information	1978		172,123.85	
169	anonymized information	2004		449,868.30	
170	anonymized information	1976		608,217.98	
171	anonymized information	1976		528,743.11	
172	anonymized information	1993		511,522.95	
173	anonymized information	1992		405,857.03	
174	anonymized information	2000		178,963.68	
175	anonymized information	1979		667,620.40	
176	anonymized information	1976	2011	234,857.29	115,192.88
177	anonymized information	2011		4,670.18	
178	anonymized information	1978		137,571.14	

179	anonymized information	1988		243,477.09	
180	anonymized information	1975		322,107.61	
181	anonymized information	1990		393,015.37	
182	anonymized information	1979		186,264.77	
183	anonymized information	1979		70,720.04	
184	anonymized information	1979		65,854.37	
185	anonymized information	1973		1,301,866.55	
186	anonymized information	1989		190,992.57	
187	anonymized information	1967		109,007.71	
188	anonymized information	1975		864,948.54	
189	anonymized information	1975		153,636.65	
190	anonymized information	1988		362,604.01	
191	anonymized information	1977		314,095.51	
192	anonymized information	1973		281,493.79	
193	anonymized information	1976	2011	190,517.83	36,962.72
194	anonymized information	1967		184,595.63	
195	anonymized information	1974		140,929.63	
196	anonymized information	1986		538,337.61	
197	anonymized information	2004		209,527.93	
198	anonymized information	1978		472,092.92	
199	anonymized information	2012		739,032.80	
200	anonymized information	1998		418,817.66	
201	anonymized information	1986		98,127.91	
202	anonymized information	1974		144,088.22	
203	anonymized information	1985		285,871.26	
204	anonymized information	1988		525,503.21	
205	anonymized information	1975		884,987.21	
206	anonymized information	1999		327,174.58	
207	anonymized information	2004		217,879.48	
208	anonymized information	2004		85,251.82	
209	anonymized information	1979		135,141.15	
210	anonymized information	1983		406,709.79	
211	anonymized information	1996		400,545.23	
212	anonymized information	1991		176,492.91	
213	anonymized information	1991		244,712.66	
214	anonymized information	1975		152,858.19	
215	anonymized information	2006		262,723.19	
216	anonymized information	1982		844,165.70	
217	anonymized information	1976		439,141.79	
218	anonymized information	1998		110,218.17	
219	anonymized information	1976		430,898.98	
220	anonymized information	1989		454,142.47	
221	anonymized information	1977		147,350.65	
222	anonymized information	1985		300,451.19	
223	anonymized information	1989		782,988.52	
224	anonymized information	1985		302,617.33	
225	anonymized information	1985		625,238.63	
226	anonymized information	1980		86,421.11	
227	anonymized information	1976		430,859.11	
228	anonymized information	1988		832,841.60	
229	anonymized information	1989		350,904.07	
230	anonymized information	1993		147,879.11	
231	anonymized information	2013		216,252.15	
232	anonymized information	2013		111,477.18	
233	anonymized information	2016		183,680.99	
234	anonymized information	1992		491,662.30	
235	anonymized information	1974		159,105.99	
236	anonymized information	1976		292,444.92	
237	anonymized information	1983		572,512.29	
238	anonymized information	1978		964,679.05	
239	anonymized information	2013		816,891.19	
240	anonymized information	2013		1,470,665.29	
241	anonymized information	1998		252,409.40	
242	anonymized information	1975		965,843.17	
243	anonymized information	1973		119,957.54	
244	anonymized information	1973		27,616.17	
245	anonymized information	2019		59,049.24	
246	anonymized information	2018		58,394.73	
247	anonymized information	1978		289,767.52	
248	anonymized information	1997		542,598.58	
249	anonymized information	1997		109,971.67	
250	anonymized information	1983		130,811.58	
251	anonymized information	1979		471,599.69	
252	anonymized information	1979		54,193.53	
253	anonymized information	1973		145,037.69	
254	anonymized information	1989		1,088,259.16	
255	anonymized information	1975		78,477.50	
256	anonymized information	2008		394,753.38	

257	anonymized information	1975		197,639.24	
258	anonymized information	1972		159,003.15	
259	anonymized information	2012		134,234.79	
260	anonymized information	1991		875,887.11	
261	anonymized information	1986		196,611.97	
262	anonymized information	1983		429,185.56	
263	anonymized information	1983	2003	957,724.75	207,072.73
264	anonymized information	1983		527,100.11	
265	anonymized information	1983		188,305.21	
266	anonymized information	1989		837,044.94	
267	anonymized information	1989		752,490.16	
268	anonymized information	1993		106,683.49	
269	anonymized information	1988		199,743.25	
270	anonymized information	1990		147,730.23	
271	anonymized information	1982	2017	456,733.51	249,505.05
272	anonymized information	1988		219,762.63	
273	anonymized information	1993		391,671.55	
274	anonymized information	1976		738,919.65	
275	anonymized information	1976		623,170.50	
276	anonymized information	1980		342,854.42	
277	anonymized information	1980		628,681.92	
278	anonymized information	1980		596,618.51	
279	anonymized information	1987		248,061.83	
280	anonymized information	1989		177,187.85	
281	anonymized information	1982	2017	457,929.21	332,259.83
282	anonymized information	1967		338,287.94	
283	anonymized information	1988		278,143.32	
284	anonymized information	1973		121,932.99	
285	anonymized information	1991		150,607.90	
286	anonymized information	1990		159,690.64	
287	anonymized information	2005		484,306.68	
288	anonymized information	1967		205,265.29	
289	anonymized information	1967		294,042.08	
290	anonymized information	2013		230,402.28	
291	anonymized information	1983	2018	190,074.56	112,709.03
292	anonymized information	2016		178,142.09	
293	anonymized information	2017		35,742.71	
294	anonymized information	1988		316,686.54	
295	anonymized information	1976		144,091.34	
296	anonymized information	1982	2017	391,024.89	387,664.59
297	anonymized information	1975		164,468.81	
298	anonymized information	2017		163,969.38	
299	anonymized information	1991		153,148.44	
300	anonymized information	1998		61,851.69	
301	anonymized information	2000		401,305.43	
302	anonymized information	2002		143,425.51	
303	anonymized information	2003		166,048.09	
304	anonymized information	2004		58,602.47	
305	anonymized information	2005		44,974.85	
306	anonymized information	2005		14,597.02	
307	anonymized information	2004		819,371.92	
308	anonymized information	1988		159,288.54	
309	anonymized information	1983		253,120.40	
310	anonymized information	1978		207,638.96	
311	anonymized information	1991		133,824.92	
312	anonymized information	1984	2019	324,554.29	28,505.21
313	anonymized information	1974	2009	347,148.91	143,331.39
314	anonymized information	1998		284,453.79	
315	anonymized information	2019		8,118.91	
316	anonymized information	2007		64,928.98	
317	anonymized information	1991		289,527.11	
318	anonymized information	1989		235,286.06	
319	anonymized information	1989		517,662.25	
320	anonymized information	1980		272,720.05	
321	anonymized information	1975		975,929.61	
322	anonymized information	1986		888,297.38	
323	anonymized information	1988		336,989.70	
324	anonymized information	1991		146,494.39	
325	anonymized information	1995		506,227.21	
326	anonymized information	1990		1,059,357.58	
327	anonymized information	1975		382,511.54	
328	anonymized information	1983		374,126.33	
329	anonymized information	2005		172,842.49	
330	anonymized information	1974		77,737.62	
331	anonymized information	1983		153,232.98	
332	anonymized information	2016		282,790.08	
333	anonymized information	1981	2016	66,055.56	74,746.96
334	anonymized information	1989		407,868.47	

335	anonymized information	2013		453,935.20	
336	anonymized information	1993		177,777.03	
337	anonymized information	2001		13,308.06	
338	anonymized information	1968		239,727.37	
339	anonymized information	1989		188,799.88	
340	anonymized information	1998		261,849.20	
341	anonymized information	1968		553,838.02	
342	anonymized information	1967		811,086.04	
343	anonymized information	1993		288,350.44	
344	anonymized information	1973		11,884.55	
345	anonymized information	1973		345,008.80	
346	anonymized information	1983		88,239.40	
347	anonymized information	1985		283,565.68	
348	anonymized information	1968	2019	269,853.53	4,151.92
349	anonymized information	2018		86,980.57	
350	anonymized information	1984		144,044.21	
351	anonymized information	1973		76,032.49	
352	anonymized information	1998		196,826.74	
353	anonymized information	1996		737,256.21	
354	anonymized information	2015		303,247.29	
355	anonymized information	2014		199,186.56	
356	anonymized information	1984		300,884.14	
357	anonymized information	1985		410,531.75	
358	anonymized information	1989		453,819.46	
359	anonymized information	1998		152,455.44	
360	anonymized information	1982		183,690.82	
361	anonymized information	1990		150,619.16	
362	anonymized information	1981		58,625.90	
363	anonymized information	2014		165,042.31	
364	anonymized information	1991		210,370.72	
365	anonymized information	1983	2018	877,326.46	181,651.43
366	anonymized information	2010		196,768.87	
367	anonymized information	1973		179,803.23	
368	anonymized information	2015		286,137.04	
369	anonymized information	1988		181,005.02	
370	anonymized information	1993		274,554.66	
371	anonymized information	1977		1,558,663.51	
372	anonymized information	1977		1,049,696.78	
373	anonymized information	1977		673,532.75	
374	anonymized information	1977		542,106.88	
375	anonymized information	2020		510,306.35	
376	anonymized information	1977		1,423,819.72	
377	anonymized information	1998		166,740.71	
378	anonymized information	1999		257,235.20	
379	anonymized information	1992		309,105.54	
380	anonymized information	1988		584,780.69	
381	anonymized information	2011		58,201.76	
382	anonymized information	1989		159,940.37	
383	anonymized information	1976		599,875.76	
384	anonymized information	1989		214,108.15	
385	anonymized information	1988		627,133.96	
386	anonymized information	1986		416,517.65	
387	anonymized information	1983		117,484.84	
388	anonymized information	1975		337,449.29	
389	anonymized information	1991		311,450.22	
390	anonymized information	1993		351,097.87	
391	anonymized information	1998		350,736.29	
392	anonymized information	1992		346,336.03	
393	anonymized information	1992		446,786.21	
394	anonymized information	1992		245,638.31	
395	anonymized information	1992		243,601.50	
396	anonymized information	1975		359,937.88	
397	anonymized information	1991		185,744.08	
398	anonymized information	1974		854,162.22	
399	anonymized information	1990		120,266.44	
400	anonymized information	1983	2018	308,256.28	348,815.79
401	anonymized information	1978		54,612.99	
402	anonymized information	2017		44,942.22	
403	anonymized information	1993		554,746.97	
404	anonymized information	1973		180,706.74	
405	anonymized information	1964		95,553.96	
406	anonymized information	1975		188,172.39	
407	anonymized information	1975		315,863.69	
408	anonymized information	2018		82,894.31	
409	anonymized information	1979		918,299.28	
410	anonymized information	1977		124,188.08	
411	anonymized information	1978		512,546.34	

Asset ID	Facility Name	A	B	C	D	E	F	G	H	I	J	K
1	Foundations	1995						3,322.07	1,031.26			
2	Basement Construction	1995						4,088.45	1,115.05			
3	SuperStructure	1995						38,118.14	10,395.98			
4	Exterior Enclosure	1995						42,987.84	11,724.10			
5	Roofing	1995						1,087.10	296.49			
6	Interior Construction	1995						12,738.01	3,474.05			
7	Stairs	1995						6,522.62	1,778.92			
8	Interior Finishes	1995						17,606.34	4,801.79			
9	Plumbing	1995						7,302.50	1,991.61			
10	HVAC	1995						40,719.10	11,105.34			
11	Fire Protection	1995						5,600.94	1,527.55			
12	Electrical	1995						38,048.61	10,377.02			
13	Equipment	1994						945.31	257.81			
14	Furnishings	1995						3,024.98	825.01			
15	Foundations	1997						2,373.59	9,705.17			
16	SuperStructure	1997						23,394.71	95,656.59			
17	Exterior Enclosure	1997						26,984.77	110,335.66			
18	Roofing	1997						682.41	2,790.24			
19	Interior Construction	1997						7,996.04	32,694.29			
20	Interior Finishes	1997						11,052.04	45,189.70			
21	Plumbing	1997						4,584.00	18,743.11			
22	Electrical	1997						23,884.27	97,658.28			
23	Equipment	1997						593.40	2,426.29			
24	Foundations	1995	2010	2017				95,289.94	41,874.57	4,089.35	973.34	
25	Basement Construction	1995	2010	2017				103,032.24	45,276.88	4,421.61	1,052.43	
26	SuperStructure	1995	2010	2017				960,607.23	422,132.86	184,432.57	9,812.18	
27	Exterior Enclosure	1995	2010	2017				1,083,327.46	476,061.51	82,723.94	11,065.71	
28	Roofing	1995	2008	2015				27,395.86	12,038.94	443,799.63	1,262.86	
29	Interior Construction	1995	2010	2017				321,007.97	141,064.95	13,776.01	3,278.96	
30	Stairs	1995	2010	2017				164,375.14	72,233.63	7,054.14	1,679.02	
31	Interior Finishes	1995	2010	2017				443,693.77	194,978.46	19,041.06	4,532.14	
32	Plumbing	1995	2010	2017				184,028.69	80,870.26	7,897.57	1,879.77	
33	HVAC	1995	2010	2017				1,026,153.50	450,936.77	129,295.44	10,481.71	
34	Fire Protection	1995	2010	2017				141,148.22	62,026.71	6,057.36	1,441.77	
35	Electrical	1995	2010	2017				958,854.98	421,362.85	41,149.13	9,794.28	
36	Equipment	1995	2010	2017				23,822.48	10,468.64	1,022.34	243.34	
37	Furnishings	1995	2010	2017				76,231.95	33,499.66	69,159.44	778.68	
38	Foundations							1,642.84				
39	SuperStructure							16,192.25				
40	Exterior Enclosure							18,677.04				
41	Roofing							472.32				
42	Interior Construction							5,534.32				
43	Interior Finishes							7,649.48				
44	Plumbing							3,172.74				
45	Fire Protection							2,433.46				
46	Electrical							16,531.08				
47	Equipment							410.71				
48	Furnishings							1,314.27				
49	Foundations							143,782.82				
50	SuperStructure							1,478,909.03				
51	Roofing							102,702.02				
52	Equipment							164,323.23				
53	Furnishings							164,323.23				
54	Foundations	1968	2004					9,442.36	13,738.29	361.31		
55	Basement Construction	1968	2004					10,209.55	14,854.53	390.67		
56	SuperStructure	1968	2004					95,187.38	138,494.18	3,642.35		
57	Exterior Enclosure	1968	2004	2012				107,347.84	156,187.19	4,107.67	26,567.35	
58	Roofing	1968	2004					2,714.68	3,949.76	103.88		
59	Interior Construction	1968	2004					31,808.95	46,280.87	1,217.17		
60	Stairs	1968	2004					16,288.07	23,698.55	623.26		
61	Interior Finishes	1968	2004					43,965.99	63,968.92	1,682.36		
62	Plumbing	1968	2004					18,235.56	26,532.07	697.78		
63	HVAC	1968	1987	2004				101,682.42	147,944.22	470,428.15	3,890.88	
64	Fire Protection	1968	2004					13,986.50	20,349.84	535.19		
65	Electrical	1968	2004					95,013.75	138,241.55	3,635.71		
66	Equipment	1968	2004					2,360.59	3,434.57	90.33		
67	Furnishings	1968	2004					7,553.89	10,990.63	289.05		
68	Foundations	1971	1981	1991	2015			10,289.59	6,191.53	1,863.37	1,132.82	14,772.40
69	Basement Construction	1971	1981	1991	2015			11,125.62	6,694.60	2,014.76	1,224.86	15,972.66
70	SuperStructure	1971	1981	1991	2015			103,728.26	62,416.17	18,784.38	11,419.82	148,918.95
71	Exterior Enclosure	1971	1981	1991	2015			116,979.83	70,390.00	21,184.14	12,878.73	167,943.75
72	Roofing	1971	1981	1991	2015			2,958.26	1,780.07	535.72	325.69	4,247.07
73	Interior Construction	1971	1981	1991	2015			34,663.07	20,857.73	6,277.21	3,816.18	49,764.53
74	Stairs	1971	1981	1991	2015			17,749.55	10,680.40	3,214.31	1,954.11	25,482.39
75	Interior Finishes	1971	1981	1991	2015			47,910.92	28,829.33	8,676.30	5,274.69	68,784.00
76	Plumbing	1971	1981	1991	2015			19,871.78	11,957.40	3,598.63	2,187.76	28,529.20
77	HVAC	1971	1981	1991	2015			110,806.07	66,675.08	20,066.12	12,199.04	159,080.31

78	Fire Protection	1971	1981	1991	2015	15,241.46	9,171.21	2,760.11	1,677.99	21,881.62
79	Electrical	1971	1981	1991	2015	103,539.05	62,302.31	18,750.12	11,398.99	158,495.18
80	Equipment	1971	1981	1991	2015	2,572.40	1,547.88	465.84	283.20	3,693.10
81	Furnishings	1971	1981	1991	2015	8,231.68	4,953.23	1,490.69	906.26	11,817.92
82	Foundations					3,781.23				
83	Basement Construction					4,088.45				
84	SuperStructure	1987				38,118.14	303,471.64			
85	Exterior Enclosure					42,987.84				
86	Roofing					1,087.10				
87	Interior Construction					12,738.01				
88	Stairs					6,522.62				
89	Interior Finishes					17,606.34				
90	Plumbing					7,302.50				
91	HVAC					40,719.10				
92	Fire Protection					5,600.94				
93	Electrical	1991	2017			38,048.61	560,114.75	416,492.74		
94	Equipment					945.31				
95	Furnishings					3,024.98				
96	Foundations	2004	2014			1,726.22	23,607.12	8,240.63		
97	Basement Construction	2014				1,866.47	8,910.18			
98	SuperStructure	2014				17,401.82	83,072.91			
99	Exterior Enclosure	2014				19,624.95	93,685.70			
100	Roofing	2014				496.29	2,369.18			
101	Interior Construction	2014				5,815.20	27,760.63			
102	Stairs	2014				2,977.73	14,215.09			
103	Interior Finishes	2014				8,037.71	38,370.45			
104	Plumbing	2014				3,333.76	15,914.72			
105	HVAC	2014				18,589.22	88,741.32			
106	Fire Protection	2014				2,556.96	12,206.44			
107	Electrical	2014				17,370.08	82,921.37			
108	Equipment	2014				431.55	2,060.16			
109	Furnishings	2014				1,380.98	6,592.51			
110	Foundations	1981	1988	1995	2017	10,278.72	8,085.95	507.44	2,918.03	8,181.38
111	Basement Construction	1981	1988	1995	2017	11,113.87	8,742.94	548.66	3,155.12	8,846.11
112	SuperStructure	1981	1988	1995	2017	103,618.64	81,513.58	5,115.40	29,416.33	82,475.54
113	Exterior Enclosure	1981	1988	1995	2017	116,856.21	91,927.16	5,768.91	33,174.35	93,012.02
114	Roofing	1981	1988	1995	2012	2,955.13	2,324.71	145.89	838.93	11,576.73
115	Interior Construction	1981	1988	1995	2017	34,626.44	27,239.55	1,709.42	9,830.11	27,561.01
116	Stairs	1981	1988	1995	2017	17,730.79	13,948.27	875.33	5,033.60	14,112.87
117	Interior Finishes	1981	1988	1995	2017	47,860.29	37,650.21	2,362.75	13,587.07	38,094.53
118	Plumbing	1981	1988	1995	2017	19,850.78	15,615.99	979.98	5,635.44	15,800.28
119	HVAC	1981	1988	1995	2017	110,688.97	87,075.59	5,464.45	31,423.53	88,103.19
120	Fire Protection	1981	1988	1995	2017	15,225.36	11,977.32	751.64	4,322.33	12,118.66
121	Electrical	1981	1988	1995	2017	103,429.63	81,364.89	5,106.07	29,362.67	82,325.10
122	Equipment	1981	1988	1995	2017	2,569.68	2,021.49	126.86	729.51	2,045.34
123	Furnishings	1981	1988	1995	2017	8,222.98	6,468.76	405.95	2,334.42	6,545.10
124	Foundations	1952	2007			302,649.28	1,292.84	101,958.16		
125	Basement Construction	1952	2007			327,239.54	1,397.88	110,242.26		
126	SuperStructure	1952	2007			2,982,986.98	12,742.52	1,004,925.12		
127	Exterior Enclosure	1952	2007			3,440,744.02	14,697.93	1,159,136.84		
128	Roofing	1952	2007			87,011.67	371.69	29,312.97		
129	Interior Construction	1952	2007			1,019,549.77	4,355.24	343,471.55		
130	Stairs	1952	2007			522,070.01	2,230.14	175,877.83		
131	Interior Finishes	1952	2007			1,409,210.72	6,019.77	474,742.69		
132	Conveying	1952	2007			1,168,982.85	4,993.58	393,813.40		
133	Plumbing	1952	2007			584,491.42	2,496.79	196,906.70		
134	HVAC	1952	2007			3,259,154.45	13,922.23	1,097,961.94		
135	Fire Protection	1952	2007			448,299.25	1,915.01	151,025.53		
136	Electrical	1952	2007	2013		3,045,408.40	13,009.17	1,025,953.99	128,663.84	
137	Equipment	1952	2004			75,662.32	323.21	683,558.13		
138	Furnishings	1952	2007			242,119.43	1,034.27	146,193.74		
139	Foundations	1995	2017			16,633.32	6,714.64	13,062.06		
140	Basement Construction	1995	2017			17,984.78	7,260.21	14,123.36		
141	SuperStructure	1995	2017			167,678.69	67,689.57	131,677.20		
142	Exterior Enclosure	1995	2017			189,100.11	76,337.10	148,499.32		
143	Roofing	1995	2017			4,782.08	1,930.46	3,755.34		
144	Interior Construction	1995	2017			56,033.51	22,619.96	44,002.82		
145	Stairs	1995	2017			28,692.48	11,582.76	22,532.06		
146	Interior Finishes	1995	2017			77,448.92	31,265.06	60,820.23		
147	Plumbing	1995	2017			32,123.11	12,967.66	25,226.11		
148	HVAC	1995	2014			179,120.11	72,308.32	190,829.41		
149	Fire Protection	1995	2017			24,638.11	9,946.07	19,348.18		
150	Electrical	1995	2017			167,372.83	67,566.10	131,437.00		
151	Equipment	1995	2017			4,158.33	1,678.66	3,265.52		
152	Furnishings	1995	2017			13,306.66	5,371.71	10,449.65		
153	Foundations	2016				5,353.42	4,284.04			
154	Basement Construction	2016				5,788.39	4,632.12			
155	SuperStructure	2016				52,764.67	42,224.61			

156	Exterior Enclosure	2016				60,861.72	48,704.23				
157	Roofing	2016				1,539.11	1,231.66				
158	Interior Construction	2016				18,034.34	14,431.87				
159	Stairs	2016				9,234.65	7,389.98				
160	Interior Finishes	2016				24,926.87	19,947.58				
161	Plumbing	2016				10,338.80	8,273.56				
162	Fire Protection	2016				7,929.76	6,345.74				
163	Electrical	2016				53,868.81	43,108.20				
164	Equipment	2016				1,338.36	1,071.01				
165	Furnishings	2016				4,282.74	3,427.24				
166	Foundations	2002	2011			91,488.51	85,543.99	1,448.43			
167	Basement Construction	2002	2011			98,921.95	92,494.44	1,566.12			
168	SuperStructure	2002	2011			922,285.46	862,359.45	14,601.51			
169	Exterior Enclosure	2002	2011			1,040,109.98	972,528.26	16,466.89			
170	Roofing	2002	2011	2017		26,302.95	24,593.90	416.42	159,557.21		
171	Interior Construction	2002	2011			308,201.91	288,176.32	4,879.41			
172	Stairs	2002	2011			157,817.68	147,563.39	2,498.55			
173	Interior Finishes	2002	2011			425,993.37	398,314.21	6,744.27			
174	Plumbing	2002	2011			176,687.18	165,206.83	2,797.29			
175	HVAC	2002	2011	2019		985,216.87	921,201.87	15,597.83	49,347.28		
176	Fire Protection	2002	2011			135,517.35	126,712.04	2,145.49			
177	Electrical	2002	2011			920,603.11	860,786.42	14,574.87			
178	Equipment	2002	2011			22,872.13	21,386.00	362.11			
179	Furnishings	2002	2011			73,190.81	68,435.19	1,158.75			
180	Foundations					1,729.31					
181	SuperStructure					8,698.35					
182	Exterior Enclosure					9,364.61					
183	Roofing					497.18					
184	Interior Construction					4,345.47					
185	Interior Finishes					1,389.51					
186	Plumbing					2,598.40					
187	Electrical					8,698.35					
188	Equipment					36,707.33					
189	Foundations	1997	2017			19,500.53	310.20	116.11			
190	Basement Construction	1997	2017			21,084.94	335.40	125.54			
191	SuperStructure	1997	2017			196,582.64	3,127.06	1,170.50			
192	Exterior Enclosure	1997	2017			221,696.62	3,526.55	1,320.03			
193	Roofing	1997	2017			5,606.40	89.18	33.38			
194	Interior Construction	1997	2017			65,692.40	1,044.98	391.15			
195	Stairs	1997	2017			33,638.41	535.09	200.29			
196	Interior Finishes	1997	2017			90,799.33	1,444.36	540.64			
197	Plumbing	1997	2017			37,660.39	599.07	224.24			
198	HVAC	1997	2017			209,996.30	3,340.44	1,250.37			
199	Fire Protection	1997	2017			28,885.16	459.48	171.99			
200	Electrical	1997	2017			196,224.05	3,121.36	1,168.36			
201	Equipment	1997	2017			4,875.13	77.55	29.03			
202	Furnishings	1997	2017			15,600.42	248.16	92.89			
203	Foundations					3,591.64					
204	SuperStructure					18,065.80					
205	Exterior Enclosure					19,449.56					
206	Roofing					1,032.60					
207	Interior Construction					9,025.21					
208	Interior Finishes					2,885.92					
209	Plumbing					5,396.68					
210	Electrical					18,065.80					
211	Equipment					76,238.30					
212	Foundations	1963	2007	2015		90,600.93	664.68	21,656.47	6,731.96		
213	Basement Construction	1963	2007	2015		97,962.26	718.68	23,416.05	7,278.93		
214	SuperStructure	1963	2007	2015		892,985.46	6,551.21	213,451.54	66,351.83		
215	Exterior Enclosure	1963	2007	2013	2019	1,030,019.37	7,556.53	255,515.24	74,297.14	32,546.29	
216	Roofing	1963	2007	2015		26,047.77	191.09	97,300.03	1,935.44		
217	Interior Construction	1963	2007	2015		305,211.90	2,239.13	72,955.22	22,678.27		
218	Stairs	1963	2007	2015		156,286.61	1,146.57	37,357.40	11,612.62		
219	Interior Finishes	1963	2007	2015		421,860.60	3,094.90	100,837.92	124,525.51		
220	Conveying	1963	2007	2015		349,946.11	2,567.31	83,648.10	26,002.18		
221	Plumbing	1963	2007	2015		174,973.05	1,283.65	41,824.05	13,001.09		
222	HVAC	1963	2007	2015		975,658.81	7,157.72	233,213.07	72,494.74		
223	Fire Protection	1963	2007	2015		134,202.63	984.55	32,078.64	9,971.71		
224	Electrical	1963	2007	2015		911,671.90	6,688.30	217,918.19	78,820.48		
225	Equipment	1963	2007	2015		22,650.23	166.17	5,414.12	1,682.99		
226	Furnishings	1963	2007	2015		72,480.75	531.74	77,062.87	5,385.56		
227	Foundations	2001				79,010.32	92,499.79				
228	SuperStructure	2001				1,159,373.50	1,357,313.90				
229	Roofing	2001				22,715.47	26,593.69				
230	Plumbing	2001				152,649.40	178,711.31				
231	Fire Protection	2001				117,034.04	137,015.32				
232	Electrical	2001				314,406.37	368,085.12				
233	Equipment	2001				119,867.43	140,332.45				

234	Foundations					10,137.13					
235	Basement Construction					10,960.77					
236	SuperStructure					102,191.26					
237	Exterior Enclosure					115,246.47					
238	Roofing					2,914.42					
239	Interior Construction					34,149.45					
240	Stairs					17,486.55					
241	Interior Finishes					47,201.00					
242	Plumbing					19,577.33					
243	HVAC					109,164.20					
244	Fire Protection					15,015.62					
245	Electrical					102,004.85					
246	Equipment					2,534.28					
247	Furnishings					8,109.70					
248	Foundations					4,035.14					
249	SuperStructure					20,296.59					
250	Exterior Enclosure					21,851.23					
251	Roofing					1,160.10					
252	Interior Construction					10,139.66					
253	Interior Finishes					3,242.27					
254	Plumbing					6,063.07					
255	Electrical					20,296.59					
256	Equipment	1992				85,652.31	216,486.08				
257	Foundations	2001	2011			8,307.48	16,525.38	15,037.93			
258	SuperStructure	2001	2011			41,786.33	83,122.08	75,640.29			
259	Exterior Enclosure	2001	2011			44,986.99	89,488.88	81,434.01			
260	Roofing	2001	2011			2,388.40	4,751.05	4,323.41			
261	Interior Construction	2001	2011			20,875.38	41,525.67	37,787.96			
262	Interior Finishes	2001	2011			6,675.14	13,278.31	12,083.13			
263	Plumbing	2001	2011			12,482.56	24,830.51	22,595.52			
264	Electrical	2001	2011			41,786.33	83,122.08	75,640.29			
265	Equipment	2001	2011			176,339.74	350,778.01	319,204.58			
266	Foundations	1984	2013	2017		4,035.14	16,293.18	318.28	414,391.24		
267	SuperStructure	1984	2013			20,296.59	81,954.14	1,600.95			
268	Exterior Enclosure	1984	2013			21,851.23	88,231.48	1,723.58			
269	Roofing	1984	2013			1,160.10	4,684.29	91.51			
270	Interior Construction	1984	2013			10,139.66	40,942.20	799.79			
271	Interior Finishes	1984	2013			3,242.27	13,091.74	255.74			
272	Plumbing	1984	2013			6,063.07	24,481.62	478.24			
273	Electrical	1984	2013			20,296.59	81,954.14	1,600.95			
274	Equipment	1984	2013			85,652.31	533,538.69	6,756.06			
275	Foundations	1987				812.99	1,344.08				
276	SuperStructure	1987				5,589.32	9,240.55				
277	Roofing	1987				508.12	840.05				
278	Electrical	1987				1,016.24	1,680.10				
279	Equipment	1987				2,235.73	3,696.22				
280	Foundations	1974	1998	2010	2016	191,044.22	6,501.49	210,224.54	4,685.63	3,054.09	
281	Basement Construction	1974	1998	2010	2016	206,566.57	7,029.73	227,305.28	5,066.34	3,302.24	
282	SuperStructure	1974	1998	2008	2014	1,608,637.96	54,744.06	4,258,956.86	853,029.11	46,222.44	
283	Exterior Enclosure	1974	1998	2010	2016	1,897,592.35	64,577.56	2,088,105.39	46,541.16	30,335.49	
284	Roofing	1974	1998	2010	2016	54,925.21	1,869.18	60,439.55	119,381.40	878.05	
285	Interior Construction	1974	1998	2010	2016	460,685.78	15,677.74	506,937.36	11,298.98	7,364.66	
286	Stairs	1974	1998	2010	2016	329,551.29	11,215.06	362,637.33	8,082.72	5,268.31	
287	Interior Finishes	1974	1998	2010	2016	706,655.22	24,048.40	777,601.45	17,331.73	11,296.81	
288	Plumbing	1974	1998	2010	2016	277,506.93	9,443.93	305,367.86	6,806.25	4,436.31	
289	Fire Protection	1974	1998	2010	2016	282,984.26	9,630.33	311,395.10	6,940.59	4,523.87	
290	Electrical	1974	1998	2010	2016	916,463.04	31,188.44	10,030,431.67	22,477.56	14,650.86	
291	Equipment	1974	1998	2010	2016	2,059,599.98	70,090.89	2,266,378.13	50,514.63	32,925.39	
292	Furnishings	1974	1998	2010	2016	152,835.38	5,201.19	168,179.63	3,748.51	2,443.27	
293	Foundations	1994	2002	2013		3,184.05	2,544.82	1,776.16	241.15		
294	Basement Construction	1994	2002	2013		3,442.75	2,751.58	1,920.48	260.75		
295	SuperStructure	1994	2002	2013		31,382.78	25,082.36	17,506.32	2,376.86		
296	Exterior Enclosure	1994	2002	2013		36,198.66	28,931.39	20,192.77	2,741.60		
297	Roofing	1994	2002	2013		915.41	731.64	510.65	69.33		
298	Interior Construction	1994	2002	2013		10,726.27	8,572.85	5,983.46	812.38		
299	Stairs	1994	2002	2013		5,492.48	4,389.81	3,063.88	415.99		
300	Interior Finishes	1994	2002	2013		14,825.73	11,849.31	8,270.27	1,122.87		
301	Plumbing	1994	2002	2013		6,149.19	4,914.68	3,430.22	465.73		
302	Fire Protection	1994	2002	2013		4,716.37	3,769.51	2,630.94	357.21		
303	Electrical	1994	2002	2013		32,039.49	25,607.23	17,872.66	2,426.60		
304	Equipment	1994	2002	2013		796.01	636.20	444.04	60.29		
305	Furnishings	1994	2002	2013		2,547.24	2,035.85	1,420.93	192.92		
306	Foundations					1,698.13					
307	Basement Construction					1,836.10					
308	SuperStructure					16,737.19					
309	Exterior Enclosure					19,305.61					
310	Roofing					488.21					
311	Interior Construction					5,720.57					

312	Stairs						2,929.27					
313	Interior Finishes						7,906.91					
314	Plumbing						3,279.51					
315	Fire Protection						2,515.35					
316	Electrical						17,087.43					
317	Equipment						424.53					
318	Furnishings						1,358.50					
319	Foundations						2,761.91					
320	Basement Construction						2,986.31					
321	SuperStructure						27,842.49					
322	Exterior Enclosure						31,399.44					
323	Roofing						794.05					
324	Interior Construction						9,304.18					
325	Stairs						4,764.29					
326	Interior Finishes						12,860.13					
327	Plumbing						5,333.93					
328	HVAC						29,742.30					
329	Fire Protection						4,091.08					
330	Electrical						27,791.70					
331	Equipment						690.48					
332	Furnishings						2,209.53					
333	Foundations						4,035.14					
334	SuperStructure						20,296.59					
335	Exterior Enclosure						21,851.23					
336	Roofing						1,160.10					
337	Interior Construction						10,139.66					
338	Interior Finishes						3,242.27					
339	Plumbing						6,063.07					
340	Electrical						20,296.59					
341	Equipment	1983					85,652.31	184,346.31				
342	Foundations	1974	1996	2010			224,929.36	113,208.79	110,919.59	134,379.33		
343	Basement Construction	1974	1996	2010			243,204.87	122,407.00	119,931.81	40,321.18		
344	SuperStructure	1974	1996	2010	2016		2,216,960.01	1,115,814.10	1,093,251.23	629,431.87	440,789.03	
345	Exterior Enclosure	1974	1996	2010			2,557,165.67	1,287,042.39	1,261,017.11	423,955.05		
346	Roofing	1974	1996	2010			64,667.19	32,547.53	31,889.38	693,241.42		
347	Interior Construction	1974	1996	2010			757,730.78	381,372.10	373,660.38	125,624.94		
348	Stairs	1974	1996	2010			388,003.15	195,285.16	191,336.30	64,327.43		
349	Interior Finishes	1974	1996	2010			1,047,327.34	527,128.41	516,469.35	173,637.44		
350	Conveying	1974	1996	2010			868,789.66	437,268.94	428,426.92	144,037.50		
351	Plumbing	1974	1996	2010			434,394.83	218,634.47	214,213.46	72,018.75		
352	HVAC	1974	1996	2005	2011	2017	2,422,208.05	1,219,117.12	1,194,465.36	231,156.80	826,216.29	
353	Fire Protection	1974	1996	2010			333,176.62	167,690.52	164,299.65	55,237.68		
354	Electrical	1974	1996	2010	2016		2,263,351.69	1,139,163.42	1,116,128.40	711,896.57	6,336.56	
355	Equipment	1974	1996	2006	2012		56,232.34	28,302.20	27,729.90	57,060.00	468,940.10	
356	Furnishings	1974	1996	2010			179,943.49	90,567.03	88,735.67	29,833.01		
357	Foundations						949.39					
358	SuperStructure						4,775.39					
359	Exterior Enclosure						5,141.17					
360	Roofing						272.95					
361	Interior Construction						2,385.66					
362	Interior Finishes						762.84					
363	Plumbing						1,426.52					
364	Electrical						4,775.39					
365	Equipment	1999					20,152.32	107,151.59				
366	Foundations						12,311.65					
367	SuperStructure						121,346.69					
368	Exterior Enclosure						139,968.06					
369	Roofing						3,539.60					
370	Interior Construction						41,474.87					
371	Interior Finishes						57,326.11					
372	Plumbing						23,776.87					
373	Fire Protection	1999					18,236.63	2,177.63				
374	Electrical	1999					123,885.96	9,947.41				
375	Equipment	1999					3,077.91	9,947.41				
376	Furnishings	1999					9,849.32	9,947.41				
377	Foundations	2000					34,523.98	85,752.06				
378	Basement Construction	2000					37,329.05	92,719.41				
379	SuperStructure	2000					348,032.35	864,456.95				
380	Exterior Enclosure	2000					392,494.44	974,893.72				
381	Roofing	2000					9,925.64	24,653.72				
382	Interior Construction	2000					116,302.64	288,877.25				
383	Stairs	2000					59,553.86	147,922.30				
384	Interior Finishes	2000					160,752.26	399,283.02				
385	Plumbing	2000					66,674.43	165,608.66				
386	HVAC	2000					371,780.06	923,442.48				
387	Fire Protection	2000					51,138.64	127,020.24				
388	Electrical	2000					347,397.50	862,880.09				
389	Equipment	2000					8,630.99	21,438.01				

390	Furnishings	2000						27,619.18	68,601.65			
391	Foundations							3,345.71				
392	SuperStructure							32,976.13				
393	Exterior Enclosure							38,036.52				
394	Roofing							961.89				
395	Interior Construction							11,270.85				
396	Interior Finishes							15,578.45				
397	Plumbing							6,461.40				
398	Fire Protection							4,955.83				
399	Electrical							33,666.18				
400	Equipment							836.43				
401	Furnishings							2,676.57				
402	Foundations							142.15				
403	SuperStructure							1,462.07				
404	Roofing							101.53				
405	Equipment							162.45				
406	Furnishings							162.45				
407	Foundations	1997						3,576.37	2,282.36			
408	SuperStructure	1997						8,940.93	5,705.91			
409	Roofing	1997						5,364.56	3,423.55			
410	Foundations	1999						112.75	2,899.56			
411	SuperStructure	1999						1,111.29	28,578.76			
412	Exterior Enclosure	1999						1,281.82	32,964.33			
413	Roofing	1999						32.42	833.62			
414	Interior Construction	1999						379.82	9,767.88			
415	Interior Finishes	1999						524.99	13,501.06			
416	Plumbing	1999						217.75	5,599.77			
417	Fire Protection	1999						167.01	4,294.97			
418	Electrical	1999						1,134.54	29,176.79			
419	Equipment	1999						28.19	724.89			
420	Furnishings	1999						90.20	2,319.65			
421	Foundations							1,352.92				
422	SuperStructure							13,334.69				
423	Exterior Enclosure							15,380.98				
424	Roofing							388.96				
425	Interior Construction							4,557.64				
426	Interior Finishes							6,299.52				
427	Plumbing							2,612.82				
428	Fire Protection							2,004.01				
429	Electrical							13,613.73				
430	Equipment							338.23				
431	Furnishings							1,082.33				
432	Foundations	2016						4,130.01	265.20			
433	SuperStructure	2016						20,773.80	1,333.94			
434	Exterior Enclosure	2016						22,364.98	1,436.11			
435	Roofing	2016						1,187.38	76.24			
436	Interior Construction	2016						10,378.06	666.40			
437	Interior Finishes	2016						3,318.50	213.09			
438	Plumbing	2016						6,205.62	398.48			
439	Electrical	2016						20,773.80	1,333.94			
440	Equipment	1991	2016					87,666.13	216,381.71	5,629.26		
441	Foundations	2016						31,927.51	31,927.51			
442	Basement Construction	2016						34,521.62	34,521.62			
443	SuperStructure	2016						321,857.64	321,857.64			
444	Exterior Enclosure	2016						362,975.85	362,975.85			
445	Roofing	2016						9,179.16	9,179.16			
446	Interior Construction	2016						107,555.79	107,555.79			
447	Stairs	2016						55,074.95	55,074.95			
448	Interior Finishes	2016						148,662.46	148,662.46			
449	Plumbing	2016						61,660.00	61,660.00			
450	HVAC	2016						343,819.34	343,819.34			
451	Fire Protection	2016						47,292.62	47,292.62			
452	Electrical	2016						321,270.54	321,270.54			
453	Equipment	2016						7,981.88	7,981.88			
454	Furnishings							25,542.01				

Asset ID	Sidewalk Section Name	A	B	C	D	E	F	G	H	I	J	K
1	anonymized information	1962						3,295.00	3,015.09			
2	anonymized information	1962						5,633.67	6,467.67			
3	anonymized information	1962						6,859.98	6,725.61			
4	anonymized information	1962						8,265.21	7,347.42			
5	anonymized information	1962						9,680.65	12,992.15			
6	anonymized information	1962	1996	1998				50,794.94	34,120.34	62,475.92		
7	anonymized information	1962	1998	2000				14,577.92	6,016.68	3,245.66		
8	anonymized information	1967	1997	1999				26,445.15	11,246.68	28,702.12		
9	anonymized information	1967						8,542.89	3,449.45			
10	anonymized information	1967						9,059.28	3,326.47			
11	anonymized information	1967						24,200.43	9,430.78			

12	anonymized information	1967						13,310.12	5,725.51		
13	anonymized information	1962						13,287.52	5,990.61		
14	anonymized information	1972						21,133.65	24,445.18		
15	anonymized information	1967						27,789.16	43,679.47		
16	anonymized information	1967	2008	2010				9,780.13	5,787.90	8,737.11	
17	anonymized information	1972						13,097.35	14,409.47		
18	anonymized information	1972						2,733.36	2,722.95		
19	anonymized information	1972						6,617.76	14,305.59		
20	anonymized information	1972						21,290.88	23,540.18		
21	anonymized information	1972						26,913.62	44,098.15		
22	anonymized information	1972						26,959.62	25,193.73		
23	anonymized information	1967						44,159.54	72,852.86		
24	anonymized information	1962						8,717.41	3,848.31		
25	anonymized information	1967	2009	2011				4,897.27	2,616.02	4,259.37	
26	anonymized information	1972						10,697.42	13,682.90		
27	anonymized information	1962	2009	2011				2,050.02	2,540.23	1,677.29	
28	anonymized information	1967	2011	2013				12,527.90	15,879.74	11,161.76	
29	anonymized information	1967	2011	2013				10,777.38	15,421.95	10,839.98	
30	anonymized information	1992						10,363.99	10,806.68		
31	anonymized information	1982						19,091.76	54,128.87		
32	anonymized information	1982						2,235.49	564.51		
33	anonymized information	1967	2015	2017				2,888.19	2,292.50	3,965.76	
34	anonymized information	1967	2015	2017				9,429.19	6,527.61	11,292.03	
35	anonymized information	1967	2015	2017				9,452.87	6,793.99	11,752.83	
36	anonymized information	1967	2015	2017				32,230.87	24,450.76	42,297.06	
37	anonymized information	1982						10,591.77	9,623.64		
38	anonymized information	1992						9,225.09	10,012.42		
39	anonymized information	1967	2016	2018				43,491.36	18,330.62	32,236.61	
40	anonymized information	1987						3,459.65	3,114.89		
41	anonymized information	1987						3,355.63	2,944.06		
42	anonymized information	1987						12,527.90	11,023.09		
43	anonymized information	1987						4,646.30	3,674.36		
44	anonymized information	1992						6,409.96	6,006.87		
45	anonymized information	1992						5,709.34	5,350.31		
46	anonymized information	1992						8,004.79	7,501.41		
47	anonymized information	1992						8,404.88	7,876.34		
48	anonymized information	1992						15,864.80	10,012.42		
49	anonymized information	1992						14,106.16	10,012.42		
50	anonymized information	1992						6,833.40	10,012.42		
51	anonymized information	1967	2018	2020				12,579.51	4,629.54	5,874.45	
52	anonymized information	1962	2018	2020				22,696.28	12,014.59	18,607.32	

Asset ID	Park Asset Name	A	B	C	D	E	F	G	H	I	J	K
1	anonymized information	2011						3,546.68				
2	anonymized information	1992	2017					19,559.58	18,915.64			
3	anonymized information							1,708.35				
4	anonymized information	2014						4,137.80				
5	anonymized information	2020						5,911.14				
6	anonymized information							20,024.01				
7	anonymized information							5,899.14				
8	anonymized information							170.84				
9	anonymized information							11,389.00				
10	anonymized information	2020						16,551.19				
11	anonymized information	2002						3,635.25				
12	anonymized information							20,024.01				
13	anonymized information	2013						767.33				
14	anonymized information	1992	2015					19,559.58	18,915.64			
15	anonymized information							4,304.52				
16	anonymized information							34,167.00				
17	anonymized information							22,778.00				
18	anonymized information	2017						8,866.71				
19	anonymized information	2011						5,911.14				
20	anonymized information	1995						10,983.10				
21	anonymized information							20,024.01				
22	anonymized information	1992						10,814.70				
23	anonymized information	1986	2004					19,618.92	18,915.64			
24	anonymized information							1,708.35				
25	anonymized information	2006						5,911.14				
26	anonymized information	2016						13,171.74				
27	anonymized information	2007	2020					16,089.18	16,089.18			
28	anonymized information							20,024.01				
29	anonymized information							5,899.14				
30	anonymized information	2017						16,551.19				
31	anonymized information	1998						5,911.14				
32	anonymized information	2020						8,275.59				
33	anonymized information							20,024.01				
34	anonymized information							5,899.14				
35	anonymized information	2020						18,915.64				

36	anonymized information	2020		7,093.37		
37	anonymized information	2002		4,728.91		
38	anonymized information	2013		2,955.57		
39	anonymized information			20,024.01		
40	anonymized information	2004		6,425.10		
41	anonymized information	2019		5,911.14		
42	anonymized information			1,138.90		
43	anonymized information			170.84		
44	anonymized information	2020		8,275.59		
45	anonymized information			20,024.01		
46	anonymized information			5,899.14		
47	anonymized information	2020		5,911.14		
48	anonymized information			170.84		
49	anonymized information			1,708.35		
50	anonymized information	1986	2004	19,618.92	18,915.64	
51	anonymized information	2000		1,324.86		
52	anonymized information			20,024.01		
53	anonymized information	1999		9,591.15		
54	anonymized information			113,890.00		
55	anonymized information			11,389.00		
56	anonymized information	2020		5,911.14		
57	anonymized information			1,138.90		
58	anonymized information			20,024.01		
59	anonymized information	1978		1,643.56		
60	anonymized information			11,389.00		
61	anonymized information	2018		16,551.19		
62	anonymized information	2018		5,911.14		
63	anonymized information			170.84		
64	anonymized information			1,708.35		
65	anonymized information			20,024.01		
66	anonymized information	2005		2,418.91		
67	anonymized information	1973	2001	16,551.19	16,551.19	
68	anonymized information	2020		5,911.14		
69	anonymized information	2009		8,275.59		
70	anonymized information	2020		16,551.19		
71	anonymized information			4,304.52		
72	anonymized information	1985	2007	2,955.57	2,955.57	
73	anonymized information	1978		15,468.79		
74	anonymized information	1993		4,429.14		
75	anonymized information	2017		16,551.19		
76	anonymized information	2017		5,911.14		
77	anonymized information			34,167.00		
78	anonymized information			4,304.52		
79	anonymized information			1,138.90		
80	anonymized information			1,138.90		
81	anonymized information			1,138.90		
82	anonymized information			1,138.90		
83	anonymized information			170.84		
84	anonymized information			1,138.90		
85	anonymized information			170.84		
86	anonymized information			22,778.00		
87	anonymized information			1,708.35		
88	anonymized information			1,708.35		
89	anonymized information			113,890.00		
90	anonymized information			20,024.01		
91	anonymized information			5,899.14		
92	anonymized information	2013		5,911.14		
93	anonymized information			1,708.35		
94	anonymized information	2003	2013	16,629.09	16,551.19	
95	anonymized information	2007		4,728.91		
96	anonymized information	2007		2,955.57		
97	anonymized information	2011		8,275.59		
98	anonymized information			170.84		
99	anonymized information	1994		28,471.01		
100	anonymized information			20,024.01		
101	anonymized information	1990	2010	6,022.70	5,788.19	
102	anonymized information	2020		5,911.14		
103	anonymized information			20,024.01		
104	anonymized information			5,899.14		
105	anonymized information			1,138.90		
106	anonymized information	2020		4,728.91		
107	anonymized information			170.84		
108	anonymized information			1,708.35		
109	anonymized information	1983	2002	4,262.08	4,137.80	
110	anonymized information			20,024.01		
111	anonymized information			5,899.14		
112	anonymized information			34,167.00		
113	anonymized information	2017		16,551.19		

114	anonymized information	2017		4,728.91	
115	anonymized information			20,024.01	
116	anonymized information			5,899.14	
117	anonymized information	1995	2007	17,184.39	16,551.19
118	anonymized information			34,167.00	
119	anonymized information			22,778.00	
120	anonymized information			20,024.01	
121	anonymized information			5,899.14	
122	anonymized information	2020		4,728.91	
123	anonymized information	2019		16,551.19	
124	anonymized information			20,024.01	
125	anonymized information			5,899.14	
126	anonymized information	2016		16,551.19	
127	anonymized information	2014		4,728.91	
128	anonymized information	2020		9,457.82	
129	anonymized information	2011		8,275.59	
130	anonymized information	2011		2,955.57	
131	anonymized information	2014		16,551.19	
132	anonymized information	1980	1988	20,521.69	13,863.58
133	anonymized information	1978		31,904.39	
134	anonymized information			5,899.14	
135	anonymized information	2020		4,728.91	
136	anonymized information			1,138.90	
137	anonymized information	1993		16,616.57	
138	anonymized information			5,899.14	
139	anonymized information	1985	1990	35,443.63	35,443.63
140	anonymized information	2011		16,551.19	
141	anonymized information			170.84	
142	anonymized information	2011		8,275.59	
143	anonymized information			1,708.35	
144	anonymized information	2020		5,911.14	
145	anonymized information	1985		69,913.63	
146	anonymized information			20,024.01	
147	anonymized information			5,899.14	
148	anonymized information	2003	2016	8,314.54	8,275.59
149	anonymized information	2015		16,551.19	
150	anonymized information	2020		5,911.14	
151	anonymized information			170.84	
152	anonymized information			1,708.35	
153	anonymized information	2013		3,546.68	
154	anonymized information			113,890.00	
155	anonymized information			11,389.00	
156	anonymized information	2009		4,137.80	
157	anonymized information			20,024.01	
158	anonymized information			5,899.14	
159	anonymized information			1,708.35	
160	anonymized information			1,708.35	
161	anonymized information	2014		5,911.14	
162	anonymized information			170.84	
163	anonymized information			20,024.01	
164	anonymized information			5,899.14	
165	anonymized information	2007		16,551.19	
166	anonymized information	1997		5,723.17	
167	anonymized information	2020		7,093.37	
168	anonymized information	1991	2007	8,275.59	8,275.59
169	anonymized information	2013		3,546.68	
170	anonymized information			26,902.84	
171	anonymized information	1991	2007	129,214.56	129,214.56
172	anonymized information			20,024.01	
173	anonymized information	1997		6,353.39	
175	anonymized information	2006		3,191.90	
176	anonymized information			1,138.90	
177	anonymized information	2006		4,323.36	
178	anonymized information	2014		14,808.97	
179	anonymized information			170.84	
180	anonymized information	2011		16,551.19	
181	anonymized information			1,138.90	
182	anonymized information	2020		5,911.14	
183	anonymized information	2008		4,728.91	
184	anonymized information	2014		3,546.68	
185	anonymized information	2000		3,356.31	
186	anonymized information			20,024.01	
187	anonymized information			5,899.14	
188	anonymized information	1999		7,800.52	
189	anonymized information	1999		3,361.39	
190	anonymized information			20,024.01	
191	anonymized information			5,899.14	
192	anonymized information			34,167.00	

193	anonymized information			22,778.00	
194	anonymized information	2009		16,551.19	
195	anonymized information			113.89	
196	anonymized information			113.89	
197	anonymized information	2006		7,025.40	
198	anonymized information			1,708.35	
199	anonymized information			170.84	
200	anonymized information	2013		5,911.14	
201	anonymized information			11,389.00	
202	anonymized information			170.84	
203	anonymized information			34,167.00	
204	anonymized information			34,167.00	
205	anonymized information	2020		4,137.80	
206	anonymized information	2020		4,137.80	
207	anonymized information			20,024.01	
208	anonymized information	2004		6,375.00	
209	anonymized information			1,138.90	
210	anonymized information	2020		5,911.14	
211	anonymized information			1,708.35	
212	anonymized information			4,304.52	
213	anonymized information			170.84	
214	anonymized information			20,024.01	
215	anonymized information			5,899.14	
216	anonymized information			11,389.00	
217	anonymized information			170.84	
218	anonymized information			1,708.35	
219	anonymized information	2015		10,640.05	
220	anonymized information	1986	2015	36,785.47	35,466.83
221	anonymized information			34,167.00	
222	anonymized information			4,304.52	
223	anonymized information			1,708.35	
224	anonymized information			20,024.01	
225	anonymized information			5,899.14	
226	anonymized information	1992	2016	19,559.58	18,915.64
227	anonymized information	2020		7,093.37	
228	anonymized information			34,167.00	
229	anonymized information	2011		2,955.57	
230	anonymized information	2009		8,275.59	
231	anonymized information			20,024.01	
232	anonymized information	1994		7,496.79	
233	anonymized information			1,708.35	
234	anonymized information			1,708.35	
235	anonymized information			1,708.35	
236	anonymized information	2002		5,911.14	
237	anonymized information			1,138.90	
238	anonymized information	1988	2002	16,795.95	16,551.19
239	anonymized information	1992	2013	19,559.58	18,915.64
240	anonymized information	1982	1998	3,546.68	3,546.68
241	anonymized information			4,304.52	
242	anonymized information	2009		8,275.59	
243	anonymized information	2007		8,275.59	
244	anonymized information	2007		3,546.68	
245	anonymized information	1977		14,018.19	
246	anonymized information			20,024.01	
247	anonymized information	1992		8,975.65	
248	anonymized information	1992	2019	19,559.58	18,915.64
249	anonymized information	2019		5,911.14	
250	anonymized information	1992	2008	31,481.06	31,481.06
251	anonymized information	2011		16,551.19	
252	anonymized information	2020		5,911.14	
253	anonymized information	1997		5,911.14	
254	anonymized information	2004		3,316.70	
255	anonymized information			20,024.01	
256	anonymized information	2013		5,754.98	
257	anonymized information	1987	2007	19,492.38	18,915.64
258	anonymized information	1995		7,364.74	
259	anonymized information			1,708.35	
260	anonymized information	2013		3,546.68	
261	anonymized information	2007		8,275.59	
262	anonymized information	2010		3,546.68	
263	anonymized information	2007		3,546.68	
264	anonymized information			20,024.01	
265	anonymized information	1992		9,195.24	
266	anonymized information	2020		16,551.19	
267	anonymized information	2018		5,911.14	
268	anonymized information			170.84	
269	anonymized information			1,708.35	
270	anonymized information	2011		3,546.68	

271	anonymized information			20,024.01	
272	anonymized information	2008		5,088.43	
273	anonymized information	2015		16,551.19	
274	anonymized information	2020		5,911.14	
275	anonymized information			1,708.35	
276	anonymized information	2009		8,275.59	
277	anonymized information			4,304.52	
278	anonymized information			20,024.01	
279	anonymized information	1985	2010	3,433.19	3,433.19
280	anonymized information			11,389.00	
281	anonymized information	2019		7,093.37	
282	anonymized information	1992	2011	19,559.58	18,915.64
283	anonymized information			11,131.30	
284	anonymized information			1,708.35	
285	anonymized information			1,708.35	
286	anonymized information	2011		8,275.59	
287	anonymized information			20,024.01	
288	anonymized information			5,899.14	
289	anonymized information			1,138.90	
290	anonymized information	1998		5,911.14	
291	anonymized information	2007		4,728.91	
292	anonymized information			20,024.01	
293	anonymized information			5,899.14	
294	anonymized information			1,708.35	
295	anonymized information	2002		5,911.14	
296	anonymized information	2008		4,728.91	
297	anonymized information			170.84	
298	anonymized information	1989	2002	20,956.01	16,551.19
299	anonymized information			4,304.52	
300	anonymized information	2002		4,137.80	
301	anonymized information	2008		3,546.68	
302	anonymized information	2020		4,137.80	
303	anonymized information			911.12	
304	anonymized information	2002		3,546.68	
305	anonymized information			113,890.00	
306	anonymized information			4,304.52	
307	anonymized information			22,778.00	
308	anonymized information			11,131.30	
309	anonymized information			1,138.90	
310	anonymized information			11,389.00	
311	anonymized information			11,389.00	
312	anonymized information			11,389.00	
313	anonymized information			20,024.01	
314	anonymized information	2004		6,713.17	
315	anonymized information	2011		16,551.19	
316	anonymized information	2011		5,911.14	
317	anonymized information			170.84	
318	anonymized information			4,304.52	
319	anonymized information			34,167.00	
320	anonymized information			34,167.00	
321	anonymized information			20,024.01	
322	anonymized information			5,899.14	
323	anonymized information	2007		16,551.19	
324	anonymized information	1993	2000	4,728.91	4,728.91
325	anonymized information	2007		5,911.14	
326	anonymized information			1,138.90	
327	anonymized information	2007		4,137.80	
328	anonymized information	2002		16,551.19	
329	anonymized information	1998		3,546.68	
330	anonymized information	2002		4,137.80	
331	anonymized information	2003		6,717.84	
332	anonymized information	1988	2015	16,250.69	16,250.69
333	anonymized information			20,024.01	
334	anonymized information	2005		6,809.63	
335	anonymized information	2018		101,828.82	
336	anonymized information	2018		17,323.18	
337	anonymized information	2018		8,748.49	
338	anonymized information	2018		3,724.02	
339	anonymized information	2018		3,546.68	
340	anonymized information	2016		219,018.75	
341	anonymized information			56,945.00	
342	anonymized information			11,389.00	
343	anonymized information			2,277.80	
344	anonymized information			11,389.00	
345	anonymized information			11,389.00	
346	anonymized information			11,131.30	
347	anonymized information			11,131.30	
348	anonymized information	2015		4,728.91	

349	anonymized information							170.84				
350	anonymized information	2015						16,551.19				
351	anonymized information	2000						1,335.63				
352	anonymized information							20,024.01				
353	anonymized information							5,899.14				
354	anonymized information	2020						16,551.19				
355	anonymized information	2006						5,911.14				
356	anonymized information	2006						4,137.80				
357	anonymized information							4,304.52				
358	anonymized information							20,024.01				
359	anonymized information							5,899.14				
360	anonymized information	1997						29,956.44				
361	anonymized information							11,389.00				
362	anonymized information	2014						5,911.14				
363	anonymized information	2011						16,551.19				
364	anonymized information							1,708.35				
365	anonymized information	1990						46,284.25				
366	anonymized information							5,899.14				
367	anonymized information							1,708.35				
368	anonymized information	2013						5,911.14				
369	anonymized information	1988	2001					16,795.95	16,551.19			
370	anonymized information	2013						3,546.68				
371	anonymized information							20,024.01				
372	anonymized information							5,899.14				
373	anonymized information	2013						16,551.19				
374	anonymized information	1990						6,995.13				
375	anonymized information	2020						4,137.80				
376	anonymized information	2011						3,546.68				
377	anonymized information							1,708.35				
378	anonymized information	1988	1997					13,612.10	8,860.94			
379	anonymized information	1994						22,134.57				
380	anonymized information							5,899.14				
381	anonymized information	2020						5,911.14				
382	anonymized information							20,024.01				
383	anonymized information							5,899.14				
384	anonymized information	1999						4,822.33				
385	anonymized information							22,778.00				
386	anonymized information							34,167.00				
387	anonymized information							34,167.00				
388	anonymized information	2018						16,551.19				
389	anonymized information	2020						5,911.14				
390	anonymized information							20,024.01				
391	anonymized information	2005						6,440.78				
392	anonymized information	2013						16,551.19				
393	anonymized information							170.84				
394	anonymized information							4,304.52				
395	anonymized information							1,708.35				
396	anonymized information							1,708.35				
397	anonymized information	2020						5,911.14				
398	anonymized information	1989						20,143.46				
399	anonymized information							5,899.14				
400	anonymized information	1986	2019					29,428.38	28,373.47			
401	anonymized information	2019						5,911.14				
402	anonymized information	2011						3,546.68				
403	anonymized information	2002						3,546.68				
404	anonymized information							20,024.01				
405	anonymized information	1982						3,305.29				
406	anonymized information	2013						678,470.65				
407	anonymized information	2007						3,461.97				
408	anonymized information	2000	2006					84,826.93	22,136.94			
409	anonymized information	1991						15,217.02				
410	anonymized information	1990						1,615.17				

Asset ID	Creek Name	A	B	C	D	E	F	G	H	I	J	K
1	anonymized information	2008	2022					934,985.18	92,964.91	1,484,732.68		
2	anonymized information	2000	2017					396,100.93	46,690.06	405,582.13		
3	anonymized information	2008	2018					611,611.23	5,965.47	550,673.53		
4	anonymized information	2008	2016					2,048,312.35	19,978.61	1,097,828.81		
5	anonymized information	2009	2019					102,097.52	435,252.90	42,075.51		
6	anonymized information	2003	2021					797,681.55	93,637.64	208,652.29		
7	anonymized information	2000	2021					1,076,936.62	139,549.01	281,698.00		
8	anonymized information	2003	2021					998,796.73	86,843.52	261,258.68		
9	anonymized information	2004	2017					1,185,015.09	171,422.76	242,753.69		
10	anonymized information	2004	2017					1,203,838.98	174,145.80	246,609.81		
11	anonymized information	2004	2017					707,480.09	102,343.16	144,929.29		
12	anonymized information	2004	2017					518,111.31	74,949.32	106,136.56		
13	anonymized information	2004	2015					1,786,663.71	300,756.79	347,975.77		
14	anonymized information	2004	2014					2,428,718.58	38,248.44	403,763.94		

15	anonymized information	2004	2014	1,602,354.82	25,234.53	266,384.54
16	anonymized information	2004	2014	1,461,451.71	23,015.53	242,960.01
17	anonymized information	2004	2014	746,915.66	11,762.73	124,171.49
18	anonymized information	2004	2014	706,218.63	11,121.82	117,405.79
19	anonymized information	2004	2014	370,006.28	5,827.01	61,511.94
20	anonymized information	2009	2021	478,618.45	126,562.09	49,633.26
21	anonymized information	2004	2015	973,590.90	163,888.74	86,993.94
22	anonymized information	2004	2012	1,743,009.26	27,449.61	110,926.32
23	anonymized information	2001	2011	533,121.12	98,212.68	19,600.52
24	anonymized information	2001	2011	488,496.82	89,991.90	17,959.88
25	anonymized information	2001	2011	162,209.99	29,882.66	5,963.75
26	anonymized information	2001	2012	1,051,902.46	77,101.55	30,953.46
27	anonymized information	2022		1,754,855.69	1,846,767.35	
28	anonymized information	2008		2,091,271.18	587,020.69	
29	anonymized information	2008		1,929,812.43	526,295.74	
30	anonymized information	2008		1,445,923.80	482,242.75	
31	anonymized information	2001		1,730,326.73	477,562.58	
32	anonymized information	2015		2,108,423.17	452,963.05	
33	anonymized information	2003		675,486.72	447,277.09	
34	anonymized information	2008		2,109,372.65	356,361.91	
35	anonymized information	2002		450,896.90	312,555.26	
36	anonymized information	2009		1,608,193.63	312,366.30	
37	anonymized information	2019		905,637.21	306,626.99	
38	anonymized information	2009		917,626.46	287,159.49	
39	anonymized information	2009		633,387.07	261,908.11	
40	anonymized information	2009		1,249,344.57	245,570.64	
41	anonymized information	2004		1,377,251.28	231,838.63	
42	anonymized information	2007		1,914,294.77	230,511.99	
43	anonymized information	2019		593,061.05	200,796.22	
44	anonymized information	2019		541,123.48	183,211.41	
45	anonymized information	2008		794,206.78	160,133.26	
46	anonymized information	2012		715,241.44	151,749.63	
47	anonymized information	2008		885,010.04	149,515.48	
48	anonymized information	2019		439,902.38	148,940.37	
49	anonymized information	2009		733,895.51	144,254.19	
50	anonymized information	2011		485,402.53	144,135.40	
51	anonymized information	2017		1,427,496.62	136,668.00	
52	anonymized information	2009		616,769.73	133,855.45	
53	anonymized information	2012		579,325.64	122,912.97	
54	anonymized information	2000		1,036,013.69	122,119.23	
55	anonymized information	2008		2,687,303.65	107,800.32	
56	anonymized information	2012		610,889.15	100,765.13	
57	anonymized information	2019		237,656.02	97,940.66	
58	anonymized information	2004		275,542.39	79,552.37	
59	anonymized information	2004		470,996.75	79,284.91	
60	anonymized information	2004		519,799.86	75,193.58	
61	anonymized information	2006		243,650.02	74,107.79	
62	anonymized information	2012		242,252.17	71,918.64	
63	anonymized information	2008		404,199.61	68,286.34	
64	anonymized information	2020		312,219.85	67,529.96	
65	anonymized information	2009		365,495.01	66,309.17	
66	anonymized information	2019		359,422.36	65,160.00	
67	anonymized information	2007		239,642.09	64,884.86	
68	anonymized information	2010		219,516.36	64,710.23	
69	anonymized information	2003		210,821.83	63,364.25	
70	anonymized information	2002		209,324.44	53,519.74	
71	anonymized information	2021		185,213.08	48,446.82	
72	anonymized information	2015		207,102.77	46,842.16	
73	anonymized information	2014		201,085.56	46,548.55	
74	anonymized information	2013		199,736.79	46,449.79	
75	anonymized information	2005		156,744.30	45,310.97	
76	anonymized information	2016		155,246.34	44,223.70	
77	anonymized information	2008		1,098,399.69	44,061.95	
78	anonymized information	2001		747,420.03	44,058.03	
79	anonymized information	2004		232,298.44	33,603.99	
80	anonymized information	2021		116,551.81	30,486.86	
81	anonymized information	2009		113,539.49	29,626.69	
82	anonymized information	2004		191,840.19	27,751.36	
83	anonymized information	2011		832,571.94	26,982.12	
84	anonymized information	2004		177,620.88	25,694.41	
85	anonymized information	2004		176,825.97	25,579.42	
86	anonymized information	2012		93,028.50	24,415.08	
87	anonymized information	2008		592,131.72	23,753.17	
88	anonymized information	2008		180,714.50	17,426.57	
89	anonymized information	2014		480,759.94	15,445.88	
90	anonymized information	2004		94,739.49	13,704.89	
91	anonymized information	2008		1,384,091.24	13,500.00	
92	anonymized information	2008		170,794.78	13,500.00	

93	anonymized information	2012	425,751.36	12,528.23
94	anonymized information	2008	91,211.80	11,980.01
95	anonymized information	2008	96,658.24	9,496.11
96	anonymized information	2008	236,288.53	9,478.64
97	anonymized information	2014	212,597.43	7,054.41
98	anonymized information	2008	124,363.78	4,988.81
99	anonymized information		393,800.09	-
100	anonymized information		361,710.71	-
101	anonymized information		3,586,797.02	
102	anonymized information		3,443,588.54	
103	anonymized information		3,223,284.88	
104	anonymized information		3,117,795.27	
105	anonymized information		2,580,862.46	
106	anonymized information		2,442,344.09	
107	anonymized information		2,130,395.57	
108	anonymized information		2,106,978.51	
109	anonymized information		1,884,202.30	
110	anonymized information		1,871,853.76	
111	anonymized information		1,855,300.44	
112	anonymized information		1,836,211.91	
113	anonymized information		1,824,967.64	
114	anonymized information		1,739,694.59	
115	anonymized information		1,645,452.54	
116	anonymized information		1,609,563.78	
117	anonymized information		1,496,136.38	
118	anonymized information		1,449,939.01	
119	anonymized information		1,383,578.29	
120	anonymized information		1,345,712.56	
121	anonymized information		1,296,527.51	
122	anonymized information		1,296,057.86	
123	anonymized information		1,276,568.92	
124	anonymized information		1,275,200.07	
125	anonymized information		1,233,739.42	
126	anonymized information		1,209,222.22	
127	anonymized information		1,168,666.53	
128	anonymized information		1,153,694.39	
129	anonymized information		1,116,725.73	
130	anonymized information		1,102,998.24	
131	anonymized information		1,046,863.89	
132	anonymized information		941,500.27	
133	anonymized information		936,139.60	
134	anonymized information		900,838.52	
135	anonymized information		898,032.85	
136	anonymized information		886,489.65	
137	anonymized information		803,932.98	
138	anonymized information		800,259.82	
139	anonymized information		797,495.34	
140	anonymized information		741,591.15	
141	anonymized information		727,891.19	
142	anonymized information		709,929.56	
143	anonymized information		704,342.27	
144	anonymized information		701,921.11	
145	anonymized information		687,251.88	
146	anonymized information		687,251.88	
147	anonymized information		686,852.17	
148	anonymized information		645,302.86	
149	anonymized information		628,867.32	
150	anonymized information		621,753.92	
151	anonymized information		606,108.57	
152	anonymized information		603,487.27	
153	anonymized information		572,816.32	
154	anonymized information		554,603.14	
155	anonymized information		553,562.94	
156	anonymized information		537,322.50	
157	anonymized information		534,365.79	
158	anonymized information		532,484.69	
159	anonymized information		522,056.16	
160	anonymized information		509,359.33	
161	anonymized information		484,907.37	
162	anonymized information		483,851.06	
163	anonymized information		470,898.70	
164	anonymized information		460,885.97	
165	anonymized information		460,424.13	
166	anonymized information		441,889.38	
167	anonymized information		440,537.11	
168	anonymized information		438,907.18	
169	anonymized information		438,907.18	
170	anonymized information		433,116.41	

171	anonymized information	403,462.13
172	anonymized information	391,387.22
173	anonymized information	387,222.63
174	anonymized information	384,795.70
175	anonymized information	373,308.33
176	anonymized information	367,467.42
177	anonymized information	342,244.47
178	anonymized information	340,839.44
179	anonymized information	311,195.83
180	anonymized information	306,093.52
181	anonymized information	298,678.81
182	anonymized information	298,011.57
183	anonymized information	295,367.40
184	anonymized information	289,681.37
185	anonymized information	285,621.65
186	anonymized information	265,247.03
187	anonymized information	238,395.49
188	anonymized information	232,749.42
189	anonymized information	215,778.44
190	anonymized information	214,731.21
191	anonymized information	203,638.25
192	anonymized information	194,246.01
193	anonymized information	177,990.04
194	anonymized information	167,311.83
195	anonymized information	163,024.09
196	anonymized information	158,173.96
197	anonymized information	149,714.51
198	anonymized information	144,282.47
199	anonymized information	142,670.86
200	anonymized information	134,219.68
201	anonymized information	131,679.91
202	anonymized information	131,610.67
203	anonymized information	111,104.86
204	anonymized information	98,483.48
205	anonymized information	94,859.09
206	anonymized information	89,206.23
207	anonymized information	82,695.91
208	anonymized information	76,592.37
209	anonymized information	74,517.07
210	anonymized information	74,288.19
211	anonymized information	72,668.59
212	anonymized information	72,347.82
213	anonymized information	72,301.98
214	anonymized information	62,212.57
215	anonymized information	61,366.39
216	anonymized information	58,330.38
217	anonymized information	43,374.26
218	anonymized information	30,890.05
219	anonymized information	30,572.59
220	anonymized information	27,051.20
221	anonymized information	16,039.40

Appendix C – Forecast Performance and Expenditure Information

Age - Based Forecasting Roads											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	56,451,085	50,294,343	41,537,444	42,693,730	40,690,257	37,683,785	39,126,748	34,429,326	36,995,131	28,114,737	24,950,337
Fair Performance	49,479,317	50,258,879	61,762,099	61,872,276	63,211,873	63,642,687	53,461,693	47,458,062	41,607,033	44,358,959	38,768,348
Poor Performance	38,323,855	43,701,035	40,954,713	39,688,251	40,352,128	42,927,784	51,665,816	62,366,869	65,652,093	71,780,561	80,535,572
Annual Expenditure ($)	2,755,933	2,769,097	2,780,360	2,762,092	2,782,922	2,772,638	2,764,533	2,763,505	2,784,206	2,770,984	2,755,265

Age - Based Forecasting Sidewalks											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	302,351	267,456	237,740	249,148	251,515	251,515	235,965	196,055	135,899	126,174	138,974
Fair Performance	27,132	76,622	113,595	101,581	110,881	110,881	167,087	226,338	286,495	308,881	302,351
Poor Performance	428,288	413,693	406,436	407,042	395,375	395,375	354,718	335,377	335,377	322,716	316,446
Annual Expenditure ($)	14,595	7,257	11,408	11,667	-	40,657	19,341	-	21,249	12,800	23,864

Age - Based Forecasting Traffic Lights											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	1,942,015	1,747,692	1,788,629	1,852,852	1,903,640	408,692	345,346	371,990	308,747	371,423	380,487
Fair Performance	2,245,839	2,501,055	2,440,719	1,111,647	915,543	1,834,363	1,686,799	1,725,386	1,788,629	1,847,039	352,612
Poor Performance	1,808,531	1,747,638	1,767,037	3,031,887	3,177,203	3,753,331	3,964,240	3,899,009	3,899,009	3,777,924	5,263,287
Annual Expenditure ($)	60,893	63,243	64,223	56,601	56,080	44,307	87,537	-	126,899	65,664	42,219

Age - Based Forecasting Bridges											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	1,477,672	1,477,672	1,358,224	1,498,738	713,965	784,643	855,438	689,448	755,199	755,199	826,040
Fair Performance	1,410,616	1,189,716	1,309,164	1,309,164	2,093,937	2,093,937	2,033,177	2,269,962	2,269,962	2,109,142	2,109,142
Poor Performance	2,487,077	2,707,977	2,707,977	2,567,463	2,567,463	2,496,785	2,486,750	2,415,955	2,350,204	2,511,024	2,440,183
Annual Expenditure ($)	-	-	140,514	-	70,678	70,795	70,795	65,751	-	70,841	65,751

Age - Based Forecasting Sanitary											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	24,996,114	24,286,501	23,689,935	23,093,281	22,226,279	22,256,031	21,448,311	21,649,503	21,750,735	20,684,289	18,744,525
Fair Performance	26,397,879	27,234,704	27,845,979	28,556,153	29,591,164	29,733,315	30,705,275	30,529,921	30,382,934	31,586,150	33,678,206
Poor Performance	29,537,325	29,410,113	29,395,404	29,281,885	29,113,874	28,941,972	28,777,732	28,751,893	28,797,649	28,660,879	28,508,587
Annual Expenditure ($)	127,212	179,283	191,710	168,010	171,902	164,240	201,192	157,997	189,563	168,064	167,631

Age - Based Forecasting Water											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	20,881,477	19,912,319	18,810,928	18,467,493	17,420,772	17,358,250	16,626,018	16,504,423	16,723,512	16,890,545	14,740,240
Fair Performance	54,237,180	55,368,983	56,706,000	57,245,813	53,893,602	52,594,916	48,308,422	45,333,664	43,049,186	38,877,271	38,704,002
Poor Performance	12,814,695	12,652,050	12,416,424	12,220,046	16,618,977	17,980,185	22,998,912	26,095,265	28,160,653	32,165,536	34,489,110
Annual Expenditure ($)	162,646	235,626	196,378	208,722	215,716	259,915	211,584	230,359	213,252	189,144	198,339

Age - Based Forecasting
Roads

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
24,936,505	24,936,664	24,947,900	24,928,165	24,925,789	24,916,652	24,933,150	24,917,552	24,912,052	24,933,483	24,936,284	24,939,033	24,926,725	24,931,312
39,913,370	37,928,165	34,900,863	36,354,110	31,664,793	34,231,626	25,330,531	22,179,353	22,181,241	22,156,145	22,174,572	22,164,978	22,155,527	22,161,256
79,404,382	81,389,428	84,405,493	82,971,982	87,663,674	85,105,979	93,990,576	97,157,352	97,160,964	97,164,629	97,143,401	97,150,245	97,172,005	97,161,688
2,780,519	2,773,328	2,763,187	2,770,262	2,755,395	2,780,003	2,768,608	2,765,485	2,776,695	2,783,320	2,776,078	2,750,878	2,774,850	2,777,477

Age - Based Forecasting
Sidewalks

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
162,838	160,895	166,198	175,460	175,807	175,807	158,822	139,481	177,833	165,172	158,902	137,001	163,069	164,451
252,860	230,483	237,740	239,848	251,515	195,308	176,714	135,899	104,925	126,174	138,974	148,243	153,638	154,791
342,072	366,393	353,832	342,463	330,449	386,655	422,235	482,391	475,012	466,425	459,895	472,527	441,064	438,529
12,652	12,561	20,669	12,014	-	23,672	-	38,352	8,587	6,530	1,963	38,720	13,943	13,541

Age - Based Forecasting
Traffic Lights

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
366,626	408,151	368,907	424,699	303,613	364,619	369,050	365,446	378,276	386,705	442,862	381,218	390,647	352,728
301,039	284,453	308,747	244,525	314,822	324,407	322,319	320,614	368,907	297,801	237,949	322,400	283,219	317,153
5,328,720	5,303,781	5,318,731	5,327,162	5,377,950	5,307,359	5,305,016	5,310,325	5,249,202	5,311,880	5,315,575	5,292,767	5,322,519	5,326,505
85,832	48,293	55,792	5,813	136,547	46,651	82,227	61,123	64,221	61,970	65,027	56,080	44,307	87,537

Age - Based Forecasting
Bridges

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
891,791	605,681	720,522	669,966	775,536	775,536	749,565	749,565	744,638	734,603	663,808	704,061	704,061	730,626
2,109,142	2,395,252	1,427,116	1,477,672	1,358,224	1,358,224	713,965	713,965	784,643	618,653	689,448	755,199	755,199	826,040
2,374,432	2,374,432	3,227,727	3,227,727	3,241,604	3,241,604	3,911,835	3,911,835	3,846,084	4,022,109	4,022,109	3,916,105	3,916,105	3,818,698
-	114,841	-	105,571	-	114,542	-	65,751	60,760	-	106,005	-	97,406	-

Age - Based Forecasting
Sanitary

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
17,990,326	17,280,692	17,054,376	16,255,218	14,326,146	11,265,846	9,089,448	8,001,790	7,640,224	7,561,516	6,076,056	5,345,441	4,943,609	4,165,331
34,600,035	35,494,036	34,747,405	33,791,124	34,858,158	37,361,345	38,181,579	38,635,642	35,676,006	33,076,639	33,236,453	31,936,254	30,959,896	27,529,266
28,340,956	28,156,590	29,129,537	30,884,975	31,747,014	32,304,127	33,660,291	34,293,886	37,615,088	40,293,163	41,618,809	43,649,623	45,027,813	49,236,721
184,366	143,492	201,344	147,171	197,096	146,375	165,439	183,122	179,375	176,469	185,102	169,725	155,243	182,106

Age - Based Forecasting
Water

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
13,922,196	13,409,985	13,107,457	12,125,333	11,923,432	10,725,974	10,382,366	9,563,714	8,570,567	8,516,137	8,010,823	6,851,156	6,154,261	5,274,385
39,658,780	40,074,353	38,931,709	37,551,876	37,017,367	37,074,194	35,759,408	35,753,743	32,726,373	30,435,833	27,684,890	25,673,337	25,065,972	20,678,296
34,352,376	34,449,014	35,894,186	38,256,143	38,992,552	40,133,183	41,791,577	42,615,895	46,636,412	48,981,382	52,237,639	55,408,858	56,713,119	61,980,671
205,702	267,397	213,635	203,027	115,698	341,617	181,488	-	440,208	206,934	-	336,531	327,042	221,832

Age - Based Forecasting Storm											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	21,665,588	21,052,448	18,784,184	16,677,732	14,254,539	11,746,892	11,121,275	10,384,313	9,187,195	6,527,234	5,512,713
Fair Performance	17,963,663	17,839,080	17,499,653	18,652,586	18,655,062	20,972,318	21,408,990	21,881,737	18,040,452	20,281,155	20,205,008
Poor Performance	83,673,519	84,411,241	87,018,933	87,972,451	90,393,169	90,583,559	90,772,505	91,036,720	96,075,123	96,494,380	97,585,048
Annual Expenditure ($)	134,398	146,361	142,847	158,408	145,470	139,552	152,742	138,528	121,221	170,652	150,001

Age - Based Forecasting Natural Assets											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	12,977,671	11,555,074	11,538,231	12,447,893	12,967,845	12,967,845	13,824,579	14,748,192	15,526,406	15,526,406	14,344,146
Fair Performance	110,043,718	112,076,843	95,767,835	95,104,466	80,760,208	68,237,091	54,816,069	39,432,829	28,072,076	18,427,928	16,534,965
Poor Performance	21,489,380	20,878,851	37,204,702	36,958,410	50,782,715	63,305,833	75,870,121	90,329,748	100,912,287	110,556,434	113,631,657
Annual Expenditure ($)	610,529	428,920	909,662	656,265	-	2,110,133	923,613	778,215	-	1,519,296	1,027,902

Age - Based Forecasting Facilities											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	65,113,136	62,424,941	59,236,534	42,224,955	36,834,490	32,683,542	29,410,811	26,682,332	25,856,469	23,171,379	22,169,452
Fair Performance	14,500,210	17,270,116	17,395,314	33,580,342	38,571,885	41,733,867	44,711,198	44,108,475	43,286,401	44,145,338	31,085,512
Poor Performance	5,750,767	5,669,057	8,732,265	9,558,818	9,957,739	10,946,705	11,242,106	14,573,306	16,221,244	18,047,397	32,109,150
Annual Expenditure ($)	268,552	262,956	213,348	273,468	325,850	121,382	354,557	11,330	592,502	76,692	386,430

Age - Based Forecasting Parks											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	984,324	926,330	815,737	835,067	188,975	199,960	201,457	201,662	201,748	200,158	199,980
Fair Performance	916,548	842,961	883,832	798,107	1,277,611	1,086,173	1,052,466	328,089	250,254	189,027	189,464
Poor Performance	3,433,909	3,565,490	3,635,213	3,701,608	3,868,195	4,048,649	4,080,859	4,805,030	4,882,780	4,945,596	4,945,337
Annual Expenditure ($)	49,915	50,081	49,942	49,937	50,000	50,079	49,997	50,022	49,911	50,051	49,963

Age - Based Forecasting Parking											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	739,121	739,121	601,974	514,828	70,397	55,046	129,958	118,150	118,150	118,854	118,854
Fair Performance	203,990	200,991	340,432	427,578	872,009	752,254	727,313	739,121	739,121	601,974	514,828
Poor Performance	205,296	208,295	206,000	206,000	206,000	341,107	291,136	291,136	291,136	427,578	514,724
Annual Expenditure ($)	-	31,004	-	-	-	87,146	-	-	31,708	-	-

Age - Based Forecasting
Storm

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
3,542,194	3,240,058	1,759,965	1,761,304	1,760,530	1,744,209	1,741,184	1,760,270	1,749,801	1,753,199	1,779,003	1,745,957	1,755,714	1,760,068
21,302,405	20,166,138	21,052,448	19,021,126	16,914,674	14,491,481	11,983,835	11,358,217	10,384,313	9,187,195	6,527,234	5,512,713	3,542,194	3,240,058
98,458,171	99,896,574	100,490,357	102,520,340	104,627,566	107,067,079	109,577,751	110,184,283	111,168,656	112,362,375	114,996,532	116,044,099	118,004,862	118,302,644
140,428	153,755	147,700	142,072	142,088	142,445	158,638	142,273	141,927	147,025	137,606	159,757	144,782	129,957

Age - Based Forecasting
Natural Assets

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
15,372,048	16,222,857	16,321,919	15,364,627	14,692,887	15,902,169	13,187,393	13,983,797	13,554,877	14,442,007	14,563,175	15,418,027	14,084,968	14,025,302
12,240,570	11,594,632	11,852,351	12,838,745	10,837,837	10,052,480	12,977,671	11,555,074	11,538,231	12,311,580	12,967,845	11,714,446	13,824,579	14,748,192
116,898,150	116,693,279	116,336,499	116,307,396	118,980,045	118,556,120	118,345,704	118,971,897	119,417,660	117,757,182	116,979,748	117,378,296	116,601,221	115,737,275
850,809	793,450	620,088	538,815	1,209,282	210,415	1,406,932	-	1,796,791	777,433	854,852	777,074	863,946	652,935

Age - Based Forecasting
Facilities

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
21,914,288	16,777,588	14,666,493	14,413,311	12,878,207	8,858,357	7,807,576	5,384,583	4,093,219	3,847,915	3,227,586	2,340,678	2,351,592	2,176,204
25,082,758	26,667,854	28,192,306	26,866,962	28,522,986	31,804,844	31,149,557	29,474,917	30,282,392	30,282,111	28,371,336	28,060,731	27,592,848	25,944,520
38,367,068	41,918,671	42,505,314	44,083,841	43,962,920	44,700,914	46,406,981	50,504,614	50,988,503	51,234,088	53,765,191	54,962,705	55,419,674	57,243,390
294,682	307,580	286,331	254,041	274,410	277,108	268,055	274,373	271,750	268,250	271,273	269,759	269,372	270,223

Age - Based Forecasting
Parks

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
199,947	224,888	225,028	225,138	225,122	200,282	214,219	214,188	213,953	214,115	200,028	214,510	214,723	200,027
184,910	174,963	174,794	156,117	152,425	174,827	174,977	175,025	150,159	164,613	178,740	149,708	149,598	149,976
4,949,924	4,934,931	4,934,959	4,953,526	4,957,234	4,959,672	4,945,585	4,945,569	4,970,669	4,956,053	4,956,013	4,970,563	4,970,460	4,984,778
49,964	50,051	50,011	49,947	49,972	49,870	49,980	49,712	50,540	50,051	49,930	50,075	49,971	49,970

Age - Based Forecasting
Parking

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
118,854	206,000	118,854	156,029	156,029	156,608	175,493	175,493	103,698	115,932	90,565	158,118	125,831	137,951
70,397	55,046	129,958	118,150	118,150	118,854	118,854	118,854	206,000	118,854	156,029	156,029	156,608	175,493
959,155	887,360	899,594	874,227	874,227	872,944	854,059	854,059	838,709	913,620	901,813	834,259	865,967	834,963
87,146	-	37,175	-	32,288	18,885	-	15,351	12,234	11,808	67,553	-	31,004	-

Consumer - Based Forecasting Roads											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	73,590,550	71,577,093	72,906,670	75,622,031	76,501,758	76,515,447	67,427,368	67,772,903	63,704,401	64,770,001	65,468,665
Fair Performance	45,388,397	42,956,658	45,259,715	45,562,411	48,342,631	49,242,899	58,778,999	58,352,071	62,167,283	56,999,925	55,231,644
Poor Performance	25,275,310	29,720,506	26,087,871	23,069,815	19,409,868	18,495,911	18,047,890	18,129,283	18,382,573	22,484,331	23,553,947
Annual Expenditure ($)	2,769,377	2,767,355	2,775,211	2,768,254	2,767,266	2,769,769	2,775,910	2,770,854	2,768,464	2,771,035	2,770,587

Consumer - Based Forecasting Sidewalks											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	304,581	323,723	300,030	311,438	311,438	366,294	350,593	339,882	341,645	318,510	326,071
Fair Performance	352,273	354,504	391,476	391,476	391,476	309,296	358,787	373,071	245,636	279,523	217,201
Poor Performance	100,917	79,545	66,264	54,856	54,856	82,180	48,391	44,818	170,490	159,738	214,499
Annual Expenditure ($)	11,827	13,884	10,750	-	34,532	15,967	15,989	11,559	18,326	13,749	3,797

Consumer - Based Forecasting Traffic Lights											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	2,704,451	2,525,920	2,701,542	2,647,151	2,778,077	2,349,740	2,231,050	1,938,455	1,943,906	2,078,539	2,004,726
Fair Performance	1,676,598	2,280,731	1,865,254	2,029,908	2,286,322	2,807,752	2,494,590	1,888,656	1,831,163	1,558,387	1,517,728
Poor Performance	1,615,336	1,189,734	1,429,589	1,319,326	931,986	838,894	1,270,745	2,169,275	2,221,316	2,359,460	2,473,931
Annual Expenditure ($)	62,709	57,137	63,594	66,889	59,391	20,503	30,780	134,676	64,905	67,542	56,463

Consumer - Based Forecasting Bridges											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	1,820,071	1,276,941	740,107	740,107	855,111	855,111	1,015,931	849,275	849,275	1,634,048	1,789,355
Fair Performance	3,388,638	4,098,424	4,635,258	4,520,254	4,520,254	3,391,298	3,391,298	3,557,954	2,773,181	2,617,875	286,104
Poor Performance	166,656	-	-	115,004	-	1,128,956	968,136	968,136	1,752,909	1,123,442	3,299,907
Annual Expenditure ($)	11,550	-	-	28,409	-	39,535	-	-	245,135	38,509	201,484

Consumer - Based Forecasting Sanitary											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	34,975,158	32,450,232	31,232,690	29,687,563	28,591,137	28,286,853	27,042,747	25,723,023	24,934,089	22,777,789	22,441,286
Fair Performance	43,232,761	45,998,244	47,478,199	49,023,326	50,119,752	50,552,943	51,523,404	51,998,221	49,117,089	45,713,430	41,637,504
Poor Performance	2,723,399	2,482,842	2,220,428	2,220,428	2,220,428	2,091,521	2,365,167	3,210,074	6,880,140	12,440,099	16,852,528
Annual Expenditure ($)	30,134	250,437	-	-	558,220	142,339	205,261	182,072	180,627	175,590	172,268

Consumer - Based Forecasting Water											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	38,296,646	32,228,284	28,810,208	26,618,897	25,425,045	23,916,352	23,388,785	22,032,971	21,870,037	20,972,604	19,817,684
Fair Performance	43,257,935	50,772,521	55,294,979	57,846,237	59,325,578	59,685,210	54,024,581	45,409,070	43,151,496	46,305,068	49,912,934
Poor Performance	6,378,770	4,932,547	3,828,165	3,468,217	3,182,729	4,331,789	10,519,985	20,491,310	22,911,818	20,655,680	18,202,734
Annual Expenditure ($)	207,171	212,284	145,993	261,445	200,721	264,468	217,760	212,795	219,700	215,625	215,331

Consumer - Based Forecasting

Roads

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
57,817,740	56,612,821	54,632,955	52,493,601	50,753,668	52,290,731	52,977,982	48,563,085	48,864,317	39,381,411	37,116,006	36,463,563	35,211,543	38,844,118
63,204,581	65,030,569	59,472,105	64,941,845	66,155,955	64,123,292	60,353,348	63,592,224	62,596,036	73,637,176	73,061,425	74,192,423	66,323,932	59,973,982
23,231,935	22,610,867	30,149,197	26,818,810	27,344,633	27,840,234	30,922,927	32,098,948	32,793,903	31,235,670	34,076,826	33,598,270	42,718,782	45,436,156
2,773,205	2,770,711	2,770,186	2,771,768	2,770,767	2,765,397	2,774,401	2,770,503	2,767,381	2,765,828	2,776,418	2,774,235	2,767,830	2,770,325

Consumer - Based Forecasting

Sidewalks

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
273,568	262,923	215,622	227,342	230,768	234,996	242,385	254,649	254,649	269,464	306,556	321,504	272,000	226,364
277,358	272,494	345,048	345,048	328,821	337,393	350,674	362,082	314,666	255,319	167,641	192,843	233,760	287,983
206,845	222,354	197,100	185,381	198,181	185,381	164,712	141,040	188,455	232,988	283,574	243,424	252,011	243,424
27,896	10,353	11,907	17,266	1,527	25,677	24,855	-	12,099	29,667	15,011	-	3,925	36,487

Consumer - Based Forecasting

Traffic Lights

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
2,109,065	2,016,644	2,080,631	1,891,548	1,606,431	1,867,081	2,101,422	1,757,674	1,820,435	1,871,176	1,923,311	1,710,808	1,619,867	1,403,854
1,563,981	1,917,179	2,097,391	2,426,517	2,370,530	1,811,059	1,348,679	2,007,426	1,794,503	2,002,266	2,000,835	2,323,357	2,398,475	2,759,276
2,323,340	2,062,562	1,818,364	1,678,321	2,019,424	2,318,246	2,546,285	2,231,286	2,381,447	2,122,943	2,072,239	1,962,220	1,978,043	1,833,255
62,666	67,468	63,906	58,211	64,089	46,726	76,291	50,279	80,940	47,930	73,326	64,152	50,429	77,025

Consumer - Based Forecasting

Bridges

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
2,409,944	2,467,619	2,680,051	2,900,462	3,071,648	3,299,277	3,418,725	2,718,416	2,718,416	3,009,966	2,202,659	1,602,278	1,460,641	1,473,936
469,254	503,322	336,666	336,666	451,670	451,670	451,670	1,397,263	1,397,263	1,397,263	2,204,570	2,804,951	2,712,882	2,933,293
2,496,167	2,404,424	2,358,648	2,138,237	1,852,048	1,624,418	1,504,970	1,259,686	1,259,686	968,136	968,136	968,136	1,201,842	968,136
54,627	54,492	56,226	51,815	47,676	29,151	64,394	-	76,018	-	-	-	135,310	-

Consumer - Based Forecasting

Sanitary

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
20,807,845	20,170,142	19,333,366	20,377,413	20,883,346	21,928,258	21,803,545	21,800,372	21,373,172	22,374,392	21,655,697	21,744,541	21,076,430	20,832,072
42,155,387	42,781,442	43,503,412	41,778,375	40,585,061	37,851,058	35,913,893	32,847,382	28,473,085	26,118,082	25,927,281	25,839,327	26,828,975	27,487,323
17,968,086	17,979,734	18,094,540	18,775,530	19,462,911	21,152,002	23,213,880	26,283,564	31,085,061	32,438,843	33,348,340	33,347,450	33,025,913	32,611,923
170,384	175,518	171,252	173,483	173,810	172,158	170,967	171,814	173,842	171,457	173,027	174,360	173,403	169,461

Consumer - Based Forecasting

Water

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
20,519,745	21,348,302	22,557,074	24,813,946	23,327,061	24,724,910	26,674,206	26,303,529	26,177,531	26,214,021	25,413,740	26,198,758	23,864,200	23,554,423
51,101,234	48,037,919	42,784,574	35,803,186	31,398,607	28,193,603	26,164,302	24,558,100	23,740,567	24,872,287	25,754,751	25,169,170	26,792,727	24,674,268
16,312,373	18,547,131	22,591,703	27,316,219	33,207,684	35,014,839	35,094,844	37,071,723	38,015,254	36,847,043	36,764,860	36,565,424	37,276,425	39,704,661
217,193	215,790	213,434	215,892	217,231	216,704	215,621	216,054	216,133	215,974	215,191	215,502	216,946	215,982

Consumer - Based Forecasting Storm											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	30,960,542	34,916,988	37,951,406	45,289,546	47,239,813	50,608,623	55,161,168	57,167,762	59,489,286	63,585,627	68,653,707
Fair Performance	80,214,525	74,750,462	74,313,833	73,900,030	72,002,475	66,301,603	65,682,433	62,367,946	59,462,143	52,625,380	51,301,965
Poor Performance	12,127,703	13,635,320	11,037,530	4,113,194	4,060,482	6,392,543	2,459,169	3,767,062	4,351,340	7,091,762	3,347,097
Annual Expenditure ($)	145,462	146,231	145,948	104,602	85,634	127,299	47,793	71,385	87,493	137,385	64,247

Consumer - Based Forecasting Natural Assets											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	33,838,261	24,013,808	18,860,283	26,073,985	27,915,540	29,291,234	30,328,805	28,035,957	25,249,519	19,501,118	27,249,215
Fair Performance	108,102,626	118,917,083	117,523,945	116,057,267	112,811,695	112,651,532	114,181,964	115,141,014	114,127,591	117,581,430	106,771,677
Poor Performance	2,569,881	1,579,877	8,126,540	2,379,516	3,783,534	2,568,003	-	1,333,797	5,133,659	7,428,221	10,489,876
Annual Expenditure ($)	242,839	65,863	1,534,182	1,294,010	885,575	453,217	-	632,734	397,854	1,198,297	2,197,171

Consumer - Based Forecasting Facilities											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	62,716,723	61,023,113	62,557,963	46,918,167	42,616,425	41,973,329	39,063,256	37,504,222	33,323,880	29,948,370	29,594,443
Fair Performance	18,788,041	18,282,315	17,882,197	34,004,481	40,252,870	42,312,759	45,357,101	47,166,978	38,796,818	36,893,326	23,975,273
Poor Performance	3,859,350	6,058,686	4,923,954	4,441,466	2,494,819	1,078,025	943,756	692,914	13,243,416	18,522,418	31,794,398
Annual Expenditure ($)	223,928	314,456	263,241	276,913	266,671	226,108	266,792	248,314	286,429	324,516	270,109

Consumer - Based Forecasting Parks											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	1,980,506	1,853,121	2,125,479	1,648,194	1,689,419	1,831,545	1,967,061	2,021,307	2,138,899	2,034,795	1,874,357
Fair Performance	2,263,398	2,260,072	2,048,710	2,498,634	2,118,001	1,786,121	1,761,404	1,759,217	1,677,458	1,839,086	1,932,249
Poor Performance	1,090,878	1,221,588	1,160,593	1,187,953	1,527,362	1,717,115	1,606,316	1,554,257	1,518,424	1,460,900	1,528,175
Annual Expenditure ($)	50,001	49,996	50,003	50,002	49,997	50,001	49,991	49,993	50,008	49,998	49,994

Consumer - Based Forecasting Parking											
Asset Replacement Value ($) in:	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Good Performance	739,121	750,661	306,230	361,975	414,178	439,118	322,140	322,408	322,408	342,000	277,990
Fair Performance	172,281	223,454	619,924	594,557	609,908	622,142	676,141	207,276	294,422	346,624	413,752
Poor Performance	237,004	174,292	222,253	191,874	124,321	87,146	150,126	618,723	531,577	459,782	456,665
Annual Expenditure ($)	16,032	22,278	17,269	17,269	9,503	-	18,585	14,441	59,449	3,924	3,128

Consumer - Based Forecasting
Storm

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
71,067,703	71,889,545	76,528,713	77,598,684	80,000,741	82,116,270	83,008,389	82,237,884	86,185,793	82,659,289	79,824,743	74,425,894	71,737,763	64,822,602
48,516,023	46,358,778	42,455,929	40,820,060	40,529,313	37,505,045	36,606,333	35,058,906	35,007,992	38,797,751	41,858,802	47,317,918	50,363,870	56,741,590
3,719,044	5,054,446	4,318,128	4,884,025	2,772,715	3,681,454	3,688,047	6,005,980	2,108,985	1,845,729	1,619,225	1,558,957	1,201,136	1,738,577
77,284	103,267	88,504	95,202	58,640	74,445	68,449	124,051	37,152	34,715	31,348	28,455	23,721	62,404

Consumer - Based Forecasting
Natural Assets

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
33,479,256	38,559,312	43,803,182	49,725,552	53,154,664	55,774,396	56,500,046	59,852,289	63,247,646	68,585,974	73,018,258	69,362,153	71,106,697	65,530,604
67,370,278	24,506,434	21,188,873	15,309,677	17,334,087	16,977,086	19,106,867	19,288,899	20,510,616	20,423,504	20,994,290	29,625,109	35,125,946	38,567,758
43,661,234	81,445,023	79,518,714	79,475,539	74,022,018	71,759,287	68,903,855	65,369,581	60,752,506	55,501,290	50,498,221	45,523,506	38,278,126	40,412,407
934,211	798,017	838,526	820,376	801,746	837,963	798,252	836,198	823,276	820,300	822,149	800,805	829,301	825,545

Consumer - Based Forecasting
Facilities

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
27,874,095	25,192,312	22,790,958	22,436,411	16,942,307	14,881,022	12,279,112	10,076,972	9,517,296	6,610,972	6,965,425	6,402,037	8,761,447	8,543,897
23,080,968	24,792,376	27,890,011	28,243,480	33,951,755	34,897,863	37,966,875	37,265,092	37,194,131	38,148,909	35,465,128	31,306,147	28,357,671	23,381,629
34,409,052	35,379,426	34,683,146	34,684,223	34,470,053	35,585,228	35,118,126	38,022,051	38,652,687	40,604,233	42,933,561	47,655,930	48,244,996	53,438,588
269,807	269,785	269,774	269,781	269,763	269,774	269,763	269,789	269,781	269,764	269,720	269,842	269,766	269,786

Consumer - Based Forecasting
Parks

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
2,010,624	2,043,223	2,254,848	2,505,978	2,427,046	1,892,252	1,867,712	1,972,658	2,065,971	1,785,556	1,926,115	1,996,989	1,876,139	1,768,905
2,033,753	2,188,057	1,591,786	1,564,825	1,710,510	2,152,730	2,115,550	2,040,632	1,879,160	2,144,479	2,114,479	2,179,339	2,341,820	2,242,934
1,290,404	1,103,501	1,488,148	1,263,979	1,197,225	1,289,799	1,351,520	1,321,491	1,389,651	1,404,746	1,294,187	1,158,454	1,116,822	1,322,943
50,005	49,915	50,086	49,930	49,641	50,144	49,620	50,504	50,105	50,013	50,050	49,823	50,087	50,044

Consumer - Based Forecasting
Parking

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
253,049	165,903	177,443	189,251	256,805	396,153	409,286	409,286	310,600	310,600	254,854	202,652	264,857	253,049
450,926	475,360	427,578	447,171	292,472	153,669	177,711	126,539	189,251	264,589	316,792	284,965	322,140	271,235
444,431	507,144	543,385	511,984	599,130	598,584	561,410	612,582	648,556	573,218	576,760	660,790	561,410	624,122
-	16,032	27,782	17,269	76,718	9,503	-	13,082	14,441	5,504	3,924	62,577	-	16,032