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University of the Witwatersrand

Faculty of Engineering and the Built Environment



RESEARCH REPORT:

In Preparedness for an Integrated Infrastructure Asset Management System for the City of Johannesburg

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A research report submitted to the Faculty of Engineering and the Built Environment, School of Civil and Environmental Engineering, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

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School of Civil & Environmental Engineering

Johannesburg, September 2015

DECLARATION

I declare that this research report is my own unaided work. It is being submitted for the Degree of Master of Science in Engineering at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other university.

Signature of James Doyle

29th September 2015 in Johannesburg

ABSTRACT

The research presented in this report set out to determine the extent to which cross-enterprise integration between three Municipal Owned Entities (MOEs) in Johannesburg, i.e. City Power, Johannesburg Water and Johannesburg Roads Agency (JRA), could be beneficial to the Council and users of the Council's assets.

The research included a comprehensive review of available literature to find the needs of / gaps in infrastructure asset management and examples of cross-enterprise integration. Interviews with MOEs' personnel were conducted to determine current levels of infrastructure asset management. A library of the costs of potential hazards arising from damages caused by MOEs to other MOEs' assets during maintenance tasks was compiled.

A simulation exercise was conducted. The exercise involved the development and application of a computer program using Visual Basic for Applications programming tool. The program created a series of job cards for maintenance works by all MOEs using available asset data for a section of the city. Conflict areas were identified where work on one asset might compromise the integrity of other assets. Costs of the damage to the assets in terms of direct costs of repairs and users' costs, due to lower levels of service, were quantified for each conflict point. The simulation exercise was run over a thirty year period. The average annual costs were costed using cost to benefit analysis. Expenses associated with the creation of new organisational structures and new cross-enterprise software systems were studied using available data in literature. The expenses and savings formed the basis of the cost to benefit analysis.

The study shows that the introduction of a cross-enterprise integrated system can significantly reduce costs to the Council and users. There are several other benefits originating from cross-enterprise integration including more efficient use of skilled personnel, efficiency in issuing of way leaves, and improved integrity of asset data.

The installation of such a system need not only service the three MOEs included in the study. It is possible that all owners of assets on Council property, including external organisations such as Telkom, Neotel, and Dark Fibre Africa, will benefit from cross-enterprise integration.

DEDICATION

To Mom, Dad, Paul, William and Caron, Lawrence, and Sacha-Lee

ACKNOWLEGEMENTS

I thank my supervisor, Professor Adesola Ilemobade, for your patient guidance and putting up with reading and editing a novice's research paper.

I thank my family for your unwavering support and encouragement and for putting up with my night time and weekend study work.

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CONTENTS

DECLARATION II
ABSTRACT III
DEDICATION IV
ACKNOWLEGEMENTS V
CONTENTS 1
LIST OF FIGURES 5
LIST OF TABLES 6
ABBREVIATIONS 8
CHAPTER 1 INTRODUCTION 10
1.1 CONTEXT 10
1.2 PROBLEM STATEMENT AND ITS IMPORTANCE 11
1.3 OBJECTIVES AND RESEARCH QUESTIONS 12
1.3.1 Research Questions 13
1.4 SCOPE AND LIMITATIONS OF THE STUDY 13
1.5 STRUCTURE OF THE REST OF THE REPORT 14
1.5.1 Literature review 14
1.5.2 Methodology 14
1.5.3 Status quo in Johannesburg Council and MOEs 15
1.5.4 Experiment 15
1.5.5 Costs of implementation 16
1.5.6 Conclusions 16
1.5.7 Requirements for the implementation of cross-enterprise integration systems 16
1.5.8 Recommendations 16
1.5.9 Further research 16
CHAPTER 2 LITERATURE REVIEW 17
2.1 INTRODUCTION 17
2.2 SCOPE AND STRUCTURE OF THE LITERATURE REVIEW 17
2.3 DEFINITION OF INFRASTRUCTURE ASSET MANAGEMENT 18
2.4 DEFINING INTEGRATION 20
2.4.1 Who manages the Infrastructure Asset Management (IAM) process 21
2.4.2 Who manages the data 21
2.4.3 The difference between Integrated and non-integrated systems 22
2.5 THE NEED FOR INFRASTRUCTURE ASSET MANAGEMENT 22
2.6 BENEFITS OF IAM 23
2.7 REQUIREMENTS OF INFRASTRUCTURE ASSET MANAGEMENT SYSTEMS 24
2.7.1 Policy 24

2.7.2 Strategy....25
2.7.3 Infrastructure Asset Management Plan....25
2.8 Challenges in implementing Integrated Systems....26
2.8.1 Affordability....26
2.8.2 Information Technology....26
2.8.3 Organisational Challenges....28
2.8.4 Skills Shortages....28
2.9 Legal Issues, Standards and Guidelines regarding IAM....30
2.9.1 Legal issues surrounding IAM....30
2.9.2 Standards and Guidelines....32
2.9.2.1 South Africa....32
2.9.2.2 New Zealand and Australia....33
2.9.2.3 British....37
2.9.2.4 United States of America (USA)....37
2.9.2.5 International Standards....38
2.10 GDS2040 and the IDP....38
2.11 Software and Customer Service Support....38
2.11.1 Cross-Enterprise Software....39
2.11.2 Case Study on the application of Enterprise Software....39
2.11.3 Software Development teams and methods....40
2.11.4 Call Centres....41
2.12 Summary of the Literature Review....41
CHAPTER 3 THE METHODOLOGY....43
3.1 Research design....43
3.1.1 The literature review....44
3.1.2 Current practices in the field of IAM in City Power, Johannesburg Water and JRA....45
3.1.3 Comparison of current IAM systems and the proposed cross-enterprise system – experimental research....46
3.1.4 Analysis of experiment results....47
3.2 Data Sources....47
3.3 Data collection techniques....47
3.4 Issues of reliability and validity....50
3.5 Sampling techniques....50
3.6 Data analysis and interpretation....51
3.7 Ethical considerations....52
CHAPTER 4 THE STATUS QUO IN JOHANNESBURG COUNCIL AND MUNICIPAL OWNED ENTITIES....53
4.1 City Power....56

4.1.1 Skills 59
4.2 JOHANNESBURG WATER 59
4.2.1 The Call Centre 63
4.2.2 Skills 63
4.2.3 Billing 64
4.3 JOHANNESBURG ROADS AGENCY (JRA) 64
4.3.1 Skills 68
4.4 THE JHB COUNCIL 68
4.4.1 Call Centre 68
4.4.2 Organisational structures 69
4.5 SUMMARY 70
CHAPTER 5 THE EXPERIMENT 71
5.1 ORIGIN OF DATA: THE AREA ROBERTSHAM AND SOUTHDALE 71
5.2 PROCESSES OF THE EXPERIMENT 73
5.2.1 Job cards 74
5.2.2 Conflict points 75
5.2.2.1 Location of assets, latitude and longitude 75
5.2.2.2 Determining intersecting points of assets 75
5.2.3 Risk costs of conflict points 82
5.3 ASSUMPTIONS 82
5.4 COSTS 83
5.4.1 The probability of damage during maintenance works 87
5.4.2 Road costs due to neglected maintenance (JRA) 89
5.4.2.1 Direct Costs: Roads 89
5.4.2.2 Risk of accidents occurring at conflict areas 92
5.4.2.3 User Costs: Roads 93
5.4.3 Electrical costs of neglected maintenance (City Power) 104
5.4.3.1 Direct costs: Electrical 105
5.4.3.2 User costs: Electrical 107
5.4.4 Water and Sewer costs of neglected maintenance (Johannesburg Water) 110
5.4.4.1 Direct costs: Water and Sewer 110
5.4.4.2 User costs: Water and Sewer 113
5.4.5 Summary of Costs 115
5.4.5.1 JRA 115
5.4.5.2 City Power 116
5.4.5.3 Johannesburg Water 116
5.4.5.4 Summary of all Municipal Owned Entities (MOEs) costs 117
5.5 EXPERIMENT RESULTS AND FINDINGS 117

CHAPTER 6 COSTS OF IMPLEMENTATION....121
6.1 INTRODUCTION TO THE INTEGRATED SYSTEM....121
6.2 SOFTWARE DEVELOPMENT....122
6.3 ORGANISATIONAL COSTS....124
6.4 TRAINING....125
6.5 OFFICES, FURNITURE AND EQUIPMENT....127
6.6 DAY-TO-DAY COSTS....128
6.7 SUMMARY....129
CHAPTER 7 BENEFITS....130
7.1 ECONOMIC BENEFITS....130
7.2 SPIN-OFFS....131
7.2.1 Way leaves....131
7.2.2 Motivation to maintain up-to-date Asset Databases....131
7.2.3 Efficient use of skilled personnel....132
7.2.4 Improved communications....132
CHAPTER 8 REQUIREMENTS FOR THE IMPLEMENTATION OF CROSS-ENTERPRISE INTEGRATION SYSTEMS....133
8.1 STANDARDISATION AND INTEGRITY OF DATA....133
8.2 ORGANISATION STRUCTURE....133
8.3 THE PROCESS....134
CHAPTER 9 CONCLUSIONS....136
CHAPTER 10 RECOMMENDATIONS....137
10.1 STEPS TO THE IMPLEMENTATION OF INTEGRATED SYSTEMS....137
10.2 PROJECT MANAGEMENT....138
CHAPTER 11 FURTHER RESEARCH....141
11.1.1 Automation of cross-enterprise integration....141
11.1.2 Reduction of asset life and investment due to incomplete maintenance....141
11.1.3 Effect of Power outages on Traffic Delays, Accidents and Increase in Crime....141
11.1.4 User Costs of Water Outages....141
REFERENCES....142
APPENDIX A QUESTIONNAIRE NUMBER 1....149
APPENDIX B QUESTIONNAIRE NUMBER 2....152
APPENDIX C PROGRAM OUTPUT TABLES....155
APPENDIX E GLOSSARY....159

LIST OF FIGURES

Figure 2.1 Processes in IAM (NAMS, 2011) 33
Figure 4.1 Different systems within City Power 58
Figure 4.2 Johannesburg Water Existing Organisational Chart 60
Figure 4.3 Composition of Asset Management Working Group within Infrastructure Planning 60
Figure 4.4 Schematic layout of data flows and process for IAM in Johannesburg Water 61
Figure 4.5 Processes in JRA IAM systems 66
Figure 4.6 JRA Organisational Chart of Corporate High Level Structure 68
Figure 4.7 Organisational Structure of the City of Johannesburg (CoJ) 69
Figure 5.1 The iterative process within IAM 71
Figure 5.2 Location of study area: Robertsham and Southdale suburbs of Johannesburg 72
Figure 5.3 Program steps 74
Figure 5.4 Location of an MV cable with load centres 76
Figure 5.5 Diagram illustrating the need for limiting the length of assets for input to the program 80
Figure 5.6 Determination of risk of damaging assets during maintenance operations 89
Figure 5.7 Graphical illustration of increased road costs over time due to delays to repairs 91
Figure 5.8 Formula for calculation of monthly risk costs in terms of fatalities (based on increased costs as shown in figure 5.6) 95
Figure 5.9 Increased rate of serious accidents (based on increased costs as shown in figure 5.6) 96
Figure 5.10 Increased rate of minor accident costs (based on increased costs as shown in figure 5.6) 97
Figure 6.1 Example of Software development team (Wallace, 2014) 122
Figure 6.2 Software development resource pool structure (Wallace, 2014) 123
Figure 6.3 Example of Infrastructure Central Committee Organisational Structure (JRA, 2014) 125
Figure 8.1 Diagram showing the use of AI software as translator / interpreter 134
Figure 8.2 Diagram of processes of integrated systems 135

LIST OF TABLES

Table 2.1 Levels of IAM (NAMS, 2011) 35
Table 3.1 Steps in research design 44
Table 3.2 Returns analysis For Questionnaire No. 1 administered to the (CoJ) and MOEs 49
Table 3.3 Returns analysis For Questionnaire No. 2 administered to CoJ and MOEs 49
Table 3.4 Interviews with CoJ and MOEs 49
Table 4.1 Categories of fields in the asset database used by the program in this research 53
Table 4.2 Key IAM Categories within the Asset Inventory File 54
Table 4.3 Summary of answers to questionnaires returned by MOEs regarding their IAM systems 54
Table 5.1 Configurations that may occur when checking for intersecting assets using overlapping circles 78
Table 5.2 Iterations for calculation of parameters for input to program 81
Table 5.3 Schedule of user costs, types and probabilities 84
Table 5.4 Comparison of costs between integrated and non-integrated systems 86
Table 5.5 Costs of road repairs due to damage in asphalt and their increase over time (McCarroll, 2014) 90
Table 5.6 Costs of road repairs due to damage in base course and their increase over time (McCarroll, 2014) 90
Table 5.7 Costs of road repairs due to damage in sub-base layer and their increase over time (McCarroll, 2014) 90
Table 5.8 Costs of road repairs due to damage in sub-grade layer and their increase over time (McCarroll, 2014) 91
Table 5.9 Summary of costs of road repairs due to damage in various layers and their increade in time (McCarroll, 2014) 91
Table 5.10 Assessment by JRA on the Visual Condition Index (VCI) of roads in Johannesburg (JRA, 2013) 92
Table 5.11 Costs of fatal accidents (Botha and van der Walt, 2006) 94
Table 5.12 Human casualty costs (De Beer, and van Niekerk, 2004) 95
Table 5.13 Vehicle damage and incident costs (National Department of Transport, 2003) 97
Table 5.14 Calculation of minimum wage in Gauteng 99
Table 5.15 Costs of carbon emissions (United States Environmental Protection Agency, 2013) 101
Table 5.16 Road user costs related to Roughness Index of road (Archondo-Callao, 1999) 103
Table 5.17 Description of Roughness Index categorisations (Archondo-Callao, 1999) 104
Table 5.18 Electricity sales and purchases for 2009_10 to 2011_12 106
Table 5.19 Average Water Demand (Johannesburg Water, 2013) 112

Table 5.20 Costs of damage to JRA's assets due to other MOEs' maintenance work...115
Table 5.21 Costs of damage to City Power's assets due to other MOEs' maintenance works...116
Table 5.22 Costs of damage to Johannesburg Water's assets due to other MOEs' maintenance works...116
Table 5.23 Summary by MOE of costs of damage due to maintenance works...117
Table 5.24 Parameters input into simulation program...117
Table 5.25 Resulting total costs per annum of risks at conflict areas (output from simulation program)...118
Table 5.26 Cost of risk of damage separated to show direct costs and user costs...118
Table 5.27 Comparisons of study area and Johannesburg parameters...119
Table 5.28 Potential cost savings for the whole Johannesburg metropolitan area...119
Table 5.29 List of MOEs and organisations with assets on Council property in Johannesburg...120
Table 6.1 Software development costs (payscale.com, 2014)...124
Table 6.2 Costs of organisational structure of new IAM committee (payscale.com, 2014)...125
Table 6.3 Costs of training (SAP, 2014; Sage Pastel Accounting, 2014; leadingtraining.co.za, 2014)...127
Table 6.4 Office, furniture and equipment rates (The Business Centre, n.d.; Abland, n.d.; Broll, n.d.)...128
Table 6.5 Summary of costs for integrated systems...129
Table 7.1 Economic benefits of cross-enterprise integration in Johannesburg...131
Table C. 1 Program output showing Job Cards...155
Table C. 2 Parameters for input to program...156
Table C. 3 Program output showing Conflicts...157
Table C. 4 Costs of risk of damage caused by MOEs to other MOEs' assets...158

ABBREVIATIONS

Abbreviation	Description
AI	Application Integration
APOSTEL	Austrian Power Outage Simulation of Economic Losses
CBD	Central Business District
CD	Compact Disk
CIDB	Construction Industry Development Board
CoJ	City of Johannesburg
CSIR	Council for Scientific and Industrial Research
DPW	Department of Public Works
EAI	Enterprise Application Integration
ECSA	Engineering Council of South Africa
ERP	Enterprise Resource Planning
GASB	Governmental Accounting Standards Board (of the USA)
GDS	Growth and Development Strategy
GIS	Geographic Information Systems
GRAP	Generally Recognised Accounting Practice
HANSEN	HANSEN is a software Corporation
IAM	Infrastructure Asset Management
IDP	Integrated Development Plan
IMQS	Integrated Management Systems (a company)
IT	Information Technology
JRA	Johannesburg Roads Agency

MFMA	Municipal Finance Management Act
MIME	Municipal Infrastructure Management Environment
MOE	Municipal Owned Entity
NAMS	National Asset Management Support Group
NIMS	National Infrastructure Maintenance Strategy
NPC	National Planning Commission of South Africa
RSA	Republic of South Africa
RUL	Remaining Useful Life
SAFCEC	South African Federation of Contracting Civil Engineers
SAICE	South African Institute of Civil Engineering
SAP	Systeme, Andwendungen, Produkte or (in English) Systems, Applications, Products. A software company originally German
SCADA	Supervisory Control And Data Acquisition
SMMT	Society of Motor Manufacturers and Traders
VBA	Visual Basic Application

CHAPTER 1 INTRODUCTION

Infrastructure Asset Management (IAM) is a tool for making decisions regarding the maintenance of infrastructure so that the infrastructure provides users with acceptable levels of service for the period of its expected life.

Asset Management is a necessary exercise implemented by large corporations. The proactive management of assets and their upkeep enables corporations to receive greatest value on their investments in the assets. IAM has been practiced by many governmental and municipal organisations since the 1970's. Many software applications are available to make the task of asset management simple and quick. These packages incorporate facilities for combining the needs of finance departments with the needs of other departments such as engineering and operations. Plans for maintenance can be easily drawn up. Assets can be scheduled for maintenance, repair, replacement, and eventual retirement in terms of engineering requirements and financial constraints.

IAM is inherently integrated, requiring input of several departments in corporations (Halfawy, 2008). The finance department needs to provide input regarding budgetary constraints, operations need to be capable of attending to scheduled works as well as other works, engineers need to check the condition of assets and report on life expectancies. These tasks are happening within the City of Johannesburg (CoJ) Council. This research went one step further in looking at the cross-enterprise integration of IAM systems.

1.1 CONTEXT

Municipal infrastructure forms the backbone of a city. Infrastructure links businesses, industry, people, cities, provinces and countries. If infrastructure fails, the effects are wide; all suffer economic losses. Even a drop in standards of infrastructure can have negative effects on economies.

Maintenance of infrastructure assets is essential. Asset management provides better levels of service and improves financial efficiencies (National Asset Management Support Group (NAMS Limited) 2011). Users of assets, government bodies and other stakeholders realise financial savings over the life cycle of an asset (Rioja, 2003).

Effective maintenance requires skilled engineers, accountants and human resource personnel as well as trained artisans and trades people, and it requires finance. Municipal resources are strained. Managers need to provide good maintenance with less finance

and dwindling skills (Rioja, 2003). Level of skills of engineers, technologists and technicians is too low in local government to maintain a consistent level of quality in the maintenance of infrastructure (Lawless, 2007).

Municipalities need to discover ways to improve efficiencies in the field of infrastructure asset maintenance. One possible way may be through cross-enterprise integration. Cross-enterprise integration may lead to more efficient use of scarce skills, to better quality and to longer life of assets.

In this context, this research analyses the employment of cross-enterprise integration of IAM systems within the (CoJ).

1.2 PROBLEM STATEMENT AND ITS IMPORTANCE

The intention of this research was to analyse and evaluate cross-enterprise integration in the field of IAM within the CoJ as a possible solution to the problems of scarcity of skills and inadequate funding for maintenance of infrastructure assets.

Infrastructure demands maintenance (SAICE 2011). In SAICE's report card of 2011 on the condition of infrastructure in Johannesburg, SAICE points to two main problems affecting the condition of infrastructure (SAICE, 2011):

1. Skills shortages
2. Lack of maintenance

The area of concern of this research is the lack of effective maintenance in Johannesburg. This absence is partly due to a shortage of skills and dwindling finance resources (Rioja, 2003).

Consequences arising out of the lack of maintenance are:

1. infrastructure will deteriorate,
2. finances of municipalities will be burdened,
3. cuts in spending will occur,
4. people will become angry at the lack of service, and
5. protests may develop.

This study is important as the CoJ needs to be efficient in maintenance tasks to minimise the consequences arising from inferior and lack of maintenance.

A cross-enterprise integrated system was studied to:

1. determine costs of the system
2. determine the needs of cross-enterprise systems
3. investigate CoJ's capability in supplying needs of cross-enterprise systems
4. determine whether benefits of the system outweighed the costs

1.3 OBJECTIVES AND RESEARCH QUESTIONS

The overarching objective of this research was to determine the benefits of cross-enterprise integration and compare these with the costs of setting up necessary systems to implement and operate cross-enterprise integration within the CoJ. In this way, this research evaluated cross-enterprise integration and produced sound arguments for, and against implementation of such systems, or, at least, for further studies on the subject.

In order to determine benefits and costs, the research:

- performed a comprehensive literature review of IAM and cross-enterprise functions in order to:
    i. define and identify infrastructure asset management requirements and worldwide trends
    ii. discover the effects of cross-enterprise integration
    iii. discover achievements in the field of cross-enterprise integration
- investigated the status quo, in terms of IAM, within the three Municipal Owned Entities (MOEs) in the CoJ (viz. Johannesburg Roads Agency (JRA), Johannesburg Water and City Power) involved in this research to highlight necessary work to be performed to implement cross-enterprise systems.
- performed a simulation of maintenance events, over a period of time, to ascertain costs of risks associated with non-integrated systems and benefits from the implementation of cross-enterprise systems.
- Analysed the outcomes of the simulation exercise in a cost to benefit study
- concluded arguments for and/or against cross-enterprise integration and provided suggestions and recommendations based on the outcomes of the above exercises.

1.3.1 Research Questions

Some of the questions addressed in this research are:

- SAICE (2011) mentions the concerning decline of infrastructure services. In what ways can infrastructure services be improved and can there be a better use of current skills and finance?
- Can cross-enterprise integration of infrastructure management systems enhance the efficiency of existing infrastructure management systems?
- What is required to enable departments in the CoJ 'talk' to each other using technology, in a way that allows cross-enterprise integration of infrastructure management?
- Does the CoJ have the organisational structure required for cross-enterprise integration of infrastructure management systems?
- How can the success of cross-enterprise integration be measured?
- Do the advantages of cross-enterprise integrated infrastructure management outweigh the disadvantages?

The research performed analysis of a simulation of infrastructure management over thirty years comparing existing systems with cross-enterprise systems. From this analysis the research put forward positive arguments for implementation of cross-enterprise systems. The simulation showed that cross-enterprise systems provide efficiencies in the field of IAM making use of scarce skills. A method of implementation was suggested.

1.4 SCOPE AND LIMITATIONS OF THE STUDY

This research dealt with the impact on persons and businesses affected by maintenance of municipal infrastructure. It showed benefits of a cross-enterprise system in reducing risks created by maintenance. The research studied a proposed system of cross-enterprise co-operation between three MOEs in the CoJ. The study only addressed economic costs of maintenance and the costs of implementation of systems. The research investigated necessary organisational structures and their costs. It did not venture to determine interaction between persons and MOEs, nor did it take into account managerial skills and leadership qualities.

The scope of this project is limited to the CoJ.

The areas of concern involved the following services:

- Roads (JRA)
- Water (Johannesburg Water)
- Storm Water (Johannesburg Water)
- Sewer disposal (Johannesburg Water)
- Electricity (City Power)

The area of the study was limited to areas south of Johannesburg central business district (CBD) viz. Southdale and Robertsham suburbs.

The CoJ was chosen as the preferred city as it is a large city with MOE divisions. This structure was deemed to be receptive to cross-enterprise integration. The CoJ is also within closest proximity of the researcher. Three MOEs were chosen, JRA, Johannesburg Water and City Power, which together have the most assets in the road reserves. The MOEs are closely linked to CoJ with CoJ being the sole shareholder of each MOE. Other organisations with assets in the road reserve include Telkom, ESCOM, Neotel and Dark Fibre Africa amongst others. These have not been included in the research as access to so many organisations would have been difficult given time constraints.

1.5 STRUCTURE OF THE REST OF THE REPORT

This sub sections listed in this section give a brief overview of the research report.

1.5.1 Literature review

The literature review involves a comprehensive review of local and international practices and trends in the fields of IAM and cross-enterprise integration.

A detailed review of available literature was studied to determine:

- requirements of IAM systems
- nature and benefits of cross-enterprise integration
- costs of IAM events
- costs of repairs and potential hazards arising from damage to an asset caused by contractors' maintenance work on a different MOE's assets

1.5.2 Methodology

Methodology is the reasoning behind the structure of the report. It shows why an experimental type approach with cost benefit analysis was selected as the means to

conducting this research. It details the analysis that was performed. It describes the design of the report

1.5.3 Status quo in Johannesburg Council and MOEs

This section is an investigation into the ways the CoJ conducts business in the field of IAM. The research investigated the status of IAM within three Municipal Owned Entities (MOEs) viz. City Power, Johannesburg Water and JRA. Interviews with relevant personnel were conducted to ascertain:

- current levels of IAM in each MOE
- organisational structures of the MOEs

1.5.4 Experiment

The research included an experimental component where simulation of IAM took place allowing the comparison of costs and benefits of scenarios of cross- enterprise integration systems with current practice in CoJ. A computer program was written allowing input of IAM data to produce maintenance schedules. Points of conflict between municipal services were highlighted and costs allocated to these points.

The hypothetical simulation of maintenance tasks was studied which involved:

- the development of a computer program that allowed users to:
    - generate annual maintenance tasks based on user defined criteria and scenarios and asset data
    - determine areas of conflict where one MOE's maintenance work may influence the integrity of another MOE's assets
    - provide a database of annual costs of conflict areas using the cost library created from literature reviews
    - re-alignment of asset data, for future years, incorporating any changes due to maintenance works assuming maintenance was performed in the period in which it was scheduled
- executing the program to create maintenance tasks for a period of thirty years from 2013
- executing the program to determine conflict areas and their associated costs

1.5.5 Costs of implementation

Expenses associated with the implementation of cross-enterprise systems formed part of the cost to benefit analysis. Costs involved in the implementation of cross-enterprise systems were detailed including:

- Customisation of existing software and/or writing new software
- Setting up Organisational structures to run the new systems
- Training of existing and new personnel
- Offices, furniture and equipment
- Additional day-to-day costs not covered by current systems

1.5.6 Conclusions

After analysis of the data output from the simulation program, a set of conclusions regarding the feasibility of cross-enterprise systems was made.

1.5.7 Requirements for the implementation of cross-enterprise integration systems

The needs of cross-enterprise systems were discussed including:

- The need for standards with regard to data
- Necessary organisation structures
- The process

1.5.8 Recommendations

Based on conclusions, a series of recommendations and a set of steps in implementation were proposed

1.5.9 Further research

Arising from this research are topics which may supplement the research into cross-enterprise systems and generally in the field of IAM. Some studies are suggested for further research.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

The literature review seeks to answer the following questions:

- What is IAM?
  A definition of IAM is important to ensure that the research is conducted and read with a proper understanding of the motives and direction of IAM.
- What is Integration with regard to IAM?
  The basic concept of integration needs to be understood to enable focused and objective assessment of current systems with a view to developing an integration implementation.
- Why perform Integration?
  Apart from the legal and regulatory issues now governing and guiding municipalities in asset management decision-making processes, there are some basic benefits to all stakeholders involved in the management of a municipality's assets and challenges associated with implementation of Integrated IAM systems.
- Are benefits measurable?
- What are the needs / requirements of IAM and its integration?
- Can cross-enterprise integration improve efficiencies of IAM systems?

An analysis of current research, articles, journals and other publications was performed to determine current trends in IAM. IAM has been applied for many years and much literature is available. IAM involves many disciplines including financial, human resources, operations, engineering and others. It certainly involves the use of computerised systems which nowadays enable users to perform complex iterative processes involving many different scenarios on large amounts of data to determine best plans and strategies for the implementation of maintenance tasks.

2.2 SCOPE AND STRUCTURE OF THE LITERATURE REVIEW

The scope of the literature review incorporated a study of available literature on the subject of IAM. It reviewed literature in the field of cross-enterprise integration.

The review comprised:

- Concepts and meanings of IAM, integration and cross-enterprise integration
- Needs and requirements and benefits of IAM systems

- Challenges in implementation of IAM systems
- Meeting legal requirements through the use of IAM systems
- Standards and Guidelines
- Future planning in terms of IAM by CoJ
- Software
- Cross-enterprise integration
- Organisational structures involved in cross-enterprise integration

The review presented a comprehensive study of the many topics identified above. It examined literature from the late 1990's to 2013. Articles were confined to the English language. Most web searches were performed using the University of Witwatersrand library function which allowed access to many electronic databases and thousands of journals, books, and research papers.

The structure of this review followed on from the topics outlined above.

2.3 DEFINITION OF INFRASTRUCTURE ASSET MANAGEMENT

There are many articles that propose definitions for the term "Infrastructure Asset Management". Most do follow similar themes:

> *"Keeping track and deploying public capital….making decisions about development, use, maintenance, repair, and retirement or replacement of infrastructure" (Lemer, 1998).*
>
> *"Assets Management is a methodology to efficiently and equitably allocate resources amongst valid and competing goals and objectives" (Danylo and Lemer, 1998).*
>
> *"The objective of asset management is to meet the required level of service, in the most cost effective manner, through the management of assets for present and future customers" (National Asset Management Support Group (NAMS Limited) 2011).*

The common themes in the above definitions lead to the following definition in this research project:

> *Infrastructure Asset Management is a tool for making efficient and effective decisions regarding the allocation of resources for current and future competing infrastructure needs while ensuring the provision of acceptable levels of service to users of the infrastructure assets.*

Likely **resources** are:

- People (labour)
- Plant
- Materials
- Funds
- Technologies

Needs include repair and maintenance, rehabilitation, and disposal.

Infrastructure Assets, as taken from the *International Infrastructure Management Manual*, include, but are not limited to:

- Transportation Networks (Roads, Rail, Ports)
- Energy System (gas, electricity, and oil production, transmission and distribution)
- Parks and Recreation facilities
- Water Utilities (water supply, waste water and storm water systems)
- Flood protection and land drainage systems
- Solid waste facilities
- Property networks such as educational, health, industrial commercial property, defence and correctional sector facilities
- Community Facilities (libraries, community halls)
- Public manufacturing and process plants
- Public telecommunication networks

Competing Infrastructure needs: Competing needs may be determined by the community. One group may demand levels of services for roads which may not be as important, as levels of service for electricity supply or another sector. Competing needs may give a sense of efficiencies to systems i.e. available funds are spent in a way that best suits the community as a whole (Danylo and Lemer, 1998).

Levels of service may be set by popular demand and originating from users. However, in some instances levels of service are entrenched in laws and regulations governing local authorities (e.g. Water quality in Johannesburg is governed by the regulations set down by the Department of Water Affairs and Forestry (DWAF))

A point to bear in mind is that IAM alone does not complete the task of efficient maintenance. Systems incorporating people, plant and materials, IT infrastructure, organisation, planning, implementing and monitoring need to be in place to ensure that IAM plans are carried out successfully.

2.4 DEFINING INTEGRATION

The Concise Oxford English dictionary, (Oxford University Press, 2008) describes "*integrate*" as: "**1** *combine or to be combined to form a whole.* **2** *bring or come into equal participation in an institution or social group*".

The municipal infrastructure management decision-making process is 'inherently integrated' (Halfawy, 2008). The process involves sets of data for components of assets having different values, life spans, maintenance requirements and other parameters. Engineering, financial, human resources and other functions need to be linked to yield even a simple asset management plan. An interview with City Power on 19 April 2013 indicated that in reality in most local/metropolitan councils, integration is limited to integration within the MOE combining input from financial and engineering sectors with no communication taking place between MOEs. This research is important because there is a possibility that cross-enterprise integration may lead to more efficient use of scarce skills, to better overall quality of infrastructure and to longer life of infrastructure which all translate into cost savings. These savings will be experienced by the council and by the users of the assets alike. One example of many companies collaborating to achieve one goal is the design and construction of Boeing 787 Dreamliner which involved the collaboration of more than 50 different companies (Accenture, 2012).

Integration in this research centres on the cross-enterprise idea of data sharing and combined cooperative efforts between organisations. An ideal approach to integration of asset management is to integrate along departmental as well as multi-disciplinary lines (Halfawy, 2008).

Much work has been done in the fields of cross-enterprise integration (Alshawi, Themistocleous and Almadani, 2004; Themistocleous and Corbitt, 2006). Since the 1970s organisations attempted to implement Enterprise Resource Planning (ERP) to integrate the different systems within their organisations (Alshawi, Themistocleous and Almadani, 2004). ERP entailed an integrated effort combining different disciplines within organisations. ERP was and still is considered to be hugely beneficial for an organisation to remain competitive. Alshawi, Themistocleous and Almadani (2004) go on to state that ERP has unfortunately not proved to be a single solution to an organisation's integration needs. In most instances ERP remains a back-office type product which struggles to integrate with manufacturing and other front-office applications. ERP has caused organisations to install a 'best-fit' application which may work well in some disciplines but may sacrifice other areas of its operations. In many instances costly and time consuming

customisation with ERP has taken place to eventually attain some form of integration (Alshawi, Themistocleous and Almadani, 2004).

Currently there is increased awareness and implementation of Enterprise Application Integration (EAI) which involves a set of tools for receiving data from different applications that are properly suited for their own tasks, manipulating the data, and transmitting the data to a single application that handles the organisation's integration needs (Alshawi, Themistocleous and Almadani, 2004) The data may then be transmitted back to relevant organisations and departments via the same EAI tools.

This approach does beg two pertinent questions (below):

- Who manages (leads) the IAM process?
- Who controls, manages, and owns the data?

2.4.1 Who manages the Infrastructure Asset Management (IAM) process

There are certain challenges that must be addressed when implementing a cross-enterprise collaborative effort which are outlined in section 2.6. Briefly the process requires a working group of personnel who are given the authority and responsibility to implement the systems, to co-opt necessary personnel and resources, to ensure that work is performed according to plans and programs and to be able to hold organisations and personnel accountable (Goethals and Newlands, 2009).

2.4.2 Who manages the data

Halfawy (2010) suggests that there are arguments for and against employing a central data repository (see section 2.6.2). Interviews with City Power on 19 April 2013 and Johannesburg Water on 13 June 2013 indicated that the MOEs studied in this research have systems that are complex and involve many sub-systems. Any attempt to produce one central data repository would involve enormous effort. It is for this reason that Halfawy (2010) states that a single system is impractical and therefore best for data to reside with the organisation most suited for its maintenance and upkeep.

In summary, integration, which is addressed in this report, involves co-ordination of infrastructure management processes, data flow, the integration of data and the integration of software applications (See section 2.5).

2.4.3 The difference between Integrated and non-integrated systems

In a non-integrated system, maintenance work is carried out on a facility without notifying the other MOEs of the maintenance carried out. Hence, the risk of damages to other works in the area is unknown, un-quantified and no plans exist for dealing with the risk.

In an integrated system, all institutions with infrastructure within the vicinity of an MOE's maintenance work are made aware of the maintenance work to be performed and the possibilities and risks of damage to their infrastructure can be quantified. Decisions to perform maintenance work on the service may be done at the time of maintenance on the other asset. This negates the need for redundant works which may occur when one MOE may later destroy maintenance works of another MOE, which may happen in the non-integrated system. But, more than the coordination of works, is the ability to inform of impending risk. This report enables the MOE to plan a strategy, based on risk, of protecting their asset or at least employing a contingency plan.

2.5 THE NEED FOR INFRASTRUCTURE ASSET MANAGEMENT

In developing countries, emphasis is often placed on building new infrastructure at the expense of maintaining existing infrastructure (Rioja, 2003). Rioja (2003) provides a model to illustrate that reallocation of funds from new capital projects to maintenance of existing infrastructure is, in some cases, a sound economic decision resulting in positive and increased efficiencies of operating performance for the lifecycle of the infrastructure assets.

This section of the Literature Review considers various factors associated with the implementation of IAM and the integration of the systems. Benefits and legal associations are outlined.

Without Asset Management tools, would assets fail? Inevitably assets are subject to wear and tear, and therefore deteriorate. Whether there is a system or not, assets will decay. It can be accepted that regular maintenance and timely repair prolong the life of an asset and give users consistent value. In a World Bank report involving 26 countries across Europe and Asia, improving infrastructure quality is estimated to save businesses between 0.5% and 4% of electricity and water bills (Iimi, 2008). In the same report, Iimi (2008) shows that reduced electricity and water outages may result in cost savings to a country equal to a figure between 0.5% and 6% of the country's GDP.

IAM systems allow us to plan maintenance. They promote the best use of resources, and through integration, can effectively create an environment of awareness of relationships between different assets with different functions. With this awareness, IAM systems may foresee possible dangers to specific assets when work needs to be performed on a linked asset.

IAM involves:

1. Identifying Assets
2. Component Separation
3. Collection of data
4. Valuation of assets, and components
5. Determination of level of service required
6. Determination of funding and resources
7. Risk analysis
8. Analysis of data
9. Construction of an IAM Plan
10. Implementation of the Plan
11. Monitoring of the Plan and
12. Reporting outcomes of the Plan

For the above tasks to take place, municipal entities will require:

- Human Resources with the necessary skills
- Technology that enables capturing of data
- Technology that stores and maintains security and integrity of the data
- Technology that enables analysis of data
- An organisational structure that allows efficient flow of data, clear instruction and implementation of plans without delay

2.6 BENEFITS OF IAM

Many sources of information on IAM highlight numerous benefits.

The International Infrastructure Management Manual lists a host of benefits resulting from improved asset management. Effective asset management yields accountability, sustainability, better customer service, effective risk management, and improved financial efficiencies (National Asset Management Support Group (NAMS Limited) 2011).

Timely maintenance results in large savings over the life cycle of an asset (Rioja, 2003), as opposed to employing expensive rehabilitation and reconstruction programs when quality of the asset reaches a point of crisis. These savings are not only to the supplier (owner) of the asset but to the users of the asset.

The Australian Austroads Integrated Asset Management Guidelines for Road Networks identifies many benefits. Among these are: efficient and effective use of funding, clear service level objectives and transparency in investment decision-making (Austroads Asset Management Reference Group, 2002).

Through integration, municipalities can make better use of resources, provide a more consistent level of service spanning different types of assets, reduce total workloads, and improve efficiencies from a financial perspective. As identified by Halfawy (2008) and Shahata and Zayed (2010), “The need to adopt an integrated approach to infrastructure management is widely recognised in industry and academia”.

2.7 REQUIREMENTS OF INFRASTRUCTURE ASSET MANAGEMENT SYSTEMS

Many of the requirements mentioned in this section have been taken from IIMM (NAMS, 2011).

Before establishing an IAM system, organisations need to develop a policy (see section 2.5.1) for IAM. With this policy in place, the next step for the organisation is to develop a strategy (see section 2.5.2) for design and implementation of the IAM plan (see section 2.5.3).

One of the most critical requirements of an IAM system is leadership. It is important that executive management buy-in to the idea of having IAM as an integral part of doing business. A department, organisation or workgroup needs to drive cross-enterprise integration and must have full authority to carry out the actions required for the successful implementation of the IAM system(s) (Goethals and Newlands, 2009).

Implementation of IAM systems needs to be performed in an organised manner i.e. coordinating management processes, data integration, data management and data distribution (Halfawy, 2008).

2.7.1 Policy

An IAM policy outlines an organisation’s principles and requirements for asset management. It identifies laws and regulations concerning asset management and

reporting. It outlines team composition and deals with the planning and implementation of system. Policies should be communicated to personnel. If personnel are to promote the objectives of the IAM policy they need to be aware of the policy and they need to identify with the objectives. Policies should be in written form and these documents should be distributed to relevant managers and team leaders. Further communication may be in the form of training workshops and seminars. Any anticipated changes and amendments to policy should first be discussed with relevant mangers to ensure that agreement on policy is reached before implementation (NAMS, 2011).

2.7.2 Strategy

The IAM strategy will determine the objectives of the IAM plan. The strategy specifies the manner in which policy objectives are to be achieved. The strategy must therefore include the following:

- Specifications regarding asset types
- Methods of measurement of service levels
- Targets of service levels for different assets
- Categories of users of assets
- Funding needs and sources
- Budgetary information which may impose restrictions on asset maintenance
- Responsibilities of team members involved in the IAM systems
- Prioritisation of maintenance by asset type and categories
- Scheduling of IAM plans.
- Methods of recording of all information regarding IAM plans and maintenance.
- Methods of recording and reporting financial data regarding IAM plans.

2.7.3 Infrastructure Asset Management Plan

A well designed IAM plan should include:

- Levels of service- definitions based on stakeholder input, regulations, laws and community participation.
- Demand forecasts – changes to population growth rates, technologies, climate and other factors are taken into account in deciding future demand and the ability of assets to withstand stresses placed on them through the anticipated demand
- A lifecycle Management Plan which spans the expected life of the asset and details costs and scheduling of maintenance, renewal, replacement and

refurbishment. The plan includes the importance rating (priority) of assets and methods and costs of disposal.

- Asset Inventories- detailed inventories are needed for constructing the IAM plan. Inventories should include technical, valuation, maintenance, condition, predictive performance, risk and lifecycle data.
- A lifecycle plan detailing maintenance and operations for a given period.
- A financial report detailing IAM requirements are compiled and reported.
- Periodic assessments of the current IAM plan to allow for improvement to the plan.

2.8 CHALLENGES IN IMPLEMENTING INTEGRATED SYSTEMS

The benefits of Integrated IAM systems might sway the reader into believing that IAM is a golden key to our asset management problems. However, the systems do not come without challenges and some needed, up-front, focused effort in the design and implementation of the systems. As mentioned in section 2.5, IAM requires a number of resources, procedures and processes; it needs skilled personnel, organisation structures, detailed data, robust hardware and software amongst other items and systems (Halfawy, 2010). Some key challenges of implementing IAM are:

2.8.1 Affordability

One challenge in installing IAM systems is to balance a city's available resources with the desired level of management. An overriding factor of influence in establishing a level of asset management is the city's budget - a question of affordability. No good can come out of aiming at an advanced asset management system if a city can only afford a simple core type system (see table 2.1). Affordability may not only mean financial affordability, it may point to other available resources e.g. skilled personnel. In any event, IAM systems are often installed in phased approaches and hence could mitigate unaffordability (Halfawy, 2010).

This research addresses some of the challenges noted above.

2.8.2 Information Technology

Halfawy (2010) notes that integrated IAM requires 3 main items:

1. Efficient coordination of data flow,
2. Efficient integration of data, and
3. Integration of software applications.

Halfawy (2010) goes on to describe the 3 main challenges to achieving the 3 requirements:

1. Systemisation of processes,
2. Data integration, and
3. Software integration.

In relation to systemisation of processes, Halfawy (2010) believes that application of current guidelines and models result in data being captured in formats based on 'trial-and-error' processes. Formalisation of models needs to be addressed at Councils in order to ensure systemic data capture, and a reduction or elimination of subjectivity in decision-making.

In relation to data integration: Data Integration is the process of combining 2 or more data sets from different sources to form one set of data. Benefits, according to Halfawy (2010), arising from data integration are:

- Integrity of data
- Completeness of data
- Reductions in duplications (of data fields, and effort)

There are arguments for maintaining a central repository of data and arguments for distributed databases. Each has advantages and disadvantages. Data must be made available to all departments efficiently and speedily, while maintaining integrity.

In relation to software integration: Software integration is the integration of software applications – bringing together separate sub systems into one system. There are many 'stand-alone' software systems in place for various disciplines and IAM activities. As indicated by Halfawy (2010), "Developing an integrated Municipal Infrastructure Management Environment (MIME) as one single system is both infeasible and impractical". Halfawy (2010) is referring to integration of whole environments (see chapter 4), which contain numerous sub systems. Integration of these software systems is a mammoth task involving complex sets of data and inter-relationships. Ideally one wants to keep these systems functioning as they are, doing the tasks for which they were initially programmed, and employ a translator to allow data to flow easily between the systems and any new IAM system while maintaining its integrity. The need for 'middle-man' software or Application Integration (AI) software is most often required (Alshawi, Themistocleous and Almadani, 2004).

One way to address problems of many stand-alone applications is to form a modular and open computer architecture (not proprietary), which allows the exchange of data or software tools without negative influence to other components of the systems (Halfawy, 2008).

Some standards for data modelling and exchange are available e.g. ISO 10303 (Halfawy, 2010).

2.8.3 Organisational Challenges

The IAM process requires commitment from governing bodies and people. IAM demands good leadership. It requires a policy, and adherence and enforcement of the policy (NAMS Limited, 2011). Also, IAM

- requires an organisational structure that promotes free flow of data.
- requires a certain set of skills. Personnel need to be positioned correctly within an organisation. On-going research, monitoring, training and development of personnel must be addressed.
- must become a 'way of life' in the ordinary activities of a municipal entity.
- is a long term process and should not be judged in the short term Gains or losses should be considered over the long term.

Goethals and Newlands (2009) argue that there are eight challenges that must be addressed when considering integration of organisational processes:

1. processes need to be clearly defined
2. processes need to be communicated to all parties involved
3. service levels and expected outcomes must be defined
4. a party must take responsibility for driving the process
5. this party should be given the necessary authority to make necessary decisions
6. this party should be able to co-opt people to perform activities
7. this party should be able to acquire relevant data
8. this party should take action if tasks are not performed correctly

2.8.4 Skills Shortages

Systems do not comprise only technologies and computers, people are an integral part of systems. Systems cannot run efficiently without people with the necessary skills.

Research, performed in South Africa and internationally, shows that the level of engineers, technologists and technicians is too low in local government to maintain a consistent level of quality in the maintenance of infrastructure (Lawless, 2007). Lawless (2007) states that South Africa, in the eighties, experienced a good supply of civil engineers in local government having 20 professional civil engineers to 100,000 people. Professional engineers are engineers accredited as professional by the Engineering Council of South Africa, (ECSA). Unfortunately, that figure dropped during the next 2 decades for several reasons. Firstly, there was a move to outsourcing which led to many engineers moving from jobs in local government to employment in the private sector. This, in turn, meant that many local governments experienced increasing dysfunctionality of teams of engineers, technicians and other technical staff. To add to this dilemma, restructuring of councils took place with many experienced personnel being offered retirement packages, and this coincided with the expansion of local government. In particular, Johannesburg expanded to include previously independent towns such as Randburg, Sandton, and Midrand and a largely neglected Soweto which required equal levels of service delivery. As a result of this restructuring, infrastructure began failing and severe backlog in service delivery developed. Lawless (2007) notes that in future, technical capacity needs to be rebuilt and organisational structures in local governments must support the training of engineering staff. Training schemes must be formalised and local government needs to put in place methods for attracting professional engineers with experience. Approximately 1 professional civil engineer is needed for every 20,000 persons (Lawless, 2007).

The National Planning Commission of South Africa (NPC) issued a document in 2011 highlighting the skills shortage situation in local government. Through employment strategies of local government in the 1990's and 2000's many professionals have moved from the public sector to the private sector. Training and mentoring have therefore been neglected. NPC (2011) discuss a "*looming crisis*", and goes on to say that, "*without in-house technical expertise, provincial and local governments lack the capacity to ensure the work is done to an adequate standard or to maintain the infrastructure once the work has been completed*."

SAICE reports on strategies put forward by the Construction Industry Development Board (CIDB) to garner more engineers and/or to reduce the demand for engineers (Watermeyer and Pillay, 2012).

Three strategies were proposed

1. Increase supply of critical skills

Strategies in 1971 and 2005 centred round the idea that supply of engineers by tertiary institutions was insufficient. It appears now that supply of engineers by tertiary institutions is sufficient and focus should now be on developing the skills of graduate engineers and ensuring that they register with ECSA as professional engineers (Watermeyer and Pillay, 2012).

2. Reduce demand

   Reduce reliance on professionals through economies of scale by structuring public sector projects into large multi-year projects

3. Accelerate development of critical skills

   Ideas for this strategy revolve around setting and publishing of standards for professionals, developing tools and techniques which may be understood by other professional disciplines, recognising and accrediting special civil engineering skills, providing professional guidance to members of engineering organisations.

The lack of engineering skills, bearing in mind that IAM demands several sets of skills, is not easily quantifiable. Even with the above mentioned strategies, Watermeyer and Pillay (2012) note that there is still a need to develop more strategies to accelerate learning and experience.

2.9 LEGAL ISSUES, STANDARDS AND GUIDELINES REGARDING IAM

2.9.1 Legal issues surrounding IAM

It is expected that local governments are accountable for the provision and maintenance of services to their constituents. The constitution of South Africa lays down these basic principles regarding the obligations of local governments:

Section 152

1. The objects of local government are-

- *(a) To provide democratic and accountable government for local communities;*
- *(b) To ensure the provision of services to communities in a sustainable manner*
- *(c) To promote social and economic development*
- *(d) To promote a safe and healthy environment*
- *(e) To encourage the involvement of communities and community organisations in the matters of local government*

Section 153

A municipality must –

(a) Structure and manage its administration and budgeting and planning processes to give priority to the basic needs of the community, and to promote the social and economic development of the community; and
(b) Participate in national and provincial development programmes

The Local Government Municipal Finance Management Act 56 of 2003 (MFMA) sets out basic regulations concerning budget and financial management within local government. The Municipal Systems Act 32 of 2000 and the National Treasury's Local Government Capital Asset Management Guidelines indicate that local governments need to construct an Integrated Development Plan (IDP). The plan must take into consideration maintenance and operations of assets. The plan is reviewed annually. Section 25 of the Municipal Systems Act shows reference to the IDP below.

Chapter 5 Municipal Systems Act Section 25(1)
***25**.(1) Each municipal council must, within a prescribed period after the start of its elected term, adopt a single, inclusive and strategic plan for the development of the municipality which –*
(a) links, integrates and co-ordinates plans and takes into account proposals for the development of the municipality;
(b) aligns the resources and capacity of the municipality with the implementation of the plan;
(c) forms the policy framework and general basis on which annual budgets must be based;
(d) complies with the provisions of this Chapter; and
(e) is compatible with national and provincial development plans and planning requirements binding on the municipality in terms of legislation.

Regulations governing local governments centre round the MFMA and Generally Recognised Accounting Practice (GRAP17) (Boshoff and Pretorius, 2010). GRAP contains many different standards. GRAP number 17 refers to property, plant and equipment (Department of National Treasury, 2008).

GRAP17 indicates the need for municipalities to:

- Componentise assets – break assets into components classified through functionality (e.g. Roads may contain layer works, surfacing, kerbing, road signs, and so on)
- Ascertain replacement costs of components – this may be performed using a cost or revaluation method. Annual reviews of replacement costs are necessary at some stage in the life of assets.
- Maintain a structured asset Register.
- Provide an Asset Management Policy. The policy should at least outline the organisation's understanding and application of asset management, its application of accounting standards, valuation method(s) used, and the useful life expectancies of its assets.

A municipality is audited periodically by the Auditor General. The Auditor General does not only investigate financial matters, he also measures performance with regard to asset management operations. The consequences of a qualified audit may be harmful to the operations of the municipality. A target has been set by the National Government in South Africa for all municipalities to achieve clean audits by 2014 (Boshoff and Pretorius, 2010).

2.9.2 Standards and Guidelines

Worldwide there are moves to aggregate experiences and expertise to form guidelines and standards in the area of IAM Systems. Documented below is some of the current work performed in some countries in respect of standards and guidelines.

2.9.2.1 South Africa

The CIDB has produced several documents concerning Asset Management in South Africa. In association with the National Treasury and Department of Provincial and Local Government, the CIDB have produced a set of guidelines and toolkits for the procurement of assets (CIDB, 2011). The guidelines are seen as "*a start to improving budgeting for infrastructure maintenance but not a substitute for proper infrastructure asset maintenance*" (CIDB, 2011). Within the guidelines, asset maintenance is mentioned as a category of expense to be considered in the procurement process. The Infrastructure Delivery Management Toolkit (CIDB, 2010) goes some way to producing a comprehensive set of guidelines and step-by-step processes for sound infrastructure maintenance.

The CIDB are also actively involved in the formulation of NIMS – the National Infrastructure Maintenance Strategy. This they are doing in conjunction with the Council of Scientific and Industrial Research (CSIR) and the Department of Public Works of the Republic of South Africa (DPW). NIMS was approved by cabinet and addresses issues of service delivery (CIDB, 2007). The strategy defines policies concerning infrastructure investment and maintenance (Wall, 2008).

NIMS refers to the plans and visions of national government. Four main areas of focus form the basis of NIMS:

1. Providing a regulatory framework including planning and budgeting regulations.
    - Linking of capital, operational and maintenance budgets with IAM plans of all government organisations.
2. Assisting organisations with non-financial resources.
3. Developing an industry specifically relating to maintenance tasks.

- Building capacity within the building and engineering sectors. Providing learnerships and mentorships and enabling training to develop skills.

4. Enabling the monitoring of assets with a view to improving the performance of an asset(s).

2.9.2.2 New Zealand and Australia

The International Infrastructure Management Manual (NAMS, 2011) is a document widely used by engineers in the business of IAM. The manual was compiled by the New Zealand Asset Management Support (NAMS, 2011). It comprehensively describes guidelines for the implementation of IAM from creating organisational policies to information systems, procurement strategies, quality management and monitoring processes.

IIMM (NAMS, 2011) identifies several processes (see figure 2.1) in building a good IAM system. Policies need to be assembled and communicated to personnel, levels of service must be set, future demand must be estimated, an asset register is to be compiled, conditions of assets listed, risks identified and catalogued and strategies for maintaining assets determined.

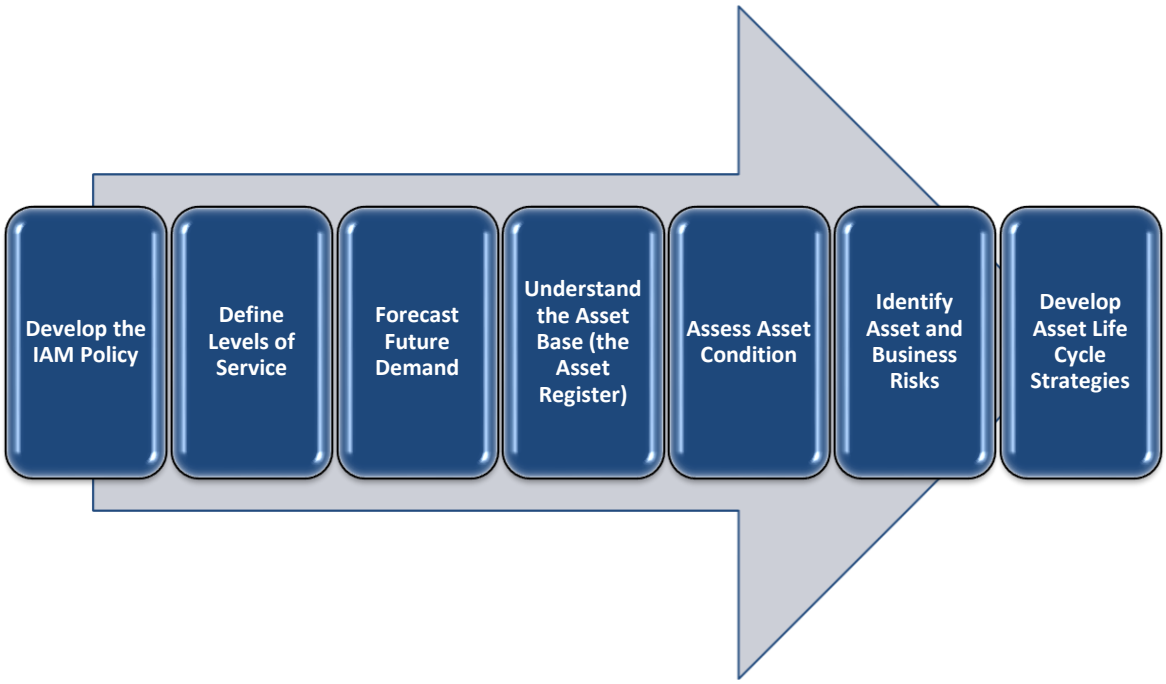


Figure 2.1 Processes in IAM (NAMS, 2011)

IIMM (NAMS, 2011) describes four levels of IAM; Minimum, Core, Intermediate and Advanced (see table 2.1). Municipalities need to fit their resources with the most appropriate level of IAM. Some sections of IAM may be minimum or core with other

sections being more advanced. IIMM (NAMS, 2011) describes the levels as the ‘maturity index’ of an organisation’s IAM.

The definitions in table 2.1 are intermittently referred to in this document with regard to the status quo of various MOEs in Johannesburg (see chapter 4).

Table 2.1 Levels of IAM (NAMS, 2011)

Level of IAM	Description of level of IAM
Minimum	Basic IAM. Achieves basic requirements as set out in legislation. **Policy:** Simple requirements of IAM are noted, e.g. asset maintenance plans to be compiled annually. **Levels of service:** Basic levels of service are defined. **Demand Forecasting:** Demand forecasts are based on experienced staff predictions. **Asset Register:** Basic physical information of assets is recorded. In instances where determination of characteristics of assets is difficult, such as underground pipes and cables, reasonable assumptions may be employed to record characteristics. **Asset Condition:** Critical assets are identified and condition noted. **Risk Management:** Risks of critical assets are analysed. **Lifecycle Strategy:** staff judgement, operational strategy and plans are mainly reactional, maintenance records are kept and maintenance is at a level compliant with legislation. Schedule of proposed capital investment projects is kept based on staff judgement.
Core	IAM is more advanced than the minimum level and can be incorporated into business processes to assist with business decisions. **Policy:** Policy is in place for all significant activities. High level action plans are in place with personnel responsibilities defined. **Levels of service:** Requirements of customers are analysed. Performance measures are in place and are monitored with annual reviews taking place. **Demand Forecasting:** Demand forecasts are based on statistics (e.g. population growth). Risk is calculated. **Asset Register:** As for minimum plus asset replacement cost and age. **Asset Condition:** Major assets are assessed. **Risk Management:** Risks of major assets are documented. Risk management strategy is developed for these assets. **Lifecycle Strategy:** Emergency response plan is in place, key maintenance objectives are defined and measured. Proposed capital investment projects are fully defined in terms of 'scope of works' and costs.

Intermediate	Provides knowledge of processes to an organisation. **Policy:** Policies and strategies are formally set out and communicated. Annual review of policies and strategies takes place. Detailed action plans including details on resource requirements, personnel responsibilities' and scheduling are included in the IAM plan. **Levels of service:** Customer requirements are analysed. Costing to provide levels of service are calculated. Alternatives are considered. **Demand Forecasting:** Demand forecasts are based on analysis of trends looking at historical data predictions concerning key factors such as population growth. Different scenarios are drafted and analysed. **Asset Register:** Physical and financial characteristics are recorded. **Asset Condition:** Condition of assets based on periodic assessments. The assessment of condition is a process that is fully integrated with other business processes. **Risk:** A risk register is kept up-to-date with periodic review and assessment of risks. **Lifecycle Strategy:** Decisions regarding IAM are based on a set of techniques involving prioritisation of assets and in accordance with the organisation's operational, maintenance and capital investments programmes and policies. Emergency response plans are in place, asset utilisation is measured, contingency plans are in place. Maintenance management software is used. Programmes for long term major capital investment are in place at least conceptually with broad cost implications.
Advanced	IAM is fully integrated with all business systems. **Policy:** Policy and strategy are fully integrated with other business processes. Audits are conducted. **Levels of service:** Customer needs are studied, strategies to supply levels of services are applied. Decision making in all areas of business incorporate the customer needs analysis. **Demand Forecasting:** Future demand is as for Intermediate plans but include further risk assessments of scenarios. Based on these risk studies scenarios with overall best attributes are selected. **Asset Register:** All assets are captured with their properties such as work history, costs, condition, performance, etc. Data is maintained. **Asset Condition:** Condition of assets is known and recorded and checked periodically. Data concerning conditions is used when establishing risk and IAM decision making. **Risk:** Risks are calculated and programmes for mitigating risk are defined. **Lifecycle Strategy:** Decision making is as for Intermediate plans but includes risk based sensitivity analysis. Outcomes from operational activities are measured and analysed routinely. Incidents of repair and maintenance are analysed and reported. Faults in assets are analysed and reported. Long term capital investment strategies and projects are compiled and analysed.

2.9.2.3 British

The British Standards Institution, in 2008, published the “PAS55” set of guidelines for Asset Management. The guidelines cover numerous aspects of Asset Management from requirements of Asset Management systems to building strategies for Asset Management plans to everyday maintenance of assets.

2.9.2.4 United States of America (USA)

The United States has many local authorities implementing infrastructure asset management practices, and consequently approaches to IAM vary greatly (US Department of Transport, 2007). While different states may implement IAM in different ways, according to the US Department of Transport (2007) they generally agree on the following items relating to IAM:

- Data Collection and integration
    - Collecting data concerning assets condition, applying standards to the data, ensuring data quality, automating data collection.
- Condition assessment
    - Creating means to assessing hidden infrastructure
    - Remote sensing and warning systems
    - Linking condition assessment with decision-making
- Performance modelling
    - Planning routine and preventative maintenance
    - Applying performance measures
- Analysis of the above
    - Prioritising maintenance on various assets
    - Risk analysis
    - Methods for selection/prioritisation of maintenance tasks

In 1999 the USA committed local authorities to comply with Governmental Accounting Standards Board Statement 34 (GASB 34) which forced local authorities to list inventories of assets on their accounting records. Further to this, the EPA had, in the 1990’s, promoted the use of a program dealing with Capacity, Management, Operation and Maintenance (CMOM) for water systems (Cagel, 2003).

The Institute of Infrastructure Asset Management (IIAM) in USA is an independent organisation that provides advice, holds seminars and workshops and provides training in the USA. It does not provide services to all of the USA, although they are currently expanding services across the USA (IIAM, 2014).

2.9.2.5 International Standards

The International Organisation for Standards (ISO), are an organisation made up of 166 member countries. They are based in Geneva, Switzerland. The ISO compile standards that enable definitive, sound specifications to be produced for services, systems and materials, “to ensure quality, safety and efficiency” (ISO, 2014).

The International Organisation for Standardisation has compiled standards (ISO 55000 series) relating to the implementation of Asset Management Systems. ISO 55000 comprises three sections:

- ISO 55000 Asset Management overview; principles and terminology
- ISO 55001 Asset Management- management systems requirements for integrated, effective systems
- ISO 55002 Asset Management- management systems - guidelines on the application of ISO 55001

The ISO 55000 series were published in 2014.

2.10 GDS2040 AND THE IDP

In terms of the Municipal Finance Management Act 56 of 2003 (MFMA), municipalities are required to produce integrated development plans (IDP) for development and maintenance of infrastructure (see section 2.7.1). Johannesburg formulated an IDP called the Growth and Development Strategy 2040 (GDS2040) which outlines strategies for development to 2040. The CoJ stated in an interview on 28 August 2012 that IAM is not included in the GDS2040 as a separate program. Work needs to be done to translate strategies to asset management plans and operations.

2.11 SOFTWARE AND CUSTOMER SERVICE SUPPORT

Many IAM software systems are available on the market.

The CoJ uses several systems for IAM; JRA uses an application called “HANSEN”, Johannesburg Water uses SAP and IMQS, and City Power uses SAP. But these applications do not function alone as they are fed data from numerous other programs and applications. JRA has various Pavement Management systems, Bridge Management systems, Storm water Management systems, Accident Management systems, and Capital Infrastructure Management systems (among others). City Power has a conglomerate of applications including SCADA systems, SAP, Operations software, Engineering services

software, Risk Assessment Compliance software and various financial components. Johannesburg Water makes use of 2 major systems, SAP and IMQS. All MOEs use GIS systems which may perform tasks related to visual inspections and query of data.

2.11.1 Cross-Enterprise Software

Enterprise integration is accepted by large organisations as critical to the success of a business (Themistocleous, 2004). Organisations began implementing Enterprise Resource planning (ERP) software as early as the 1970's. ERP involves the sharing of data and applications that allow the automation of certain activities. ERP presented some challenges however: software was generally more suited to back office tasks and did not integrate well with front office tasks such as operations and manufacturing processes. The ERP systems generally required costly and time consuming customisation.

2.11.2 Case Study on the application of Enterprise Software

In one particular case study outlined by Alshawi, Themistocleous and Almadani (2004), a Telecoms company, given a fictitious name of S-Tel by Alshawi, Themistocleous and Almadani, faced the problems of having to integrate old software (legacy systems). Software of this nature often has little or no documentation and data integrity is often questionable.

The company was a large corporation with offices in different parts of the world. It supplied a set of diverse telecoms equipment and systems.

The company hoped to install SAP software but discovered that SAP software did not address HR requirements sufficiently. They were faced with 3 options:

1. To install SAP and endure a long, extended and expensive period of customisation with its pitfalls.
2. To attach add-on software to existing and new systems
3. To develop a middle-man software application to interface between new HR systems and SAP software.

The company chose to develop a middle-man software application to interface between the HR software and SAP software by extracting data from systems, building adapters and uploading new data to both systems. This link between the 2 systems was developed using EAI tools. Central to the success of the company's EAI solution was:

- A centralised database, allowing control of data, integrity and security

- Allowing access to the manipulation of data within a secure environment for reporting purposes
- Real time access to data
- Automation of processes with the reduction of personnel involvement
- An attempt to create paperless processes
- The avoidance of customisation

This case study showed that it was feasible, time efficient and cost effective to promote EAI solutions.

2.11.3 Software Development teams and methods

The size of a software development team will vary according to the amount of code to be written, the complexity of the application and the constraints of budget and time on the project (Putnam, 2014). Putnam (2014) performed research to determine optimal sizes of software development teams that achieve greatest productivity in a short period of time at least cost. The method of Putnam's (2014) research was to select 491 projects which had between 35000 and 95000 lines of code. The sizes of teams for the projects were grouped into 5 sets. Putnam (2014) concluded from his study that a team size of between 3 and 7 persons was optimal. This team, Putnam (2014) states allows the team to operate efficiently despite any member leaving the team. Individual members will be able to contribute meaningfully to the project without being overwhelmed by others in the group. Communication is better within a smaller team and no large overheads are present.

Various methodologies exist for software development. Two common methodologies of software development are the Waterfall method and the Agile method (Wallace, 2014). The Waterfall method employs a set of sequential steps involving analysis, design, programming, and testing. The Agile method of software development is an iterative or incremental method which allows development to take place in short, quick runs producing a modular design. Both methodologies have advantages and disadvantages. Waterfall is a traditional project management system which has a rigid structure, enforces good record keeping and documentation but lacks flexibility and may not use resources efficiently (Wallace, 2014). Agile allows for greater flexibility, and easier changes to software which means the software can address latest trends but it needs good control by management or the process can move off its intended direction and benefits of the system may not be realised (Soundararajan, Arthur and Balci, 2012).

2.11.4 Call Centres

Call Centres have been around since the early 1970's. They have advantages and disadvantages. Call centres can sometimes become distant from the organisations that make use of them. Some questions may be asked of call centres and those who employ them: "What is the relationship between the call centre and the rest of the organization? Are there proper measurable achievements and/or failures that can say whether or not the call centre is functional and helpful to an organisation and its customers?" (Dawson, 2007).

It is important that call centre reports do get through to the right MOE and the right departments within MOEs. The ability to attend to faults quickly, or at least to assess risk, is enormously profitable to the organisation and users. In order to do this, organisations need some security on data and channels for dealing with data. Calls must all be addressed; manual capturing of data at any point provides a weak link in the system. Furthermore, there needs to be a method of examining the usefulness and effectiveness of the call centre operation (Dawson, 2007).

2.12 SUMMARY OF THE LITERATURE REVIEW

Key to this research is examining the benefit of cross-enterprise integration, in the field of IAM, within the CoJ. Looking back at the review there are instances of successful co-operation between different companies in cross-enterprise environments that promote greater efficiencies of systems (Accenture, 2012; Alshawi, Themistocleous and Almadani, 2004; Themistocleous and Corbitt, 2006). There is no evidence of this form of co-operation between MOEs in the CoJ. There is a gap in the literature with reference to cross-enterprise systems within the municipal context. The research must address this issue and answer the following questions:

- Can cross-enterprise solve or mitigate problems relating to scarcity of skills and inadequate funding?
- Has the CoJ the need to implement cross-enterprise integration?
- Which is the best way forward for CoJ in respect of IAM?

Several key concepts emerge from this review:

- The need for standardisation of data. Cross-enterprise systems access data from different sources. Data needs to be standardised or, at least, converted to a standard format through the use of applications that can act as translators and interpreters of data to enable cross-enterprise systems to function correctly

- Cross-enterprise systems comprise more than software. They comprise people with skills, IT-infrastructure, software, communication channels, and organisational structures.
- A shortage of skills is prevalent in the CoJ and the MOEs.

IAM is a system for the maintenance, renewal, replacement and refurbishment of infrastructure assets with the aim of achieving the required levels of service for the life of the asset. Integrated IAM systems outlined in most literature, refer to inter disciplinary integration such as co-operation between financial and engineering departments. The benefits of IAM include better use of resources and the provision of consistent levels of service.

IAM systems are necessary due to legal obligations on local government institutions. Various acts of law enforce local government to produce inventories of infrastructure items and components of items, with the condition, value and expected life of each asset listed.

IAM functions through good leadership and management commitment to the processes of IAM. Systems require policies, strategies, and sets of reliable, accurate and up-to-date data. Maintenance plans are produced periodically and work should be monitored and events reported to enable maintenance of databases.

Several other challenges exist in producing and operating successful IAM systems. Data for IAM inventories has over years and through the use of many different computer applications become fragmented. Skills are scarce. South Africa faces challenges in terms of skills shortages and reduced funding. Municipalities need systems that promote best use of scarce resources. Organisational structures must allow for good, decisive leadership, and communications that enable flow of necessary data. The structures should clearly show levels of responsibilities for personnel and personnel must be held accountable for the outcomes of the IAM systems.

Integration requires more than software development. It requires the establishment of systems. Systems include people, plant and materials as well as IT infrastructure and proper processes that involve planning, implementation and monitoring. IAM requires its own organisational structures and the continuous commitment of management.

Several challenges exist when implementing cross-enterprise integration. Organisations need to find ways of adapting data from different sources, which is in many instances in varying formats. They need to have a body controlling the process of integration, planning, monitoring, and implementing operations. Communications between participants is vital to the success of a cross-enterprise system.

CHAPTER 3 THE METHODOLOGY

The Methodology developed for this research addressed the four objectives crafted for this research project i.e.

1. To undertake a detailed Literature Review
2. To investigate IAM in the CoJ Council and the following MOEs: City Power, Johannesburg Water and JRA
3. To develop a tool that would permit the study of a hypothetical series of maintenance events over time in two suburbs of Johannesburg which would allow the comparison between integrated and non-integrated systems and analyse their performance.
4. To compile a final report that will:
    a) show the costs, benefits and impacts of IAM on CoJ, its MOEs and other stakeholders;
    b) conclude arguments for and/or against cross-enterprise integration and provide suggestions and recommendations based on the outcomes of the above exercises.

3.1 RESEARCH DESIGN

The intention of this research was to analyse and evaluate cross-enterprise integration in the field of IAM within the CoJ as a possible solution to the problems of scarcity of skills and inadequate funding for maintenance of infrastructure assets.

On the path to investigating the proposed solution, several questions were asked as outlined in section 1.3.1.

1. Is there a way to improve levels of service – can we make better use of current skills and finance?
2. Can cross-enterprise integration of infrastructure management systems enhance the efficiency of the current Infrastructure management systems?
3. What is required to enable departments in the CoJ to ‘talk’ to each other using technology, in a way that allows cross-enterprise integration of infrastructure management?
4. Does the CoJ have the organisational structure required for cross-enterprise integration of infrastructure management systems?
5. How do we measure the success of cross-enterprise integration?
6. Do the advantages of cross-enterprise integrated infrastructure management outweigh the disadvantages?

To address the problems and investigate solutions, the research performed the steps shown in table 3.1.

Table 3.1 Steps in research design

Procedure step in research	Answers research questions
1. Conduct a literature review to understand a) the requirements of cross-enterprise integration b) current trends with regard to IAM and its integration c) costs of implementation of cross-enterprise systems d) costs of benefits of cross-enterprise integration	1 and 2
2. View current practices in the field of IAM within CoJ and the MOEs	3 and 4
3. Perform some form of comparison between existing systems of IAM and proposed cross-enterprise systems	5
4. Analyse results from the comparison and based on the analysis, produce conclusions and recommendations for or against implementation of cross-enterprise systems	6

3.1.1 The literature review

The literature review provided insight into IAM, its workings, its needs and requirements, its benefits. The review provided information on current trends, locally and internationally. It supplied data on cross-enterprise systems including examples of its use and software applications.

The detailed literature review was undertaken to:

1. provide a definition for IAM.
2. provide a definition of integrated IAM.
3. determine the reasons for applying IAM systems.
4. discover the requirements of IAM systems.

5. ascertain current standards and guidelines for application of IAM.
6. discover the current use of IAM in various countries.
7. discover computer software which may be used for application of IAM and cross-enterprise integration systems.
8. determine costs from literature surrounding IAM events.
9. The report required that extensive research was conducted to determine costs associated with risk of damage to other MOE's assets caused by another MOE performing routine or emergency maintenance.
10. list the benefits of IAM.
11. list the benefits of cross-enterprise integration.

3.1.2 Current practices in the field of IAM in City Power, Johannesburg Water and JRA

It was important to ascertain the nature of existing IAM within the three MOEs to enable good comparison with proposed cross-enterprise systems. This involved gathering of information on the workings of the CoJ Council and MOEs. The study developed a body of knowledge on the status of IAM within the three MOEs, including adequacy and integrity of databases and the MOEs' potential to implement cross-enterprise integration. The information was gathered by:

1. interviewing relevant personnel at the MOEs and the Council with regard to the current manner in which IAM is conducted and determining organisational structures within CoJ and the above MOEs.
2. developing and administering a questionnaire to the relevant MOE personnel in order to ascertain current levels of IAM

It was important to know where the MOEs are in terms of IAM policy, data capture, and continual development and monitoring of systems for IAM. The steps in the IAM process are clearly defined in the International Infrastructure Manual (NAMS, 2011) (see figure 2.1) and the progress of the Council and MOEs are measured against these steps. Ultimately, this research attempts to determine whether Johannesburg can embrace cross-enterprise integration across the selected MOEs (JRA, Johannesburg Water and City Power) and possibly to other enterprises with assets in the road reserve. This research therefore attempted to understand the work involved in establishing cross-enterprise integration, the needs to be addressed, planning that needs to be done, and implementation of these systems.

3.1.3 Comparison of current IAM systems and the proposed cross-enterprise system – experimental research

To determine the effectiveness of cross-enterprise systems, the research compared the proposed system with the current system. The best manner to perform the comparison was to simulate maintenance over a period, generating data for both systems using the same input data and criteria. A sample of existing asset data supplied by the three MOEs was used for the simulation.

A common factor for measuring performance of the systems was created through reducing maintenance incidents to currency values (e.g. leisure time; the loss of leisure time due to delays in traffic caused by maintenance has a real value in the eyes of the person experiencing the delay). By creating costs for maintenance tasks for both systems a cost to benefit study was performed to determine the net benefit of cross-enterprise systems. Costs for events surrounding IAM were obtained from literature studies and interviews with the MOEs. Although time consuming, gathering of data was, to a large extent, straightforward. The ability to compare the two different systems using one common unit made the comparison simple and clear. Cost to benefit analysis is often used in public investment studies (European Commission, 2014; Ingle, 2014).

Data was collected from JRA, Johannesburg Water and City Power for two suburbs in Johannesburg, viz. Robertsham and Southdale. A computer program was developed to identify conflict areas where maintenance performed on one MOE's assets may have influence over the integrity of another MOE's assets. A series of hypothetical events involving maintenance work was incorporated into the program. The events entail ordinary maintenance based on a user-defined period for the time between maintenance tasks. Output from the program detailed maintenance tasks, and costs of neglected repair work at the points of conflict. Analysis of the output allowed the researcher to perform cost-benefit analysis of integrated vs non-integrated systems. This research project was limited to the study of only JRA, City Power and Johannesburg Water and the cross-enterprise conflict in terms of maintenance works. However, the findings of this report may well be applied to other external organisations such as Telkom, Eskom, Neotel, Dark Fibre Africa and others.

The next step in the Experiment determined conflict areas where one MOE's work influenced the integrity of another MOE's assets. A record (excel file) of these conflict areas was then created.

Costs were applied to the conflict areas to create a record of risk costs. Costs for the implementation of systems were identified and listed as expenses of the systems.

3.1.4 Analysis of experiment results

Output from the simulation experiment consisted of a series of job cards detailing maintenance tasks for each year and each MOE in the study period. In addition, output by the program was lists of the conflict areas where risk of damage and costs to stakeholders had occurred. Costs were assigned to these conflict areas by the program and these costs formed part of the output from the program. In cross-enterprise system, the conflict and risk cease. The value of the cost then may be considered a measured benefit of the cross-enterprise system.

A report was drafted showing potential cost savings through the implementation of cross-enterprise systems.

Cross-enterprise systems do come with set-up expenses and these were detailed (e.g. organisational structure, office space, furniture and software development costs). The implementation costs were compared with the potential benefit costs of cross-enterprise systems and a net benefit derived.

3.2 DATA SOURCES

The following sources of information were identified as part of the study:

- CoJ
- City Power
- Johannesburg Water
- JRA
- Software suppliers
- Books, Journals, Websites

3.3 DATA COLLECTION TECHNIQUES

The techniques for data collection involved:

- Literature review. To gain insight into the needs of IAM systems and cross-enterprise systems literature had to be studied and presented.
- Questionnaires. Initially basic data could be gained using simple questionnaires. These questionnaires formed a common set of data for each MOE, which could be analysed and compared in terms of the readiness of MOEs to adopt different IAM systems.

- Interviews. Data gained from questionnaires was limited. More data was gained in a formal interview with MOEs. Through these interviews, conditions and age and other attributes of assets was obtained.

To investigate the status of IAM within the MOEs, a two-pronged approach was employed. Firstly, comprehensive data gathering questionnaires requesting information concerning the level of IAM and the adequacy of data were developed and administered to relevant personnel at the three MOEs. Details regarding questionnaires administered and returned are shown in Tables 3.2 and 3.3. These questionnaires were completed and results from the questionnaires are included in this report. Templates of the developed questionnaires are shown in Appendix A and Appendix B. The key aspects of the questionnaire are:

- General asset management
- Software
- Integration within the MOE IAM system (not cross-enterprise)
- Organisational structures
- Skills
- Ability to meet IAM plans
- Level and detail of planning (long, medium, short term)
- Detail of data in terms of locations (co-ordinates)

The second approach was to interview personnel in the MOEs directly connected with the development and implementation of IAM in the MOEs (see Table 3.4). Through these interviews, the complexity of systems was discussed. Organisational structures of the various MOEs were acquired and analysed. The interviews addressed the following key aspects:

- Levels of IAM for each MOE
    - Policy
    - Asset database
    - Condition of assets
    - Age of assets
    - Any items that are known to be outstanding
- Level of the MOE's IAM in terms of the IIMM descriptions (Simple, Core, Intermediate, Advanced)
- Performance in terms of IAM - ability to meet plans
- Implementation of IAM plans
- Operations

- Skills
- Organisational structures
- Software used for IAM and processes supplying information to IAM systems
- Schematic layout of the software systems
- Call centres and their function with regard to the MOEs
- Billing

Table 3.2 Returns analysis For Questionnaire No. 1 administered to the (CoJ) and MOEs

Institution	**Number of respondents**	**Position of respondent within institution**	**Questionnaire administered (YES/NO)**	**Questionnaire returned (YES/No)**
CoJ	1	CoJ, Environment and Infrastructure Services	YES	NO
Johannesburg Water	1	Johannesburg Water, Infrastructure Planning	YES	YES (Scanned to data disk included with research)
City Power	1 1	City Power, GIS City Power,Learning Academy	YES YES	NO YES (Scanned to data disk included with research)
JRA	1	JRA, Asset Management	YES	YES (Scanned to data disk included with research)
Number of questionnaires returned				3

Table 3.3 Returns analysis For Questionnaire No. 2 administered to CoJ and MOEs

Institution	**Number of respondents**	**Position of respondent within institution**	**Questionnaire administered (YES/NO)**	**Questionnaire returned (Y/N)**
CoJ	0	CoJ, Environment and Infrastructure Services	NO	NO
Johannesburg Water	1	Johannesburg Water, Infrastructure Planning	YES	YES (Scanned to data disk included with research)
City Power	1	City Power, GIS	YES	NO
JRA	1	JRA, Asset Management	YES	YES (Scanned to data disk included with research)
Number of questionnaires returned				2

Table 3.4 Interviews with CoJ and MOEs

Institution	Number of officials interviewed	Position of respondent within institution	Date of interview	Evidence of interview attached
CoJ	1	CoJ, Projects	28 August 2012	YES (Scanned to data disk included with research)
Johannesburg Water	1	Johannesburg Water, Infrastructure Planning	13 June 2013	YES (Scanned to data disk included with research)
City Power	1 1	City Power, GIS City Power, GIS	19 April 2013 29 September 2014	YES (Scanned to data disk included with research) YES (Scanned to data disk included with research)
JRA	1	JRA, Asset Management	10 May 2013	YES (Scanned to data disk included with research)
City Parks	2	City Parks Johannesburg, Facilities Management Pragma Africa, Asset Care	15 November 2012 25 April 2013	YES (Scanned to data disk included with research) YES (Scanned to data disk included with research)
Number of interviews				7

3.4 ISSUES OF RELIABILITY AND VALIDITY

Questionnaires were addressed to departments without prior meeting of the respondents. Not all questionnaires were returned. Only willing respondents were then approached for interviews.

All personnel from the three MOEs were in organisational positions relating to IAM. They were all senior personnel in the MOEs.

Data was used as supplied by MOEs – no editing of data took place.

The experiment program was tested using small subsets of data from the data supplied by the MOEs. Section 5.2.2 illustrates checks to determine intersections of infrastructure.

3.5 SAMPLING TECHNIQUES

The research required a selection of an area of Johannesburg containing services from all three MOEs. It also required availability of sufficient up-to-date data on the services. A

constraint encountered occurred with the speeds of processing data by available computers.

A small selection of data from each MOE was used in the research (see section 5.1). An area including the suburbs of Robertsham and Southdale was used in the research. Data for assets in this area was sufficient for the study. Data of assets in this area had been recorded and the area presented a small cross section of an average section of Johannesburg's population. The area contains industrial, residential and business zones and has several schools, churches and shops. The suburbs are neither very poor nor very rich suburbs.

3.6 DATA ANALYSIS AND INTERPRETATION

Data was collected from JRA, Johannesburg Water and City Power for two suburbs in Johannesburg, viz. Robertsham and Southdale. A computer program was developed in this study to identify conflict areas where maintenance performed on one MOE's assets may have influence over the integrity of another MOE's assets. A series of hypothetical events involving maintenance work was incorporated into the program. The events entail ordinary maintenance based on a user-defined period for the time between maintenance tasks. Output from the program detailed maintenance tasks, and costs of neglected repair work at the points of conflict. Analysis of the output allowed the researcher to perform cost-benefit analysis of integrated vs non-integrated systems. This research project was limited to the study of only JRA, City Power and Johannesburg Water and the cross-enterprise conflict in terms of maintenance works. However, the findings of this report may well be applied to other external organisations such as Telkom, Eskom, Neotel, Dark Fibre Africa and others.

Various assumptions (see section 5.3) were made in order to gain some meaningful data in the short term.

The experiment produced records of maintenance work needed in the form of a list of Job Cards.

The next step in the experiment determined conflict areas where one MOE's work influenced the integrity of another MOE's assets. A record (excel file) of these conflict areas was then created.

Costs for the implementation of systems were identified and listed as expenses of the systems.

Expenses come with the implementation of new systems. These expenses were determined to properly check the viability of the integration.

Costs that are associated with the introduction of Integrated Systems are:

- Customisation of existing software and/or writing new software
- Setting up Organisational structures to run the new systems
- Training of existing and new personnel
- Offices, furniture and equipment
- Additional day-to-day costs not covered by current systems

A cost-to-benefit analysis was performed to determine the worthiness of integration across enterprises.

3.7 ETHICAL CONSIDERATIONS

Persons were interviewed for the purposes of research. These persons occupy positions within organisations. Their identity and position need to be safeguarded.

The focus and object of the interviews were explained to all participants in the research

Minutes of interviews were typed and distributed to those present at interviews.

Participants were requested to agree in writing to be interviewed and answer questionnaires. Only information given by participants who agreed to interviews and questionnaires was used in the research.

The research does not specify any participant’s name.

Confidentiality of information was guaranteed.

CHAPTER 4 THE STATUS QUO IN JOHANNESBURG COUNCIL AND MUNICIPAL OWNED ENTITIES

Questionnaires were compiled and issued to City Power, Johannesburg Water and JRA. Interviews were also conducted in order to gain an insight into the workings of IAM within Johannesburg Council and the three MOEs. Through the interviews, the complexity of systems was more clearly understood.

The International Infrastructure Management Manual (NAMS, 2011) has a clearly defined process detailing the events that should happen in IAM (illustrated in figure 2.1).

In relation to figure 2.1, the following questions beg answering in this research project:

- How far advanced are CoJ's MOEs with IAM?
- Are current systems adequate?
- What is outstanding, in terms of the steps described by the IIMM (NAMS, 2011)?
- What standards for data are employed?
- Does the current IAM system impede cross-enterprise integration?
- Can CoJ MOEs begin the process of employing cross-enterprise integration?
- How does restructuring of organisational hierarchy and line of command affect people currently working in the IAM systems?

The status quo section of this research aims to discover whether or not MOEs can move on to a cross-enterprise integrated system. The status quo does not compare MOEs and the levels of their separate IAM systems and it doesn't judge whether an MOE's system is good in any terms. This research examines whether or not the MOEs are ready for cross-enterprise integration.

The simulation experiment described in chapter 5 uses the following fields (table 4.1) to produce job cards and to create maintenance tasks.

Table 4.1 Categories of fields in the asset database used by the program in this research

Categories used by the research experiment
Unique identifier
position Latitude
position Longitude
Remaining Life

A small section of the MOEs' asset databases was received from each MOE. Key IAM categories for an IAM system that were considered important in the data files are shown in table 4.2.

Table 4.2 Key IAM Categories within the Asset Inventory File

Key Items for Inventory Files
Unique identifier
position Latitude
position Longitude
Description including all related parameters according to asset type
Condition
Remaining Life
Expected Life
Value
Future Demand
Expected levels of service

While some MOE's data were more detailed than other MOE's data, all MOEs did have sufficient data to enable the completion of the experiment detailed in chapter 5. The asset database constantly requires updating due to ongoing maintenance, capital investment in new infrastructure and emergency repairs. Table 4.3 shows a summary of the status of each MOE's IAM system.

Table 4.3 Summary of answers to questionnaires returned by MOEs regarding their IAM systems

Questions to MOEs	**City Power**	**Johannesburg Water**	**JRA**
Does the MOE have an asset database?	Yes	Yes	Yes
Are assets valued?	Yes	Yes	No
Are assets componentised?	Yes	Yes	Yes
Are components valued?	Yes	Yes	No
Is the condition of assets captured?	No	Yes	Yes
Are life expectancies of assets captured?	No	Yes	No (see section 4.3. Assets are inspected periodically and condition assessed)
Is data spatially represented?	Yes	Yes	Yes
Does spatial software aid IAM?	Yes	Yes	Yes

Does IAM software allow for logging and tracking of service calls?	Yes	Yes	No - alternative system is used for service calls
Does the IAM system produce job cards?	Yes	Yes	Yes
Does the IAM system track work on job cards?	Yes	Yes	Yes
Does the MOE have an IAM policy	Yes	Yes	No - In process of being developed
What is the level of IAM in terms of the IIMM definitions?	Intermediate	Advanced	Core
What software is used for IAM?	SAP	SAP & IMQS	HANSEN
Does the software allow integration within MOE (between disciplines such as engineering and finance)	Yes	Yes	Yes
Where is data located?	Central server within City Power	Data is stored in Johannesburg Water's offices	Central repository within JRA
Can the software export data in different formats?	Yes	Yes	Yes
Can data be read from other systems?	Yes	Yes	Yes
Does integration between disciplines involve manual intervention	Yes	Yes	No
Can different departments in the MOE enter data directly to the IAM system?	No	No	No
Does the MOE have a separate department for controlling IAM	Yes	Yes	Yes
Does the MOE have an organisational chart showing reporting / authority / responsibilities	Yes	Yes	Yes
Do employees understand levels of reporting and responsibility	Yes	Yes	Yes
Are there sufficient skilled staff to operate IAM efficiently	No	No	No
What skills needs improving, and to what extent?			
Financial	50%	25%	25%
Engineering	50%	50%	75%
Information Technology	50%	25%	25%
Operations	25%	75%	75%
Do you generate maintenance programs based on asset databases?	No answer	Yes	Yes
Are the programs for the entire Johannesburg area? If not, include a percentage of the Johannesburg area	No answer	Yes	Yes

For what periods does the MOE plan? Include the level of detail (high, medium, low, not applicable)			
1 year	No answer	Yes - High	Yes - High
2 to 5 years	No answer	Yes - High	Yes - Low
6 to 10 years	No answer	Yes - Medium	No - not applicable
11 to 20 years	No answer	Yes - Low	No - not applicable
20+ years	No answer	No - not applicable	No - not applicable
What percentage of IAM planned works is completed in the period for which it was scheduled?	No answer	100%	70%
Are uncompleted jobs carried over to the next period?	No answer	Not applicable	Yes
Is IAM maintenance work inspected by qualified personnel?	No answer	Yes	Yes
Is IAM maintenance work and changes to assets recorded on the asset database?	No answer	Yes	Yes
Do assets have start and end co-ordinates?	No answer	Yes	Yes
What is the average delay in attending to emergency repairs?	No answer	No answer	3 days

4.1 CITY POWER

Two questionnaires were issued to City Power. Two responses to Questionnaire one were received and one response to Questionnaire two was received. Two interviews were conducted with City Power, GIS department in City Power.

The following factors were identified from the completed questionnaires

City Power IAM systems include:

- An IAM Policy
- An Asset database. All new work (for the last 10 to 15 years) has been logged on the register and this includes asset types, classes, values, and conditions.
- Valuation of assets. For older townships, where infrastructure may be more than 50 years old, algorithms are used to determine the overall value of assets taking into account estimated upgrades and the age of the townships.
- Componentisation of assets (Assets are broken into components).
- Valuation of components.
- Data which is spatially represented (GIS system).
- Spatial software to interrogate data

- Systems within the IAM to allow for recording and tracking of service calls
- Systems for producing job cards for maintenance and emergency repairs and procedures to check outstanding work.
- Functions to export data in different formats

City Power still requires:

- The condition of assets to be captured
- The life expectancies to be captured

City Power's IAM is regarded as an Intermediate Plan (see section 2.7.2.1) i.e. detailed action plans are in place to meet policies and strategies and the plans are reviewed annually. To a large extent, data within the asset register is up-to-date. Details of new assets are captured at the time of installation.

Integration between disciplines takes place within City Power. City Power makes use of SAP software for their IAM main system but it needs data from various other systems (see figure 4.1). The software accepts input from different departments (e.g. Finance and Engineering) to develop asset management plans. Integration within the MOE between different systems involves manual intervention. The manual intervention requires data from one component to be exported, modified and then read into other components. This is inefficient, time consuming and data integrity may be compromised.

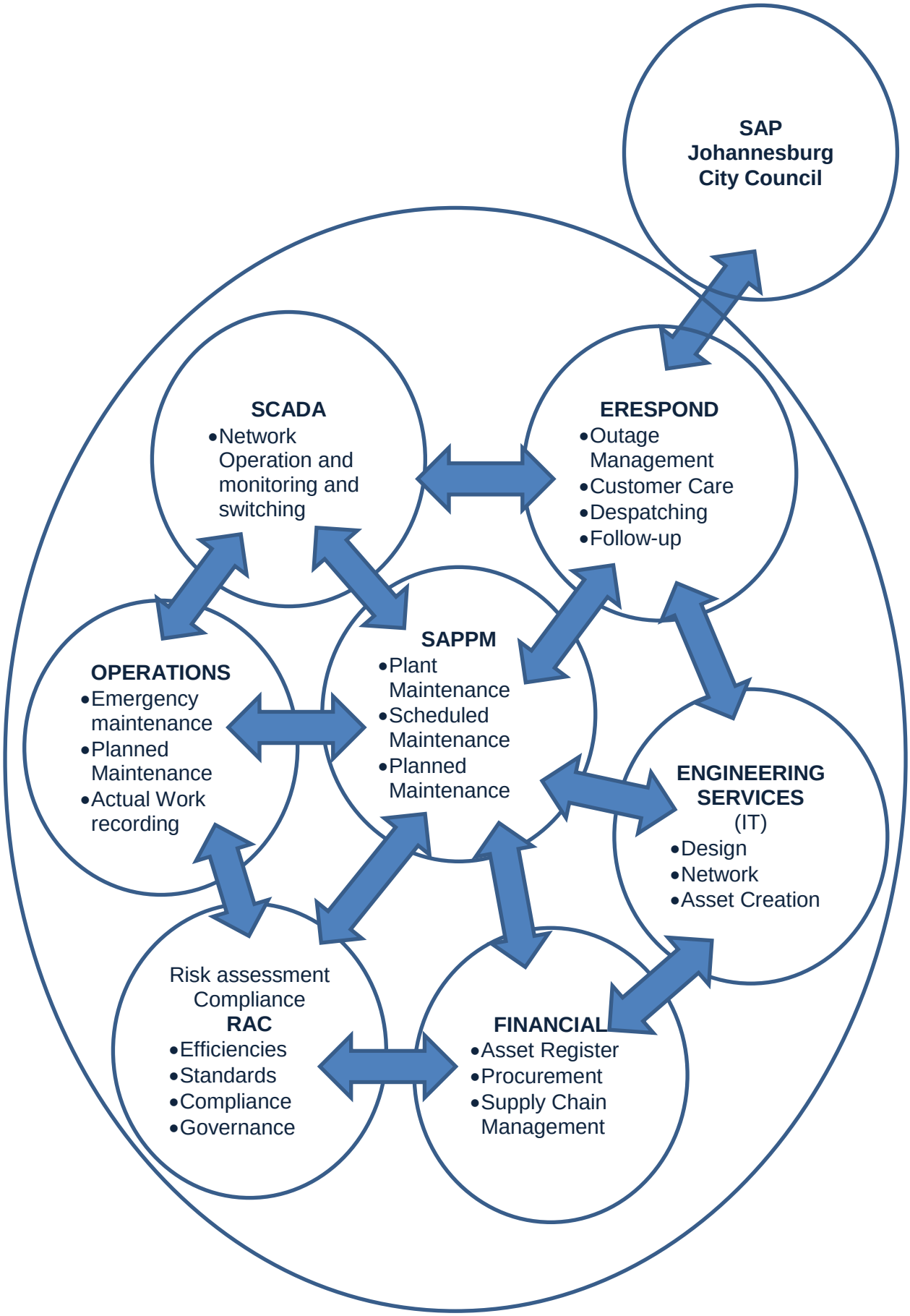


Figure 4.1 Different systems within City Power

Data is not shared with other MOEs or organisations. Data is maintained in a central repository (central server) located within City Power. However, different systems may have their own data bases.

City Power uses mobile computers to track work progress on repairs, maintenance and new works to ensure that standardisation of data occurs. Emphasis is placed on the need for standardisation. Some systems operate on SQL platforms while others operate on Oracle platforms (SAP is Oracle).

A separate department dealing with Plant Data and Compliance in City Power controls the input of data to IAM systems at City Power.

4.1.1 Skills

Skills shortages are problematic: City Power (2013) states that the following skills need improvement. Figures in brackets indicate the extent of improvement required.

- Financial (50%)
- Engineering (50%)
- IT (50%)
- Operations (25%)

4.2 JOHANNESBURG WATER

Two questionnaires were delivered to Johannesburg Water and an interview took place with the Infrastructure Planning department. Both questionnaires were returned. Johannesburg Water has an Asset Management Working Group (see figure 4.3). This working group consists of EXCO members (see organisational chart in figure 4.2). The inclusion of EXCO members lends weight to the importance of IAM and ensures that implementation of policies and new processes run smoothly.

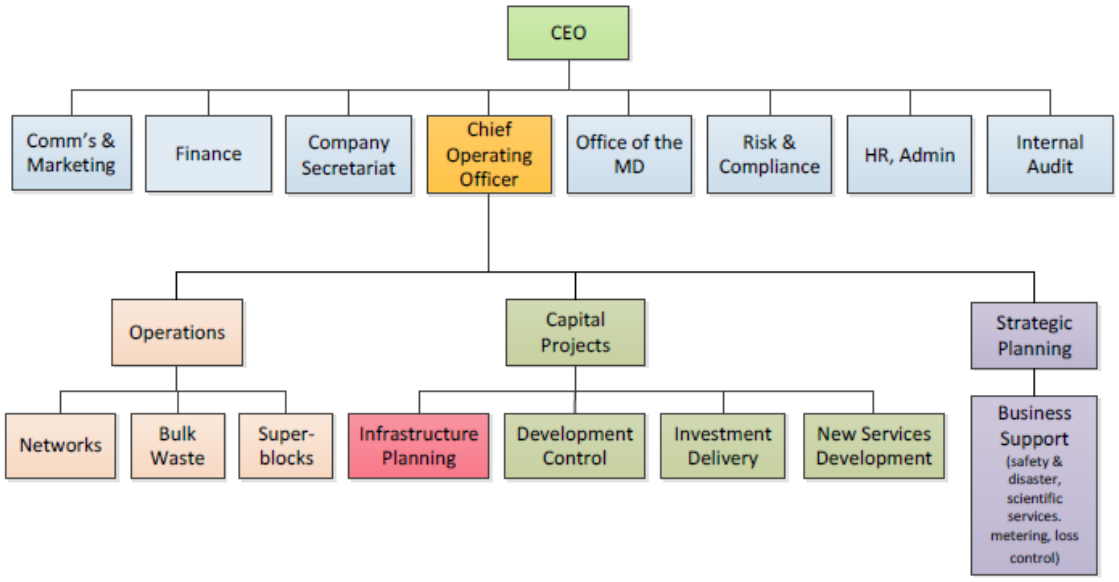


Figure 4.2 Johannesburg Water Existing Organisational Chart

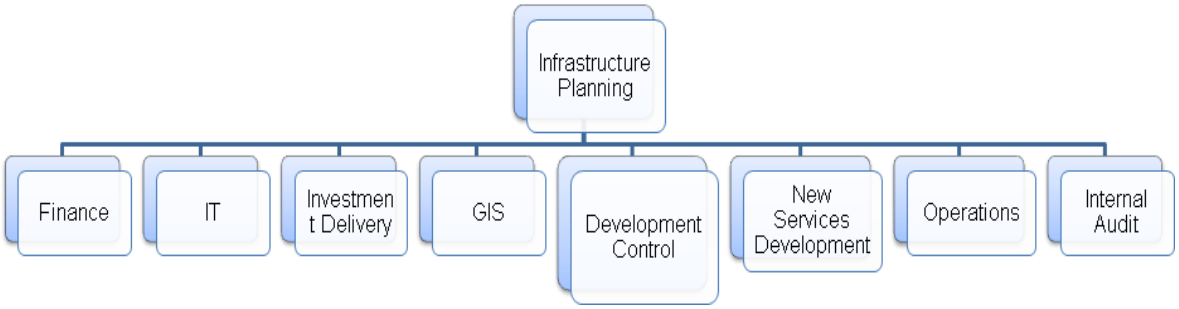


Figure 4.3 Composition of Asset Management Working Group within Infrastructure Planning

The infrastructure planning department plays the co-ordinating role and chairs the Asset Management working group. Infrastructure planning also performs the cut-crossing functions with respect to IAM within Johannesburg Water.

This infrastructure planning department accesses the expertise and obtains input from other departments such as IT, Operations, and Finance.

From the completed questionnaires, Johannesburg Water's IAM systems include:

- An IAM Policy.
- An Asset database.
- Valuation of assets.
- Componentisation of assets (Assets are broken into components).

- Valuation of components.
- Asset conditions and life expectancies.
- Spatial representation of data (GIS system).
- Spatial software that interrogates data
- The recording and tracking of service calls
- Systems for producing job cards for maintenance and emergency repairs and procedures to check outstanding work.
- Functions to export data in different formats

Johannesburg Water employs several systems in the IAM processes. Predominantly there are two systems, i.e. IMQS and SAP (see figure 4.4).

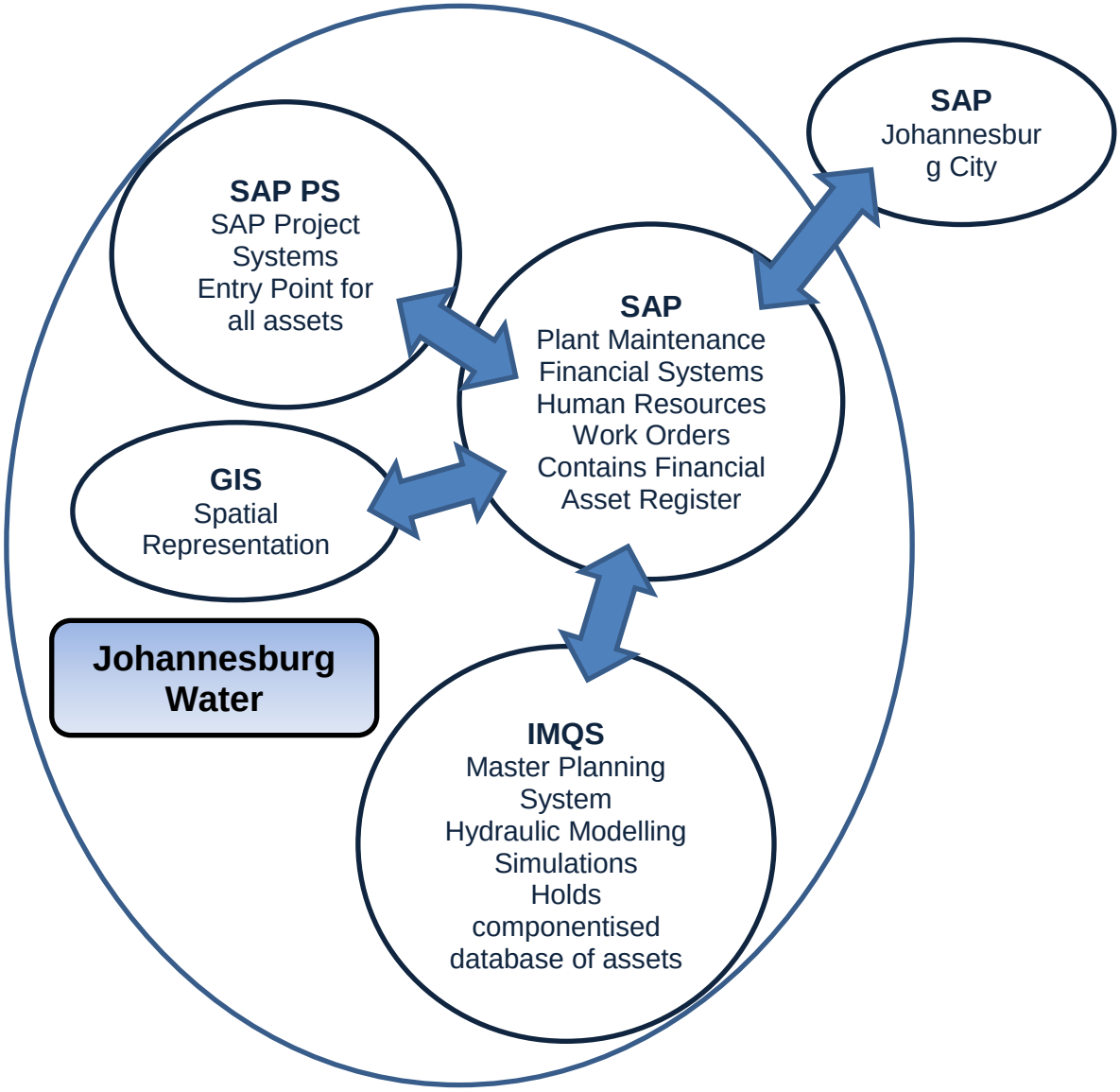


Figure 4.4 Schematic layout of data flows and process for IAM in Johannesburg Water

IMQS acts as the master planning system. Johannesburg Water uses IMQS for the purposes of maintenance planning and the IMQS database serves as the primary source of infrastructure asset information. It is used as the primary asset management system housing the asset register and strategic reporting dashboards. It also holds the 'technical' database – a database of components, networks and segments of water networks. Hydraulic modelling and simulations are performed in the IMQS system.

The SAP system is used to create work orders and effectively open and close projects or jobs. The system is also used as the plant maintenance system. It acts as the central finance system at Johannesburg Water. Human Resources components form part of the SAP system – an integral part of allocating work orders.

The separate systems and the different naming structures in the two databases cause problems in maintenance of the databases. Obviously, the databases are prone to some error and the different systems do require some duplication of work in their maintenance. Johannesburg Water is busy with a project to integrate its internal IAM functions. Currently any integration involves manual input. When this project is complete, it is understood that Johannesburg Water will have synchronised databases in both SAP and IMQS.

The upkeep of the IMQS and SAP systems are outsourced – Service Level Agreements (SLAs) are in place for the software support. The day to day running/utilization of the systems is done internally by Johannesburg Water staff. The IAM department in Johannesburg Water is minimalist (effectively 2 persons run the department).

In an interview with Johannesburg Water on 13 June 2013, the organisation stated that they are forging ahead with systems integration to counter the typical risk as outlined below:

Some faults on water lines may not be due to a seemingly obvious cause. Several water pipe leaks and bursts may indicate that a region of the city requires new water pipes, when, in fact, the pressure in the pipeline may be the cause of the series of faults. Two noteworthy ideas arise; IAM systems, with their wealth of information allow accurate and objective assessment of faults and, secondly, IAM is indeed an operation that requires skilled personnel within several fields including engineering, financial, IT, and others.

Current legislation indicates that it is the financial side of corporations that should be responsible for the IAM systems (Boshoff and Pretorius, 2010), but clearly, engineers need to provide input if an IAM system is to be successful. Organisational difficulties are involved in bringing together personnel from different levels in a company hierarchal structure to work together in a project management type structure which may in some

cases, cause a company superior to be placed under control of a sub-ordinate (Johannesburg Water, 2013).

Some obstacles to IAM are misunderstanding by one department of another department's function and their needs e.g. engineers should understand why financial personnel require certain data representations and vice-versa.

A third system forms part of the IAM group of sub systems and this is a Geographic Information System (GIS). GIS aids the process of maintenance planning. Database systems currently interface with GIS systems. The geographical locations of water pipe faults can sometimes pinpoint engineering faults in the network.

Another route by which assets find their way into the asset register is through new water and sanitation networks as part of new township establishments. Private developers construct these networks according to Johannesburg Water standards. On commissioning of these developments, Johannesburg Water takes over these networks and they become Johannesburg Water assets. These networks are componentized to satisfy GRAP requirements and enter the Asset Register as Asset Additions.

Johannesburg Water's IAM is regarded as Advanced (see section 2.7.2.1) i.e. policy and strategy are integrated into the organisation's business and IAM is subject to periodical audit and review.

4.2.1 The Call Centre

Calls made by residents or other interested parties reporting faults on water lines go through a central call centre at the CoJ. From there, the information is routed to Johannesburg Water. Johannesburg Water captures the report into their system manually. The SAP system tracks the work order, and the status should be reported back to the City.

4.2.2 Skills

Johannesburg Water appears to have two IAM personnel. Many IAM tasks are outsourced to consultants operating SAP and IMQS systems. No succession plan is in place and a change plan is been compiled to shed some insight into this. The current position regarding skills within Johannesburg Water is not sustainable with respect to IAM (Johannesburg Water, 2013). Johannesburg Water needs to resource the IAM section/division and then to upskill the staff.

One area of concern is that people with much knowledge learnt through many years of experience are or have already retired or resigned from Johannesburg Water. It takes many years to gain the experience needed to run IAM systems well. The experience must be directly related to Johannesburg's water networks. IAM systems are only as good as the data input.

4.2.3 Billing

Billing of water is now done by the City and not by Johannesburg Water. This includes meter reading.

4.3 JOHANNESBURG ROADS AGENCY (JRA)

Two questionnaires were delivered to JRA and an interview took place with the Infrastructure Planning department. Both questionnaires were returned. The following evaluation of JRA's databases and IAM systems are based on the interviews and data received from the MOE.

JRA controls roads, storm water, bridges, road signs, traffic lights and the associated assets found in the road reserve.

From the completed questionnaires JRA IAM systems include:

- An IAM Policy.
- An Asset database.
- Valuation of assets.
- Componentisation of assets (Assets are broken into components).
- Valuation of components.
- Spatial representation of data (GIS system).
- Spatial software that interrogates data
- The recording and tracking of service calls
- Systems for producing job cards for maintenance and emergency repairs and procedures to check outstanding work.
- Functions to export data in different formats

The JRA IAM is regarded as a Core System (see section 2.7.2.1) i.e. corporate policy is in place and data meets policy requirements only. JRA is prioritising the implementation of the key activities of IAM systems. Maintenance programs are generated for the whole Johannesburg area (all seven regions). Maintenance plans are made for a period of 0-5

years; the first year has a high level of detail, while the remaining years have a broad outline of detail.

Approximately 70% of maintenance is performed in the same year in which it was scheduled to be done (JRA, 2014). Maintenance work is inspected by qualified personnel of the MOE and all information regarding repairs and standard maintenance is entered into the databases. Emergency repairs are attended to within approximately 3 days of receipt of report.

Outstanding items on the JRA IAM system are:

- IAM Policy to be properly developed
- Assets to be valued
- Life Expectancies to be determined and captured

JRA performs maintenance in a different manner to that of the other two MOEs. Assets are inspected periodically and asset management plans are developed using knowledge of the existing condition at time of inspection. Bridges are inspected every 5 years and Pavements are inspected every 2 years as per SANRAL specifications. At the time of the report, some inspections were behind schedule.

Asset monitoring is performed using RAMS (Road Asset Maintenance Systems) (see figure 4.5)

RAMS contains several sub systems:

- PMS Pavement Management System using Microsoft Excel
- BMS Bridge Management System using Microsoft Excel
- Storm water Management System using Microsoft Excel
- GIS Geographic Information Systems
- AMS Accident Management System using Microsoft Excel
- CIMS Capital Infrastructure Management System (Budgeting and Capital projects)

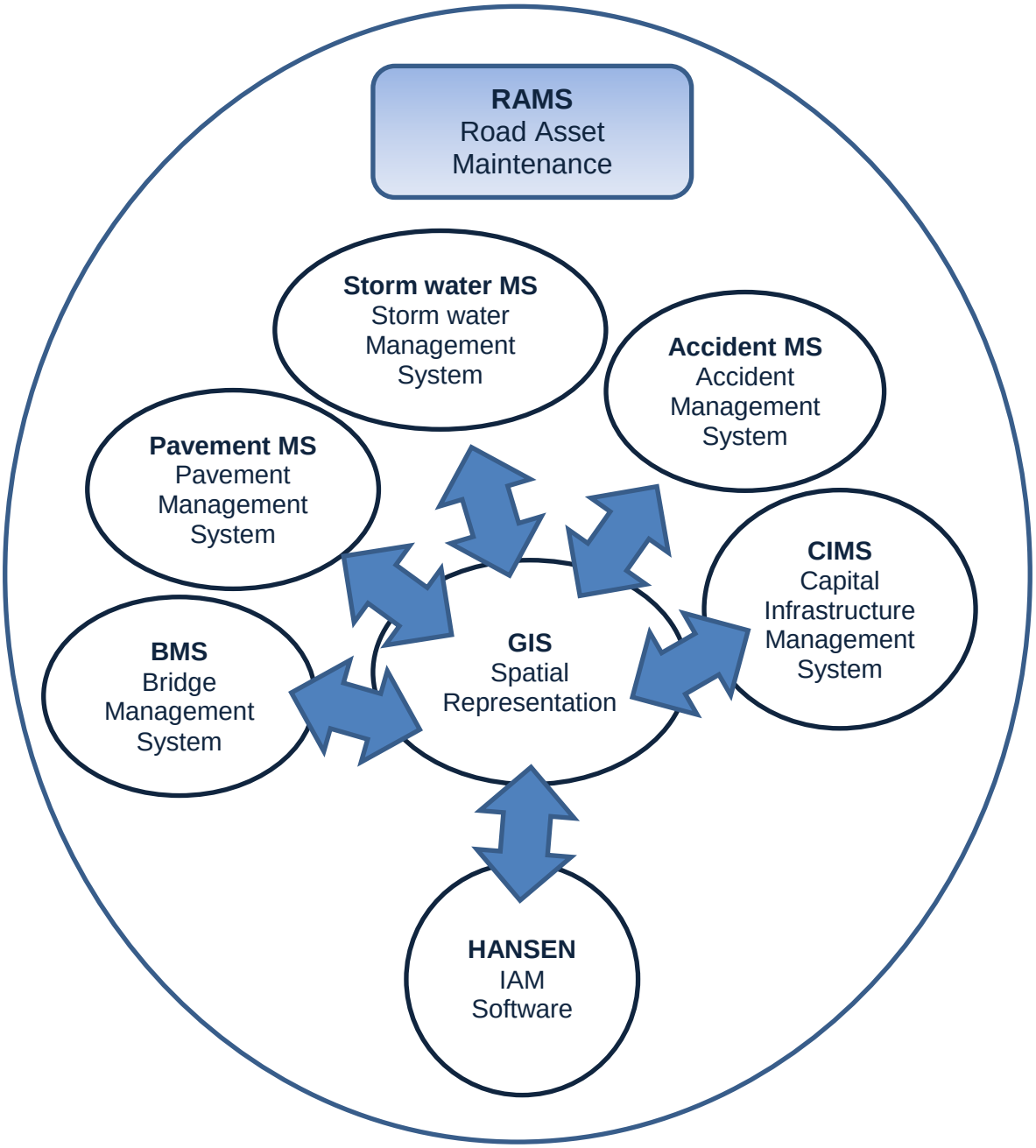


Figure 4.5 Processes in JRA IAM systems

All these systems feed data into a system called HANSEN. The sub-systems are stand-alone systems. HANSEN can integrate between disciplines (e.g. Finance and Engineering). The software can read and export data in different formats.

JRA is currently working on integrating all the separate systems into one IAM system.

A central database contains data concerning assets.

Parameters include (amongst others):

- Condition
- Value
- Depreciation
- Maintenance Costs

An engineering consulting firm performs the Pavement Management task at present.

Procedures for Assessment of Assets

1. The assets are checked by consultants
2. The assets are checked by JRA
3. Any differences between the consultants and JRA's analysis is evaluated
4. If differences are large, the asset is re-checked.
5. The asset parameters are captured into the PMS

Procedure for repair:

1. Report is input to AMS (Accident management system)
2. An engineer investigates the report
3. The engineer submits his report to JRA
4. JRA makes decision on action
5. Priority is allocated to work
6. An emergency repair order is issued or a CIMS strategy is developed
7. Work is performed

JRA's organisational chart is shown in figure 4.6. The Infrastructure Development division in JRA reports directly to the managing director of JRA. There may be arguments for placing a new IAM department within CoJ to control the cross-enterprise functions but there exist arguments for placing the department within JRA. City Power stated in an interview on 29 September 2014 that JRA acts as the custodian of the road reserve and the services contained within the reserve. Way leaves are channelled through JRA and

therefore it may then make sense to place the controlling organisation or department for cross-enterprise IAM systems within JRA.

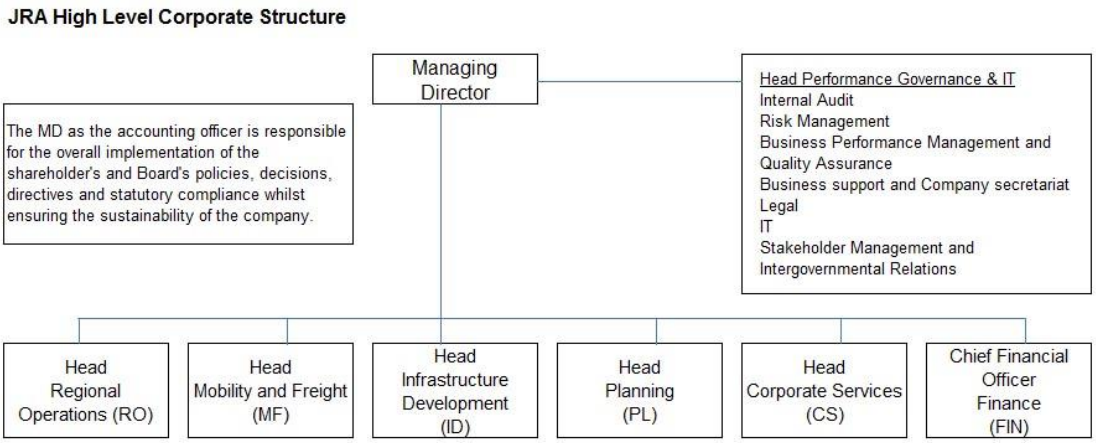


Figure 4.6 JRA Organisational Chart of Corporate High Level Structure

4.3.1 Skills

JRA faces challenges in terms of a lack of skills concerning infrastructure asset maintenance. A number of the experienced employees at JRA left the MOE during the 1990's. Current personnel need to gain experience in the functions of asset maintenance (JRA, 2014).

From the questionnaire the following skills need improvement. Figures in brackets indicate the extent of improvement required.

- Financial (25%)
- Engineering (75%)
- IT (25%)
- Operations (75%)

4.4 THE JHB COUNCIL

4.4.1 Call Centre

Calls by interested parties reporting faults are routed to a call centre in the CoJ Council.

Details of reports are noted and forwarded to the relevant MOE.

The MOEs capture the data manually into their systems.

Status on the faults should be reported back to City Council, manually, to update their records.

This research does not examine call centres in Johannesburg Council and the MOEs but it is important that faults on MOE's assets do get reported and captured into maintenance systems. With this in mind, the system of fault reporting should be further addressed by the Council to minimise risks of 'lost' data.

4.4.2 Organisational structures

The organisational charts for the CoJ showing departments for Environment and Infrastructure services are shown in figure 4.7. At first it may seem logical to have CoJ controlling the process of IAM in a cross-enterprise situation as the Council appears to be the overall controlling body for all MOEs and it is the only shareholder of the MOEs. However, as stated by City Power in an interview on October 2014, JRA acts as the custodian of the road reserve and the services contained within the reserve. All way leaves permissions to work in the road reserve are channelled through JRA. It may then make sense to place the controlling organisation or department for cross-enterprise IAM systems within JRA. This idea was reiterated by JRA in an interview on 24 November 2014.

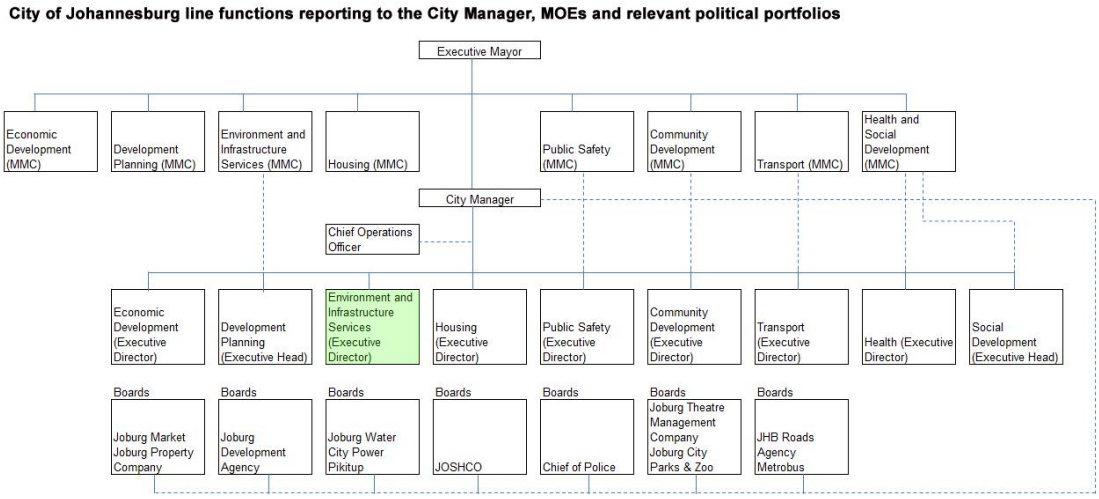


Figure 4.7 Organisational Structure of the City of Johannesburg (CoJ)

4.5 SUMMARY

The three MOEs studied in this research have databases of assets. They are obliged to have these in place to meet requirements of law i.e. municipalities are required to represent the value of the assets in terms of current value and they are further required to have plans in place to ensure that values are maintained (*Municipal Finance Management Act 56 of 2003 (MFMA)*).

Some work still needs to be done with regard to the databases of the three MOEs. To a large extent, most assets have been captured. Parameters need updating such as conditions, expected life, etc. The nature of assets and the quantity of assets changes from time to time, the databases remain dynamic and need constant updating.

No form of integration with regard to the scheduling of coordinated maintenance between MOEs is taking place.

Several systems work together to produce data for input into IAM systems. Within specific MOEs, there may be some standardisation but this could differ enormously from the standards of another MOE.

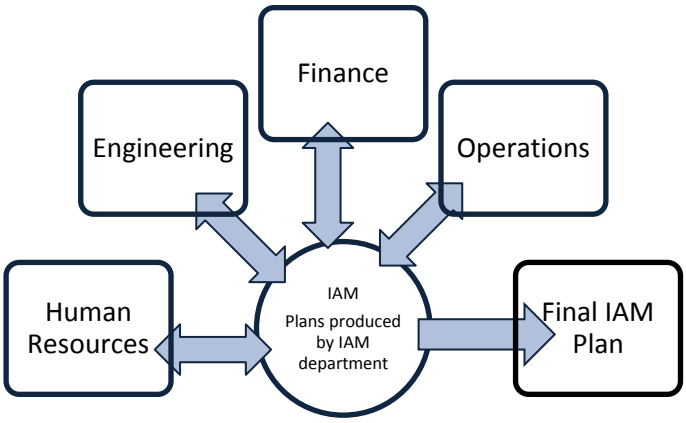
To a certain extent, integration within the CoJ and its Municipal Owed Entities (MOEs) takes place in terms of combining disciplines (e.g. Financial and Engineering) to form a single management solution. Currently engineering and financial departments in MOEs communicate in ways to produce maintenance plans for infrastructure. This integration is contained within the MOE. CoJ, MOEs and external organisations which have assets in the road reserve do not speak to each other in any meaningful way with regard to maintenance. Apart from a group of way leave applications[1] being signed and issued to contractors, it appears that organisations tend to mostly work separately without knowledge of the influence(s) of other MOE work on their assets despite the close proximity of their individual assets.

[1] A right to use property without possessing the property - often used to give utility organisations the right to install cables and pipes in the road reserve. The way leave shows the nature and location of existing assets (JRA, 2014).

CHAPTER 5 THE EXPERIMENT

A simulation of the maintenance planning and implementation tasks of IAM for each MOE and their effect on other MOE's assets in the vicinity of the maintenance work was performed. The procedure involved applying a set of criteria for determining dates for maintenance of the assets of Johannesburg Water, JRA and City Power.

IAM is generally run on large computers with sophisticated software. It is an iterative process (CIDB, 2006), producing plans that are then subject to interrogation and investigation by the IAM department. The plans are reworked and new plans produced which are subject to further investigations and so on (see figure 5.1). Eventually, an IAM plan is established for a period and submitted for implementation.



IAM plans are initially drafted with input from all relevant sectors of an organisation.
In instances where needs of different disciplines may conflict (e.g. where engineering needs may exceed available budgets), compromises may be investigated.
The initial plan with changes is passed back to departments for analysis. A second plan is then suggested and so on until a final plan is agreed.

Figure 5.1 The iterative process within IAM

Maintenance on one MOE's assets may leave other MOE's assets in a state of disrepair. This is, in this report, referred to as "unknown, neglected, or incomplete maintenance". Unknown, neglected or incomplete maintenance produces risks. Costs of risks have been identified and are detailed in section 5.4. In an integrated IAM system, incomplete maintenance should not occur.

5.1 ORIGIN OF DATA: THE AREA ROBERTSHAM AND SOUTHDALE

Data from the three MOEs, relating to utilities in the suburbs of Robertsham and Southdale in the South of Johannesburg (see Figure 5.2) was obtained from the personnel interviewed; the Asset Manager of Johannesburg Water, the Asset Manager of JRA, and the GIS Manager of City Power (see section 3.1). The data has most of the

parameters needed by IAM systems. Some parameters had to be added or updated and the assumptions made during the adding or updating of parameters are presented in section 5.3.

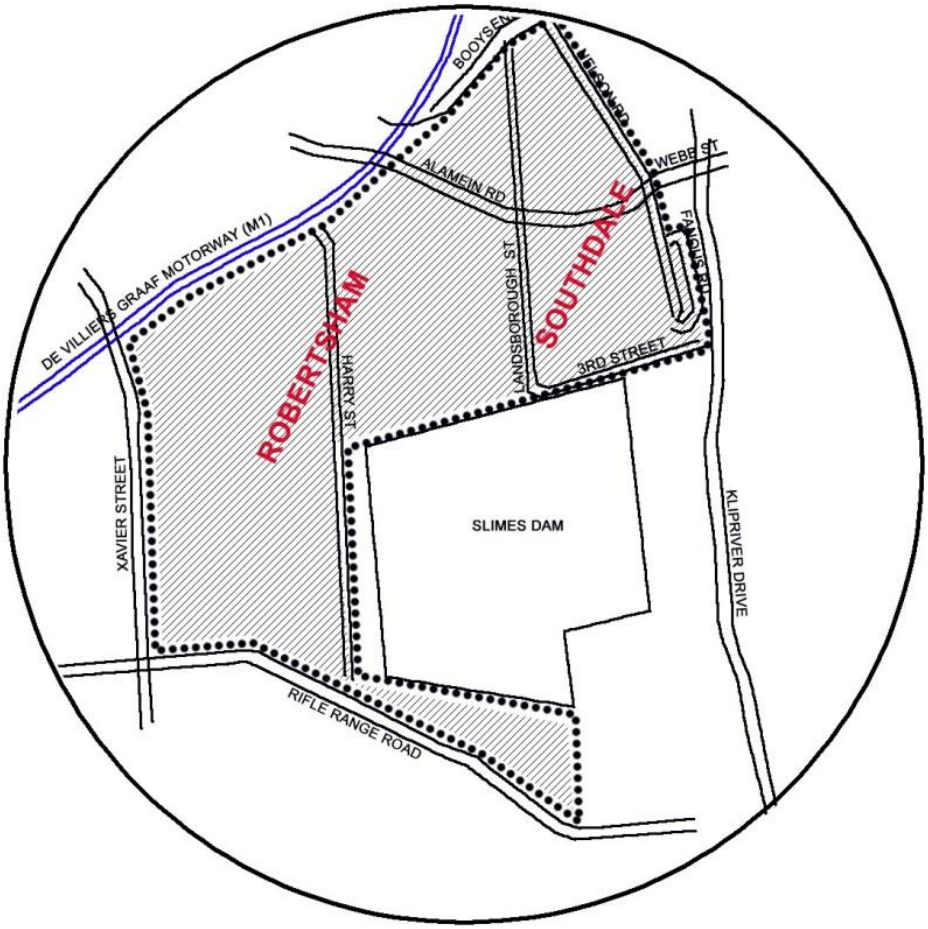


Figure 5.2 Location of study area: Robertsham and Southdale suburbs of Johannesburg

The area under consideration is approximately 4 square kilometres. The overall area of Johannesburg as reported on the official website of the CoJ is 1664 km^2 (CoJ, 2014). This means the study area examines 0.24% of the city in terms of area. To a large extent, assets in this area have been recorded and the area does present a small cross section of a reasonably average section of Johannesburg's population. The area contains industrial, residential and business zones and has several schools, churches and shops. The suburbs are neither very poor nor very rich suburbs. The area is found in Section F of Johannesburg which includes many areas from a fairly poor urban CBD to wealthy suburbs of Bassonia and Mulbarton. CoJ considers the area as having a "well-maintained infrastructure" (CoJ, 2014).

Johannesburg Water (2013) supplied the following information regarding Robertsham and Southdale:

- 830 sewer pipes, measuring 47,112m
- 440 water pipes measuring 66,880m
- Hydrants, manholes and valves were excluded

City Power (City Power, 2013) supplied the following information regarding Robertsham and Southdale:

- 609 load centres
- 501 MV cables measuring 317,889m
- 3 stations
- Light voltage cables were excluded

JRA (JRA, 2014) supplied the following information regarding Robertsham and Southdale:

- 4 grids
- 1 inlet manhole
- 32 junction boxes
- 134 kerb inlets
- 2 kerb outlets
- 66 manholes
- 240 roads measuring 40,891m
- 7 signals
- 2 undefined

5.2 PROCESSES OF THE EXPERIMENT

A Visual Basic Application (VBA) computer program written in Microsoft Excel was developed to run the simulation of maintenance events over a user-defined period. Assumptions made are recorded in section 5.3. The program was tested to run on the Windows 7 operating system running Microsoft Excel Version 10 and has not been released as freeware. The program is included on the compact disk (CD) included with this research report.

Data describing assets was obtained from the three MOEs. The sample data was received in the form of Excel files. Formats differed from MOE to MOE. Critical data fields required by the developed program were:

- asset identification
- position of the asset (longitude and latitude)
- length of the asset (cables, roads, pipes)
- Remaining Useful Life (RUL) of the asset

Not all obtained databases provided this information. Formats of data were modified manually to produce a standard format for input into the developed program. Assumptions described in section 5.3 were made where data was missing or insufficient.

The program follows a series of steps shown in figure 5.3.

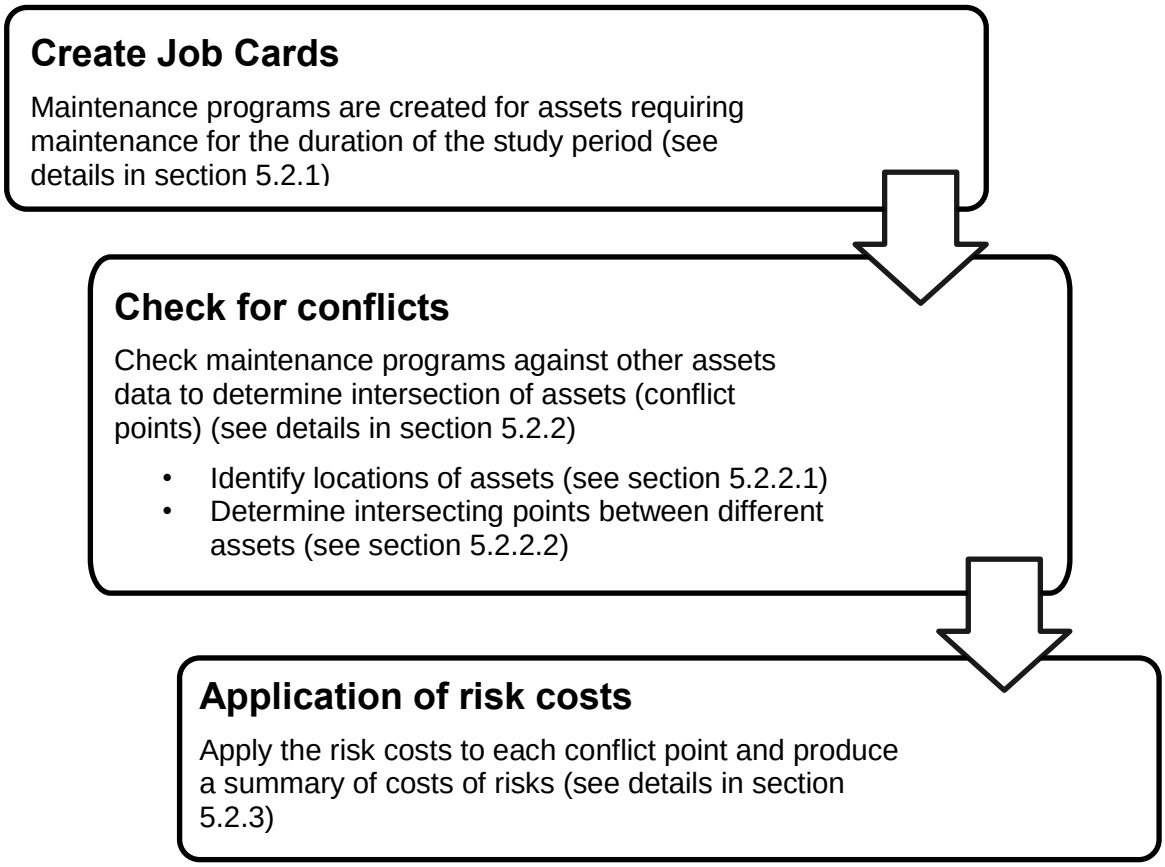


Figure 5.3 Program steps

5.2.1 Job cards

The first step, after ensuring data has been sufficiently modified, was to produce a set of job cards for maintenance works in the area. This operation is initiated by the user by selecting the appropriate option. Job cards are produced for each MOE. The user is prompted to enter the number of years for the study. All MOEs must have job cards

produced for the same periods. For this report the number of years chosen for the study is 30 years.

5.2.2 Conflict points

The user then has the option to determine conflict areas. Work on one MOE's assets that intersects with another MOE's asset is highlighted. Microsoft Excel files were generated containing all conflicts. The total number of conflict points was identified and recorded in the conflict file. The application does not attempt to reschedule conflicts.

5.2.2.1 Location of assets, latitude and longitude

The computer program developed for this research identifies assets that require maintenance. It then checks whether these assets may intersect with other MOE's assets. In order to do this, the program requires locations for all assets. Data received from Johannesburg Water has only one set of coordinates for the location of the asset. These coordinates are the mid-point of the asset (Johannesburg Water, 2014). Data from JRA indicated only one set of coordinates on the asset which may coincide with any point on the asset (JRA, 2014). City Power supplied mid-point latitude and longitude coordinates for assets and it identified links between load centres and the cable (City Power, 2014). With this information, the start and end x-y coordinates for their assets could be determined.

Longitudes and Latitudes were converted to standard Cartesian X-Y coordinates using simple conversion methods. Since both suburbs represent a relatively small area, no elevations above mean sea level were entered into these calculations. Longitude and Latitude were expressed in decimal degrees.

5.2.2.2 Determining intersecting points of assets

An exercise was performed on City Power's data linking all load centres with relevant cables. In most cases, MV cables are connected to two load centres. The MV cable therefore has three sets of latitude-longitude coordinates. There are coordinates for the two load centres which coincide with start and end coordinates for the cable, and there is a mid-point latitude-longitude coordinates for the cable.

Output from the GIS system of City Power showing only MV cables will show an *x-y* pair of co-ordinates describing the mid-point of the cable. This coincides with the description given by Johannesburg Water (2014), "the system outputs the mid-point of their pipelines."

Observations of the exercise are illustrated in figure 5.4:

- MV cables are often not straight.
- Using the start and end x-y coordinates of the cable will produce a straight line which clearly does not match the path of the cable. The straight line is shown in green in figure 5.4; the cable path is shown in red.
- Attempts to find intersections of assets by using start and end x-y coordinates and the straight line between them will therefore fail.

In figure 5.4 the cable (ref 184) runs from west to east for approximately half its length before turning 90 degrees to the north. Any attempt to join a straight line from the start to the end of this cable would produce a path that would not follow the path of the cable and would not intersect with any other services that may in practice intersect with the cable.



Figure 5.4 Location of an MV cable with load centres

There is capability within GIS systems, currently installed in City Power, as shown by City Power in an interview on 29 September 2014, that can produce an accurate report detailing intersections. This exercise may produce listing of all intersections but it doesn't have the input of the required assets that will be maintained. Also, the MOEs do not have the other MOEs' data installed and ready to interrogate. They do have data from other MOEs but work needs to be performed before it can be accurately investigated for the intersections.

In the meantime, this research must attempt to obtain a meaningful report of the following:

- all maintenance tasks for each MOE for the study period
- all intersections of assets (conflict points) for the set of maintenance data

To this end, this research adopts the following strategy for determining intersecting points:

- The asset position (latitude and longitude) of each asset that requires maintenance is checked against all other MOEs' assets.
- For City Power and Johannesburg Water the assets' x-y coordinates are in the middle of the asset. It is assumed that this is the same for JRA.
- Two circles are formed. One for the asset being maintained and the other for the other MOE's asset, using half the length of the asset as radius and the x-y coordinates as centre point of the circle.
- The program calculates the overlap of the circles. If the overlap falls within the user defined value (circles may overlap between 0% and 100%) then it is assumed the assets intersect.

Of course, this is an approximation or estimation. However, with the percentage value for overlapping set to a reasonable value, the results may be assumed to be reasonably accurate for preliminary studies. If the CoJ Council wishes to pursue further studies with regard to cross-enterprise integration the facility available within GIS must be put to use and a procedure developed for comparing list of assets marked for maintenance with other MOEs' assets.

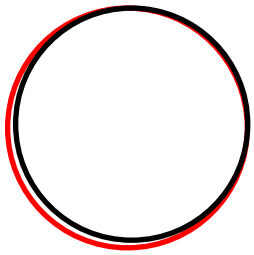
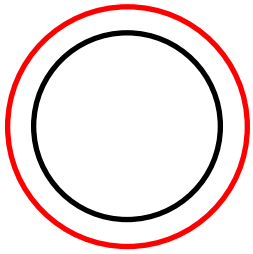
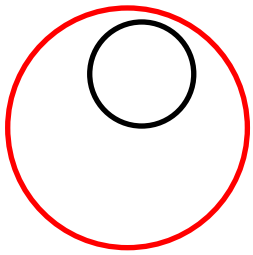
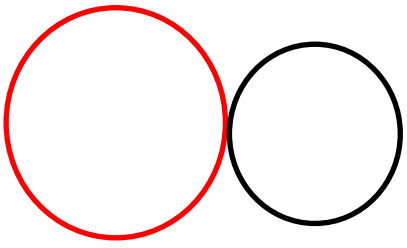
Checks in program for determining overlaps of circles around assets.

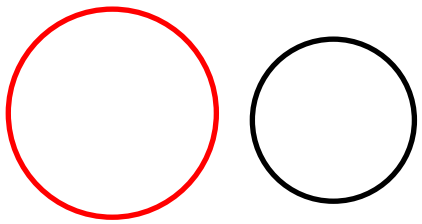
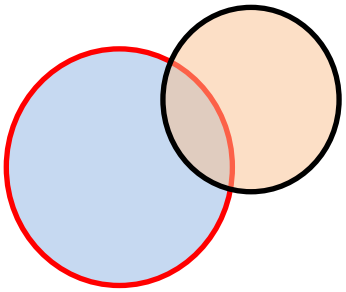
A circle is constructed around the coordinates of the centre point of the two assets.

The circle uses the mid-point co-ordinates (longitude and latitude), as given by the MOEs, of each asset as a centre point of a circle which has half the length of the asset as the radius of the circle.

When drawing two circles around the midpoints of different assets to estimate the probability of intersection of the assets, 6 scenarios may occur (see table 5.1):

Table 5.1 Configurations that may occur when checking for intersecting assets using overlapping circles

1.	Circles may coincide completely. The centre point coordinates are the same and the radii are the same. In this case, the area of intersection (overlap of circles) is determined as 100%. The assets do intersect. The drawing in the next cell shows two such circles. For illustration purposes, the one circle is shown as slightly larger than the other circle.	
2.	The centre points of the circles may be the same but the radii differ. In this case, the assets must intersect and area of intersection is said to be 100%.	
3.	A larger circle may encompass a smaller circle. Centre points of the circles differ but the radius of the asset with the greater length is sufficient to encompass the shorter asset. In this instance the circles are said to overlap by 100%. Assets do intersect	
4.	Circles may touch. This occurs when circles drawn around the two assets overlap at one point only, centre points are distanced from each other by an amount equal to the sum of the two radii. The circles do not overlap more than by a single point. The assets do not intersect.	

5.	Circles are apart completely. Assets do not intersect.	
6.	Circles overlap by a portion less than the sizes of the circles. In this instance, the area of the overlap is calculated and compared to the total area of the circles. If this intersection area, as a percentage of the total area of the circles, is greater than the percentage specified in the file “lifeparm.xlsx”, the assets are said to intersect. This is the only instance where there is uncertainty of intersection.	

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Length of assets

A problem that exists with the data is the length of electrical cables. Some of these cables can be kilometres in length. This means that the circle with half the cable length as radius is bound to overlap circles circumscribed by other MOE’s assets around their mid-points with radii half of their asset length. There needs to be a limit to the length of assets.

In figure 5.5 an electrical cable is show running between the load centres LC1 and LC2. A water pipeline runs between manhole MH1 and MH2. The cable is not straight and has a length far in excess of the length of the water pipeline. If the circles around the assets are drawn using half the length of the assets the program will determine that conflict exists. If the length of assets is limited by a determined amount (see next section on tests for determining best values of parameters) then this conflict point will not be added to the list of conflict points.

The maximum length of assets can be defined by the user. This may skew results unfortunately, but with the limited programming resources available for this research this cannot be overcome. This problem can be overcome through the use of MOE’s existing GIS systems (see section 5.2.2.2). A series of tests were performed to determine best values for the length of assets as shown in the following section.

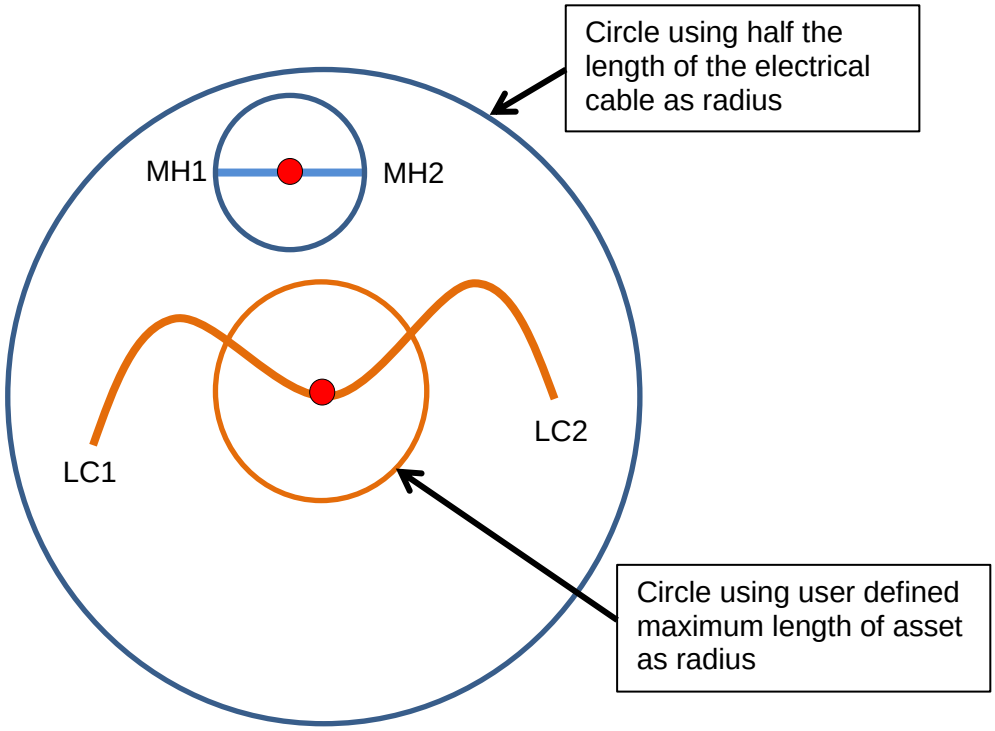


Figure 5.5 Diagram illustrating the need for limiting the length of assets for input to the program

Tests for determining best values of parameters

All roads and all MV cables in the study area were identified from the data supplied by JRA and City Power. Intersections of the roads and cables of JRA and City Power were manually counted to determine the total possible number of intersections between these assets. The number of intersections between assets of JRA and City Power was 754.

The data supplied by the MOEs was altered so that the Remaining Useful Life's (RUL's) for all roads within JRA's data were set to 1 and all other data in the JRA asset file was deleted. The same procedure was applied to City Power's data, setting RULs for MV cables to 1 and deleting all other assets from the file. When the program was executed and job cards generated, this altered data forced the program to generate a maintenance list for all roads and all MV cables. The maintenance files for City Power and JRA were checked for conflicts. The number of conflicts reported by the program should have been similar to the number of conflicts counted manually.

The parameters for the percentage overlap of circles and the maximum length of assets as described in sections 5.2.5.1 and 5.2.5.2 were adjusted until an approximate match of intersections was output from the program. As shown in table 5.2, the parameters most suited for producing approximately 754 intersections were a 50% overlap and a maximum length of 187 metres.

Table 5.2 Iterations for calculation of parameters for input to program

Scenario	percent overlap (%)	maximum length of asset (m)	Number of conflicts	
			JR-CP	CP-JR
1	25%	200	843	863
2	30%	200	839	844
3	40%	200	833	835
4	40%	150	502	502
5	40%	175	641	641
6	40%	190	785	787
7	50%	190	785	785
8	50%	180	671	671
9	50%	185	715	715
10	50%	187	738	738

“JR-CP” refers to conflicts between JRA’s maintenance file and the entire set of assets belonging to City Power. “CP-JR” refers to the conflicts between City Power’s maintenance file and the entire set of assets belonging to JRA. Output from the program has been abbreviated for easy reference within the program using a set of only 2 characters.

In this test, the conflicts are effectively duplicated as both MOEs produce sets of maintenance cards that match entirely with their asset file. In practice, duplications (an asset marked for maintenance that intersects with a different MOE’s asset which is also marked for maintenance) will be few. JRA has 488 records marked for maintenance, City Power 1113 records and Johannesburg Water has 1270 records in this study. Maintenance records for each year are between 10 and 20 job cards (see Appendix C). In an initial run of the program JRA with 488 records generated an average of 10 maintenance job cards. The conflicts amounted to 33 between JRA and Johannesburg Water and 16 between JRA and City Power. The actual average number of maintenance records for Johannesburg Water was 21. The probability that these 21 records matched the 33 conflict records gives the probability that duplicates may appear. This is calculated as the probability of any one asset being selected as a maintenance record 21/1113 (1.89%) and 33/1113 (2.96%) as the probability that a record may be a conflict. The probabilities are multiplied to obtain the probability that the maintenance and conflict records are the same: 1.89% * 2.96% = 0.06%.

The chances therefore for finding duplicate conflicts are small. Even if conflicts are duplicated costs may still be effectively double depending on when the work on the assets

is scheduled and coordinated. In a non-integrated system, maintenance works are mostly not coordinated.

5.2.3 Risk costs of conflict points

When job cards have been created and the conflict points defined, the user can apply a series of costs to each conflict point to determine overall cost of risk of damage and/or neglected maintenance. Costs have been calculated as described in section 5.4.

5.3 ASSUMPTIONS

In order to simulate integrated and non-integrated IAM systems, the following assumptions were necessary in order to produce meaningful output within a short period:

- No new assets were added during the study period.
- Maintenance is done in the year in which it was planned– no maintenance is carried over to the next year. No events interrupt or interfere with maintenance tasks.
- A single value for RUL (the period between two maintenance events) was allowed – in practice, this value would be different for different classes of roads, pipes, cables or other assets. This may be altered by the user by editing a text file. Several instances of maintenance works may be performed during the RUL.
- Any assets having a RUL equal to 1 year or less are marked for maintenance. This may be altered by the user by editing a text file.
- A single cost for each MOE is applied to each conflict using the costs defined in section 5.4. These can be edited by the user in a text file.
- RUL values are provided in Johannesburg Water data files. RUL values were not provided by JRA and City Power. These values have been randomly generated using Excel's RANBETWEEN function and selecting a range from 0 to 50 years.

Intersection of assets uses the methodology defined in section 5.2. Circles are drawn around assets with half the length of the asset as the radius. If the circles overlap by a user defined percentage, then it is assumed that the assets intersect.

A maximum length of any asset can be set by the user. The reason is explained more fully in section 5.2. Cable lengths are sometimes in excess of several kilometres. With the methodology of using overlapping virtual circles to determine intersections, these long lengths produce many false intersections.

Different scenarios were evaluated while choosing different lengths for the maximum length of assets and different percentages for checking the overlap of circles.

The application assumes that for IAM systems, the coordination of events will take place and consequently, the additional costs of repairs through delay in attendance to incomplete maintenance repair will fall away. Obviously various factors (other emergency tasks, tardiness, etc.) may influence this; these are ignored.

Cost savings of IAM systems therefore can be seen as:

- Savings due to immediate repair of affected assets (direct saving for the MOE).
- Savings due to reduced user inconvenience (saving to the user).

5.4 COSTS

This research looks at the benefit of scheduling infrastructure maintenance and rehabilitation works within road reserves in a cross-enterprise integrated manner. It does not look into costs of non-maintained assets which is a real problem in itself. The research uses details of costs of damaged utilities as the basis for calculating costs associated with non-integrated works. The research takes into account that assets of one utility damaged by the work performed by another utility may encounter a period of low quality and consequential increased costs to the CoJ Council and to the users of the assets.

In order to quantify these benefits or the costs associated with non-integrated systems vs integrated systems the following items need to be addressed:

- The nature and extent of damage to assets
- The effect of this damage to council (Direct costs)
- The effect of this damage to users of the assets (User costs)

Costs for the events surrounding incomplete maintenance are difficult to predict with great certainty. The research has made assumptions concerning possible events occurring at conflict areas (e.g. a road crossing[2], potholes and damage caused after maintenance to an underground pipe). Table 5.3 shows possible events occurring at these areas of conflict and attempts to highlight the risk of the event.

[2] A road crossing refers to a trench excavated across a road to install services. The excavation generally runs perpendicular to the flow of traffic but may run with the flow of traffic in some cases.

Table 5.3 Schedule of user costs, types and probabilities

MOE	Type of damage	Hazard / risk	Seriousness (1=low impact, 5=high impact	Probability of event (1=low, 5=high)	Type of cost	Who does this affect
JRA	Potholes / road crossings	Accident - fatality	5	1	• Fatality Costs • Medical costs • Repairs to vehicles • Production losses • Loss of family breadwinner	• Council • Companies • Families • Individuals, Organisations Insurances • Financing
		Accident - serious, resulting in hospitalisation	4	3	• Medical costs • Repairs to vehicles • Production losses • Reduced income to families	• Council • Companies • Families • Individuals, Insurances
		Accident - minor	3	3	• Medical costs • Repairs to vehicle	• Council • Companies • Families • Individuals, Insurances
		Damage to vehicle (e.g. Tyres, rims, etc.)	3	4	• Repairs to vehicle	• Council • Companies, Individuals, Insurances
		Delay through increased travel time	2	4	• Time costs • Operating costs	• Council • Companies • Individuals
		Need for Alternative routing	1	3	• Time delays • Time for planning routes • Operating costs	• Council • Traffic Management • Companies Individuals
		Damage to goods in transit	3	3	• Goods • Raised prices	• All • May have a ripple effect of price increases
		Carbon emissions	4	5	• Manufacturing costs • Operating costs • Raised prices	• May have a ripple effect of price increases
		Increased operating costs to the user	1	5	• Increased operating costs	• Users of the roads • May have a ripple effect of price increases
City Power	Power outage	Loss of production	3	5	• Losses • Raised prices	• Companies • Individuals • May have a ripple effect of price increases
		Damage to stored goods	3	3	• Losses • Raised prices	• Companies • Individuals
		Loss of vital services (hospitals)	5	1	• Institutional • Emergency	• Institutions • Companies • Community • Individuals
		Needs for duplication of service (backup systems)	3	5	• Equipment • Personnel	• Institutions • Companies • Community • Individuals • May have a ripple effect of price increases

MOE	Type of damage	Hazard / risk	Seriousness (1=low impact, 5=high impact	Probability of event (1=low, 5=high)	Type of cost	Who does this affect
City Power (continued)	Power outage (continued)	Interruption to traffic - lights	3	4	• Time delays • Time for planning routes • Operating costs	• Institutions • Companies • Community • Individuals
		Increase in crime	4	3	• May lead to businesses closing or moving to different location • People may move to different locations • Fatality and injuries • Vigilantism	• Institutions • Companies • Community • Individuals • Insurances
		Increase in accidents	4	3	• Medical costs • Costs of damage to property • Time delays • Production losses	• Institutions Companies Community Individuals • Insurances
	Power spike	Damage to equipment	5	1	• Equipment damage • Need for power stabilising devices	• Companies • Organisations Individuals • Insurances
	Inconsistent power	Inability to plan processes	3	3	• Loss of production • Need for backup devices • Need for redundant strategies	• Companies • Organisations • May have a ripple effect of price increases
		No assurances that certain operations may be undertaken	3	3	• Need for backup equipment • Need for standby power supply	• Companies • Organisations
Johannesburg Water	Reduced supply of water	Damage to manufacturing processes	5	1	• Equipment replacement • Equipment repair	• Companies • Organisations • Insurances
		Loss of production	5	1	• Losses • Raised prices	• Companies Organisations
	Inconsistent water supply	Inability to plan processes	3	3	• Loss of production • Need for backup devices • Need for redundant strategies	• Companies Organisations • May have a ripple effect of price increases
		No assurances that certain operations may be undertaken	3	3	• Need for backup equipment • Need for standby power supply	• Companies Organisations • May have a ripple effect of price increases

Table 5.4 shows comparisons between integrated and non-integrated systems for a hypothetical situation where work on a water pipeline causes damage to a road.

Table 5.4 Comparison of costs between integrated and non-integrated systems

NON-INTEGRATED SYSTEMS	INTEGRATED SYSTEMS
• Road remains damaged until reported. • Delay causes costs to Council and User. • The longer the delay in repairing, the higher the costs. • No cross-enterprise communication leads to lack of coordination of activities. This may result in unnecessary damage (and costs) to recently maintained assets.	• Scheduling of pipe maintenance is coordinated with maintenance on the road. • No maintenance is conducted on the road before the pipe is maintained. • JRA are made aware of Johannesburg Water works and plan for emergency repairs. • In this instance, no delay is encountered

The costs of the Non-Integrated system for all works in the road reserve may be made up of:

- Increased plant, labour, materials, fuel and contractor costs through duplication of works (e.g. a road may have been recently resurfaced when the Water MOE performs maintenance on a pipeline causing damage to the road.)
- Increased costs of plant, labour, materials, fuel and contractor costs due to the increase in damage caused by neglected or delayed damage- (e.g. potholes become larger over time due to vehicle use, and climatic conditions)
- Asset quality is lowered and cannot be wholly recovered (e.g. recently resurfaced roads cannot have small sections reworked without some loss of quality. This results in weak points in the road and reduced asset life resulting in earlier future maintenance)
- User Costs
    - Loss of production (power outages, water supply outages)
    - Damage to goods in transit (quality of road surfaces)
    - Damage to vehicles (quality of road surfaces)
    - Time cost of delays – extended time needed to negotiate damaged areas
    - Damage to equipment (power spikes, water and power outages)
    - Damage to goods in storage (power outages)

- Possible need for redundant (back-up) systems – alternative means to be available for:
  - Methods of production
  - Storage
- Accidents
- Additional Fuel costs
- Additional costs associated with use of alternative transport routes and/or types
- Inconsistent power, water supply makes planning difficult and manufacturers may spend additional time on rescheduling processes around periods of low or no supply
- Insurance costs escalate through claims for damages

Additional costs for implementation of an integrated system comprise:

- Writing of integration software
- Training of personnel
- Establishment of necessary departments and organisational structures
- Offices and equipment

In the projection of costs over a 30 year study period, cost figures are maintained as provided at the base year of 2013. No escalation is applied here or in other projections concerning savings and expenses of new cross-enterprise systems and therefore no discounting is performed.

5.4.1 The probability of damage during maintenance works

A damage event occurs when maintenance by one MOE causes physical damage to other MOE's assets. This may result in assets requiring emergency repairs. Levels of service may be adversely affected. For some damage events, literature or information gained from interviews was available in some form to provide methods of calculation of probabilities of the frequency of occurrence of the damage event. However, after rigorous literature review, the probabilities of occurrence of some damage events for certain maintenance activities could not be determined. This was especially the case with regard to buried assets such as electrical cables and water pipes. If means were found to calculate probabilities of the events, it is contained in the sections concerning costs of the damage events. If no means were found to determine the probability of the frequency of the occurrence of a damage event, this research adopted the probability described in the following two paragraphs.

Initially the risk of damage may be thought of as a 50/50 chance. During excavations either a cable or water pipe is hit or it is not hit. However, a number of factors influence the chances of damage (see figure 5.6). No contractor wants to damage an existing asset, the expense of repairing the asset is normally passed on to the contractor so, most contractors take precautionary measures to avoid damage to other assets. The competency of the contractor is a factor in determining risk of damage. Competent contractors will have experience in making good observations of the area in which work is to take place. Tell-tale signs of buried services are often visible. Existing manhole covers may indicate cables, sewers and water valves. A line or pathway on a road of different coloured and textured asphalt and cut edges may indicate a road crossing below which a pipe or cable may have been installed. Electrical sub stations, traffic lights and street lighting are evidence of electrical cables.

There are other factors that influence risk of damage. If the asset is marked on way leaves, the contractor knows that it is there. However, if databases are not up to date there is a possibility that the contractor is not informed of the service as it is not displayed on way leaves. Another important factor is the accuracy of current plans and drawings; an asset shown in a specific location but existing elsewhere may be as bad as, or worse than, an asset not shown. Further factors include soil conditions; soft soil makes locating a service easier while a dense rocky soil can force a contractor to exert more force while digging and consequently the risk of damage increases. Finally, the depth at which an asset is located affects the chance of damage. Assets near the surface are located easily by hand excavation, greater depths encourage machine excavation and the possibility of damage to assets becomes greater.

With little or no information regarding frequency of events resulting in damage to assets during maintenance, a figure of 2% (a 1 in 50 chance of damage occurring) of all maintenance work is assumed and where applicable, is noted in the following sections concerning costs.

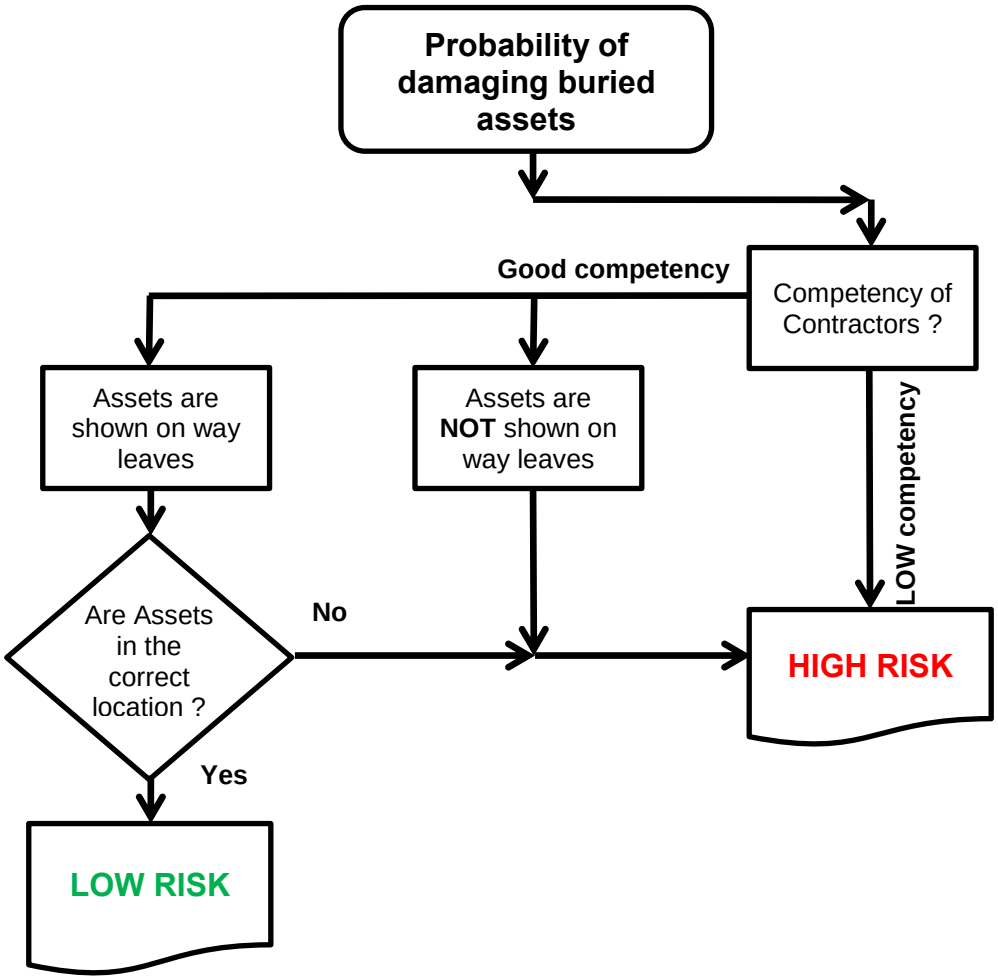


Figure 5.6 Determination of risk of damaging assets during maintenance operations

5.4.2 Road costs due to neglected maintenance (JRA)

5.4.2.1 Direct Costs: Roads

The costs of repair of a road crossing on a minor road may be calculated as follows:

Damage to the road will increase if the repairs are not affected immediately. Eventually work will need to be performed on base, sub-base, and sub grade road layers. The area of the road crossing may increase substantially if left unattended. Surfaces tend to unravel with traffic and cracking extends to areas surrounding the initial damaged area. Figures in tables 5.5 to 5.9 and figure 5.6 showing costs of repair have been estimated by a civil engineering contractor (McCarroll, 2014) and validated by JRA (2014).

Table 5.5 Costs of road repairs due to damage in asphalt and their increase over time (McCarroll, 2014)

Increase in Asphalt area Area increases due to unravelling and cracking of roadway surrounding crossing				
Delay (weeks)	**increase in area and additional work required**	**Original / base cost of road crossing (rands)**	**Increase in costs (rands)**	**New cost (rands)**
0	0%	5 907	0	5 907
2	50%	5 907	2 955	8 863
5	134%	5 907	7 935	13 843
8	178%	5 907	10 490	16 397
11	207%	5 907	12 221	18 128
14	229%	5 907	13 531	19 439
17	247%	5 907	14 586	20 494
20	262%	5 907	15 470	21 377

Table 5.6 Costs of road repairs due to damage in base course and their increase over time (McCarroll, 2014)

Delay (weeks)	**increase in area contamination and lost aggregate**	**Original / base cost of road crossing (rands)**	**Increase in costs (rands)**	**New cost (rands)**
0	0%	0	0	0
2	50%	2 436	1 218	3 654
5	114%	2 436	2 777	5 213
8	147%	2 436	3 581	6 017
11	170%	2 436	4 141	6 577
14	187%	2 436	4 555	6 991
17	200%	2 436	4 872	7 308
20	212%	2 436	5 164	7 600

Table 5.7 Costs of road repairs due to damage in sub-base layer and their increase over time (McCarroll, 2014)

Delay (weeks)	**increase in area and lost aggregate**	**Original / base cost of road crossing (rands)**	**Increase in costs (rands)**	**New cost (rands)**
0	0%	0	0	0
2	0%	0	0	0
5	0%	0	0	0
8	50%	2 625	1 313	3 938
11	114%	2 625	2 993	5 618
14	147%	2 625	3 859	6 484
17	170%	2 625	4 463	7 088
20	187%	2 625	4 909	7 534

Table 5.8 Costs of road repairs due to damage in sub-grade layer and their increase over time (McCarroll, 2014)

Delay (weeks)	increase in area and lost aggregate	Original / base cost of road crossing (rands)	Increase in costs (rands)	New cost (rands)
0	0%	0	0	0
2	0%	0	0	0
5	0%	0	0	0
8	0%	0	0	0
11	50%	3 203	1 601	4 804
14	114%	3 203	3 651	6 853
17	147%	3 203	4 708	7 910
20	170%	3 203	5 444	8 647

Table 5.9 Summary of costs of road repairs due to damage in various layers and their increade in time (McCarroll, 2014)

Delay (weeks)	Asphalt	Base	Sub-base	Sub-grade	Total
0	5 907	0	0	0	5 907
2	8 863	3 654	0	0	12 517
5	13 843	5 213	0	0	19 056
8	16 397	6 017	3 938	0	26 352
11	18 128	6 577	5 618	4 804	35 126
14	19 439	6 991	6 484	6 853	39 767
17	20 494	7 308	7 088	7 910	42 800
20	21 377	7 600	7 534	8 647	45 158

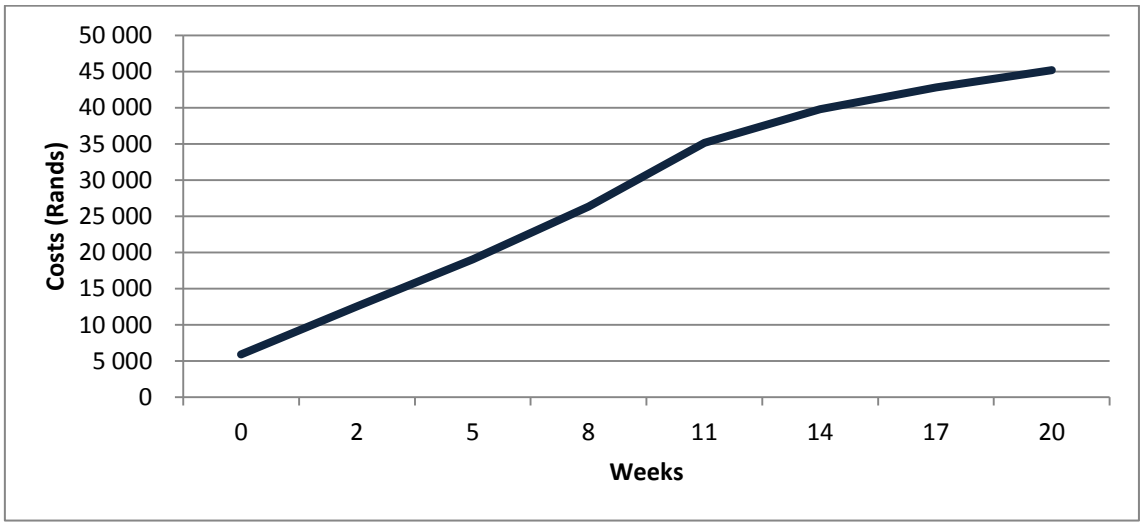


Figure 5.7 Graphical illustration of increased road costs over time due to delays to repairs

For purposes of this research the cost savings in all conflicts is set as the value of additional costs encountered after three days i.e. R9,212.00. This takes into account the average response time for repairs after receipt of report as three days (see section 4.3).

5.4.2.2 Risk of accidents occurring at conflict areas

Literature exists for statistics concerning accidents at road works and accidents caused as a result of poor road conditions (Botha and van der Walt, 2006). The following provide an estimate of the ratio of accidents at conflict areas to overall poor road conditions at the study area.

The road network in the study area is 40,891m long.

With an average width of 7m, as described on JRA standard drawing JRA-SD-R005, this yields an area of 286,237 m^2.

An assessment conducted by JRA (2013), shown in table 5.6, shows that the percentage of poor and very-poor conditions of roads is 27.69% in Region F of Johannesburg, Applying this percentage to the area of roads in the study area, a value of 79,259 m^2 is considered as poor in the study area.

Table 5.10 Assessment by JRA on the Visual Condition Index (VCI) of roads in Johannesburg (JRA, 2013)

	Very Good	Good	Fair	Poor	Very Poor
Region A	34.13%	19.52%	7.99%	27.39%	10.97%
Region B	24.14%	15.64%	29.78%	22.10%	8.34%
Region C	31.95%	18.95%	12.15%	29.50%	7.45%
Region D	51.59%	13.36%	20.61%	11.17%	3.27%
Region E	20.62%	23.50%	26.77%	21.50%	7.61%
Region F	30.11%	15.30%	26.90%	21.24%	6.45%
Region G	44.48%	18.10%	21.90%	12.54%	2.98%
Average	33.86%	17.77%	20.87%	20.78%	6.72%

Preliminary runs of the simulation program showed the number of conflicts points between JRA and the other two MOEs as between 76 and 303.

Using the average width of a road (7m) (JRA standard drawing JRA-SD-R005) as the length of a conflict point and an average width of the conflict area as 1m, the area of a conflict point is calculated as $7m^2$. With 76 conflicts, the area of conflicts is $532m^2$. As a percentage of the overall poor road condition area this equates to 0.7% and is rounded to 1%.

This value is used in the calculations that follow.

5.4.2.3 User Costs: Roads

As Table 5.3 shows, user costs may originate at different sources and involve various events. This research considers the following user costs:

- Road Accidents
    - Fatalities
    - Casualties
    - Damage to Vehicles
- Time Delays
- Alternative Routing
- Carbon Emissions
- Increased Operating Costs

Fatal Accident Costs

Botha and van der Walt (2006) identify that 1% of road accidents are attributable to poor road conditions. As outlined in section 5.4.2.2, 1% of accidents due to poor road conditions are attributable to neglected and unfinished maintenance works. Table 5.7 shows the forecasted figure for costs of fatalities in Johannesburg.

No allowance is made in table 5.7 for costs concerning loss of breadwinners, loss of manpower and productivity.

Table 5.11 Costs of fatal accidents (Botha and van der Walt, 2006)

Estimated costs of fatal accidents in the Republic of South Africa (RSA)			
2003	8.02	billion rands	
2004	8.89	billion rands	
2005	9.99	billion rands	
No. of fatal accidents by province			
	Gauteng	RSA	Gauteng's % within RSA
2003	2284	10239	22.31%
2004	2284	10471	21.81%
2005	2621	11614	22.57%
No. of fatalities by province			
	Gauteng	RSA	Gauteng's % within RSA
2003	2608	12353	21.11%
2004	2564	12636	20.29%
2005	2922	14126	20.69%
Based on the percentages of accidents occurring in Gauteng, approximate costs in the province of Gauteng are shown below:			
2003	1.69	billion rands	
2004	1.8	billion rands	
2005	2.07	billion rands	
Costs attributable to poor road conditions in Gauteng (1%)			
2003	16.9	million rands	
2004	18	million rands	
2005	20.7	million rands	
1% of poor road conditions is due to unattended maintenance (see section 5.4.1.2)			
2003	169 000	rands	
2004	180 000	rands	
2005	207 000	rands	
At an inflation rate of 6%, the current value (2013) based on the 2005 costs is:			
	329 927	rands	

A fatality is unlikely to happen at incomplete maintenance areas but in the event of a fatality, results are catastrophic and affect many persons. It becomes difficult to allocate a risk cost to this event and other accident type events. No direct studies into the frequency and costs of accidents at incomplete maintenance areas have been performed and capturing of such data is difficult. The above figures serve rather as a starting point for further calculations outlined later. Pronouncing the costs of a fatality as R300,000 is clearly understating the obvious; one fatality costs millions of rands.

Further to the figures quoted in table 5.11, De Beer and van Niekerk (2004) show that the costs of fatalities including other associated costs amount to R898,000 per fatality. The study also shows costs for serious and slight injury type accidents as shown in Table 5.12.

Table 5.12 Human casualty costs (De Beer, and van Niekerk, 2004)

Summary of human casualty costs by cost category and severity of injury			
Category	**Fatal**	**Serious**	**Slight**
Lost future earnings	348 384	323 728	-
Lost past earnings	52 643	68 616	2 743
Value of lost support	280 097	22 399	
Hospital and medical costs	15 940	111 631	2 312
Funeral costs	9 792		
Legal costs - RAF	68 901	73 803	23 768
Legal costs - claimant	38 267	74 557	35 648
Other costs		23 989	
Pain and suffering	84 900	62 891	17 835
Total (Standardised cost)	**898 924**	**761 614**	**82 306**

Using an average inflation rate of 6% and applying the formula, $FV = PV \times (1 + i)^n$ where FV is future value, PV is present value, *i* is the inflation rate and *n* is the number of years, the 2013 the cost of fatalities is calculated as R1.6 million per annum. The quality of assets decline over time at an increasing rate (Cagel, 2003), and hence risk also increases over time. The annual figures shown in table 5.7 therefore are made up of daily figures that grow at an increasing rate through the year. Taking into account the increase in costs of direct repairs as outlined in section 5.4.2.1 and relating this directly to the risk of fatalities and fitting a quadratic polynomial curve to the data, the formula $y = 11.914 \times x^2 + 25.325 \times x - 19.512$ is derived for the rate of increase through the year. This is illustrated in figure 5.7.

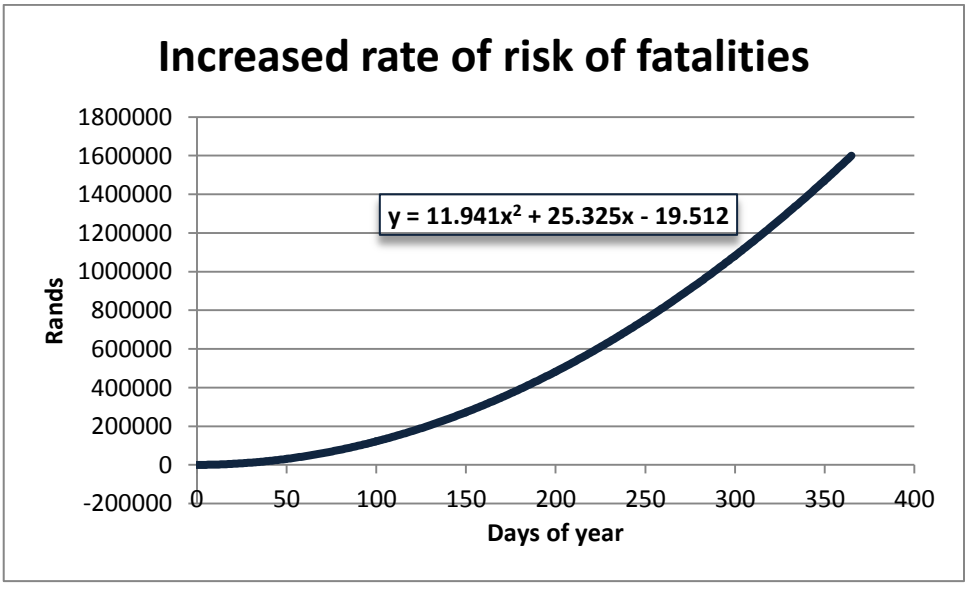


Figure 5.8 Formula for calculation of monthly risk costs in terms of fatalities (based on increased costs as shown in figure 5.6)

As stated by JRA (2014), repairs should take no more than 3 days to execute. If the value of risk of fatality is taken at 3 days, the value of risk cost is R163.69 per conflict point.

Cost of Serious Accidents – Resulting in Hospitalisation

Serious accident costs are tabled as R761,614 per annum in Table 5.8. Applying an average rate of inflation of 6%, the figure of R1,363,935 is calculated as the annual costs of serious accidents requiring hospitalisation.

Applying the notion that degradation of assets increases over time (Cagel, 2003), and using the polynomial formula as shown in figure 5.7, but applying the annual costs of serious accidents of R1,363,935, the formula $y = 10.179 \times x^2 + 21.588 \times x - 16.634$ is derived. Extracting the value at 3 days gives the risk cost per incident which amounts to R139.74.

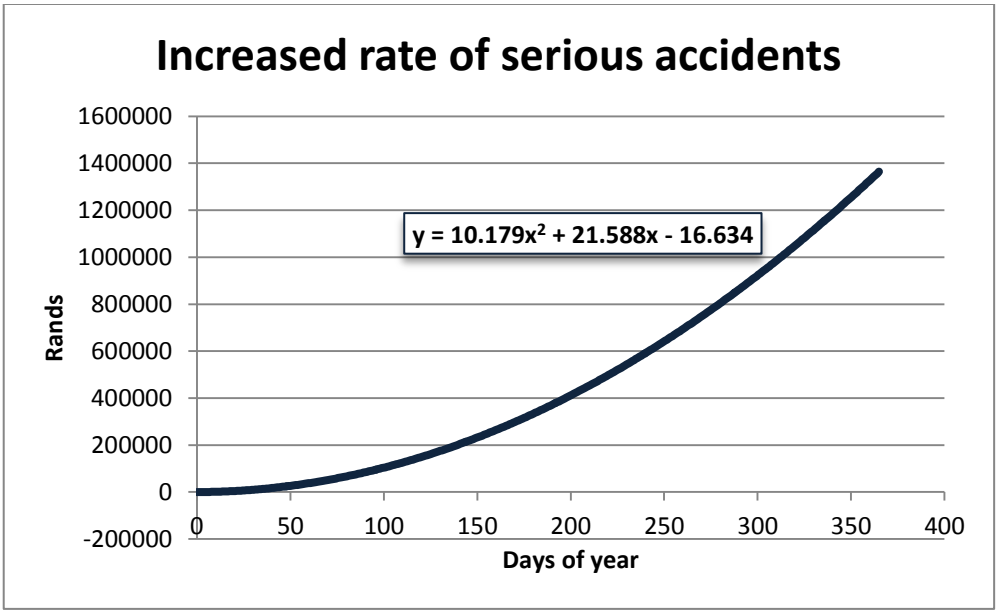


Figure 5.9 Increased rate of serious accidents (based on increased costs as shown in figure 5.6)

Cost of "Vehicle Only" Accidents – No Medical costs

A Contract Report from the National Department of Transport (2004) shows the statistics in table 5.9. In line with the study by Botha and van der Walt (2006) (see section 5.4.2.3), the amount for Gauteng is taken as a percentage of 20% and the amount attributable to poor road conditions is taken as 1%. As outlined in section 5.4.1.2, 1% of accidents due to poor road conditions are attributable to neglected and unfinished maintenance works.

Table 5.13 Vehicle damage and incident costs (National Department of Transport, 2003)

Vehicle damage and incident costs		
Urban areas	17 494	Million rands
Rural areas	1 184	Million rands
Total	18 679	Million rands
if Gauteng has 20% of these (Botha and van der Walt, 2006)	3 735	Million rands
if 1% is attributable to poor road conditions (Botha and van der Walt, 2006)	37 358 529	Rands
if 1% if this is attributable to neglected repair (see section 5.4.1.2)	373 585	Rands per annum

In a similar fashion to the determination of rate of change of increases to the growth of the risk in previous calculations for fatality risks and serious accident risks a polynomial trend is used to obtain a formula for calculating the value at 3 days. The resultant formula is: $y = 2.788 \times x^2 + 5.9131 \times x - 4.556$, and the value at 3 days is R38.28.

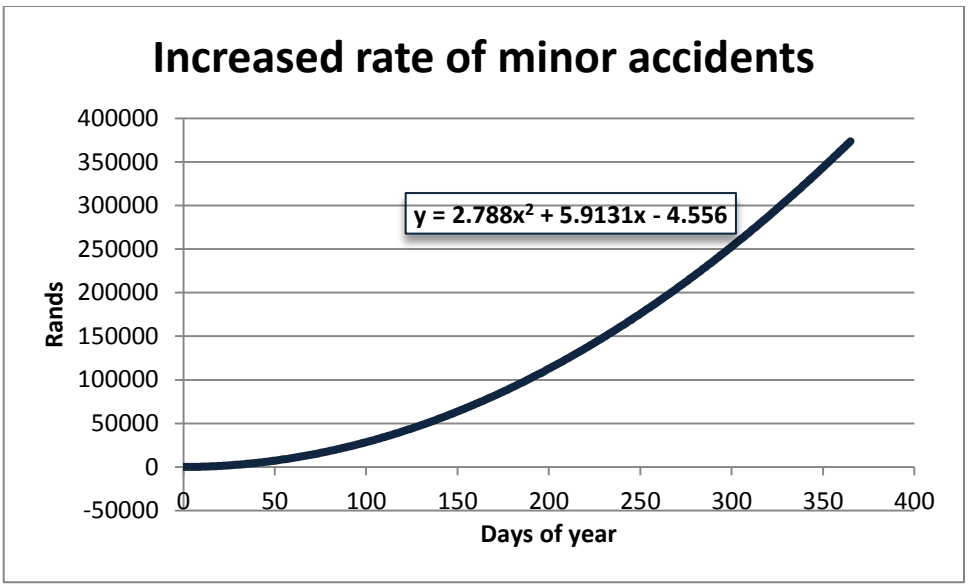


Figure 5.10 Increased rate of minor accident costs (based on increased costs as shown in figure 5.6)

Costs of damage to the rims and tyres of vehicles

This type of damage is the most common damage at place where roads are in bad condition. Effectively, road crossings become dangerous potholes.

The costs of a tyre may vary from brand to brand. A cost selected for Dunlop 205/55/16" tyres from the website Pricecheck.co.za in October 2014 is R780.00 per tyre. Prices of rims vary greatly as well. A set of four alloy rims was found to be R2,590.00 on the www.pricecheck.co.za website in October 2014. This means that the price for a tyre and rim is approximately R1500.00.

Various reports (CSIR, 2010) state large figures for costs of repairs for damage caused by potholes. In a CSIR non-technical document, the authors quote from a South African Road Federation study that potholes are costing road users R50 billion in vehicle repairs and injury annually (Carte Blanche 2010, cited in CSIR, 2010).

Estimating that there may be six incidents (JRA, 2014) of damage at one road crossing; then costs in one area can amount to R9,000.00. As time increases and road surface deteriorates and repairs are not affected, the possibility of further incidents and larger costs grow. Not all road crossings turn into hazards however, and some estimation of the risk that they do cause these costs needs to be determined. In keeping with the previous assumptions that 1% of overall costs may be attributable to unfinished maintenance work, the cost used in the research is set at R90.00 per incident.

Costs of Time Delays

There are many unknown variables that make determining a cost for delay at road works and damaged roads difficult.

A truck delayed at a damaged road will cost in terms of:

- additional fuel use
- less deliveries
- costs may impact on other operations reliant on the truck
- maybe more vehicles needed

A passenger vehicle may produce additional costs

- passenger late for work/appointments/other operations
- changes to schedules necessitated
- maybe more vehicles needed

Gao and Zhang (2013) have produced means for calculating the costs associated with time delays in traffic. A series of formulae are of some relevance to the problem of determining delay costs at road works and low quality areas on roads.

The cost of delays is directly proportional to the time spent in traffic and the ‘average social reward’: social reward is a measure of the value of time to road users (Gao and Zhang, 2013).

This research uses Gao and Zhang’s (2013) formula (equation 5.1) to calculate an estimate of the costs of delays at areas of incomplete maintenance.

$D(t) = Textra * R(t)$ .....Equation 5-1

Where: *D(t)* is delay cost of year *t*

Textra is the extra time

R(t) is Social reward of year *t*

The South African minimum hourly wage across various industries is approximately seventeen rands per hour as shown in Table 5.14.

Table 5.14 Calculation of minimum wage in Gauteng

Minimum wages in Gauteng as at March 2013		
Sector	**Wage per hour (rands)**	**Source**
Civil Engineering	22.56	South African Federation of Civil Engineering Contractors (SAFCEC), 2013
Hospitality Industry	13.81	Department of Labour of RSA, 2013
Domestic Workers	8.95	Department of Labour of RSA, 2013
Drivers	21.6	National Bargaining Council for the Road Freight and Logistics Industry (NBCRFLI), 2013
Average wages	R 16.73	

then social reward is approximately R36.43 per hour for passenger cars and R58.89 per hour for commercial trucks.

These are calculated by taking Gao and Zhang's ratio between minimum wage and social reward in Hong Kong and applying the ratio directly to the South African context. The ratio is 60/28 (2.14) for cars and 97/28 (3.46) for commercial trucks – 60 and 97 being Hong Kong's social rewards and 28 the minimum wage.

By applying equation 5.1, and assuming that 100 vehicles pass the point of damage before repairs are executed and these vehicles are made up of 60 cars and 40 commercial trucks then:

R(t) = 2.14 * 60 * 17 + 3.46 * 40 * 17 =R4,536

If the average extra travel time is 5 minutes per month; that translates to 500 minutes or 8.33 hours for the vehicle make-up, then:

D(t) = 8.33 * 4536 = R37,785 per month

It is clear that, at the estimate of a 5 minute delay per month per vehicle, user costs are significant. Reducing the monthly figure to 3 days, the time it takes JRA to repair damage

after reports of damage are received (JRA, 2014), the risk cost per incident of R3656.61 is derived.

Costs of Alternative Routing

Many large logistics companies maintain software that monitor trips and plans best routing. In the event of delays on certain routes their software may select different routes and communicate these to the drivers. Drivers of vehicles not linked to routing software (the vast majority of vehicles on the road) suffer delays at the point of hold-up, possibly for a couple of days or weeks before they plan for different routes. Obviously the extra kilometres travelled are an extra expense to the driver in terms of wear and tear and fuel costs; so too is the extra time taken for the new trip.

Additional costs that may be associated with the new route include

- Increased travel time due to additional distance
- Increased fuel use
- Tolls
- Wear and tear costs
- Insurances

An estimate for the average operating costs is based on a vehicle with an engine capacity of 1800 cc and petrol driven. Figures from the AA operating costs calculator (2014) estimate costs in the region of 144 cents per kilometre. Assuming an additional distance required is 5km the additional cost is calculated as R7.20 per vehicle per trip.

If there are 100 vehicles subjecting themselves to the extra distance then:

Vehicles = 100 per day

Costs = cost * no. vehicles * 365 = R262,800 per annum

= R21,900 extra per month

Reducing the monthly figure to 3 days, the time it takes JRA to repair damage after reports of damage are received (JRA, 2014), the risk cost per incident of R2,119.35 is derived.

Costs of Carbon Emissions

Carbon emissions are increased during idling times and they are increased if an alternative route taken is longer or takes more time to drive than the original route. (Rahman et al, 2014)

Many variables are encountered when carbon emissions are considered. The number and categories of vehicles at a point of delay is unknown. There is also the factor of surface roughness or road damage which can affect the output of emissions.

The costs of emissions are a subject of discussion. The effects of climate change and the extent to which carbon emissions are responsible for climate change are not clearly understood and depend on future predictions and scenario planning. The future is quite unpredictable in terms of climate change and the effects that today's emissions may have on future needs or damage is vague.

Various organisations put forward arguments for the social costs of emissions ranging from US$21 to US$900 per ton.

Reports from the United States Environmental Protection Agency (EPA) talk of the Social Cost of Carbon (SCC) which includes amongst other items, the damage costs directly attributed to the emissions gases. Table 5.11 shows SCC costs in America dollars.

Table 5.15 Costs of carbon emissions (United States Environmental Protection Agency, 2013)

Social Cost of CO_2, 2015-2050 [a] (in 2011 US Dollars)				
	Discount Rate and Statistic			
Year	**5% Average**	**3% Average**	**2.5% Average**	**3% 95thpercentile**
2015	$12	$39	$61	$116
2020	$13	$46	$68	$137
2025	$15	$50	$74	$153
2030	$17	$55	$80	$170
2035	$20	$60	$85	$187
2040	$22	$65	$92	$204
2045	$26	$70	$98	$220
2050	$28	$76	$104	$235
The SCC values are dollar-year and emissions-year specific.				

The average value of US$39 per ton for the year 2015 as shown in table 5.11 is used as a basis for further calculations. US$39 is approximately R400.00 (loosely based on an exchange rate of US$1 to R10.25). Therefore 1 ton costs R400.00.

Emissions for the average new car in the United Kingdom are 128.3g/km (Society of Motor Manufacturers and Traders, 2014). As a starting point this figure is used to

calculate costs associated with emissions. The figure is considered conservative as the makeup of vehicles at incomplete maintenance areas will include old and new vehicles which may be cars and trucks. For ease of calculation the cost is rounded to 130g/km. The cost is therefore R0.052 per km

If, in alternative routing, an additional 5 km is travelled the additional costs for emissions amounts to R0.26 per vehicle

If there are 100 vehicles choosing an alternative route the total costs is R26.00 per damaged area or incomplete maintenance area.

Additional idling causes extra emission costs and wear and tear on the engine of a vehicle.

Emissions range between 4034 and 9743 g/hr CO2, depending on speeds and loads of the vehicles (Brodrick et al, 2002).

An average of these values is taken: 6888.5 g/hr

For a 10 minute additional delay, the emissions are 1148.083 grams

The costs are then R400.00 per ton or R0.0004 per gram, so cost is R0.459233 per vehicle. For 100 vehicles R44.92 per conflict area.

Total emission costs including idling and alternative routing emissions amount to R71.92 per area of incomplete maintenance.

Additional Operating Costs

Operating costs include:

- Wear and Tear costs. Damage to engine and body of vehicles over time
- Maintenance costs:
    - Services
    - Tyres
- Fuel

Taking an estimate for the average operating costs based on a vehicle with an engine capacity of 1800 cc and petrol driven, figures from the AA operating costs calculator (2014) estimate costs in the region of 144 cents per km.

Again, accurate assessment of additional operating costs is difficult due to the different vehicle make-up, loads carried, weather conditions, etc.

In determining the operating cost increases, the questions were discussed, “Can a cost per kilometre to the operating costs be applied or must a static increase for an event in time be used?” There are arguments for both; firstly the operating costs do increase during the delay and period of negotiation through the incomplete maintenance area, and secondly any serious shock to the vehicle may result in on-going additional costs due to damaged components.

Working on the application of the increased roughness index and related costs increases, a figure for operating costs over a short distance was calculated. If the roughness index increases to 16 or 17, as may easily happen with incomplete maintenance, then operating costs may increase by 80% see Table 5.16.

Table 5.16 Road user costs related to Roughness Index of road (Archondo-Callao, 1999)

Typical Economic Unit Road User Costs per Roughness Level for Flat Terrain (US$ per vehicle-km)												
Roughness (IRI)	Motor cycle	Medium Car	Delivery Vehicle	Light Truck	Medium Truck	Heavy Truck	Articulated Truck	Small Bus	Medium Bus	Large Bus	Average	Cost Increase (%)
2	0.04	0.20	0.20	0.19	0.46	0.79	0.97	0.25	0.35	0.50	0.395	
4	0.04	0.21	0.20	0.21	0.49	0.84	1.02	0.26	0.37	0.53	0.416	5%
6	0.04	0.22	0.22	0.22	0.54	0.93	1.11	0.28	0.40	0.58	0.454	15%
8	0.05	0.23	0.24	0.24	0.59	1.02	1.21	0.31	0.45	0.65	0.498	26%
10	0.05	0.25	0.27	0.26	0.65	1.13	1.33	0.34	0.50	0.73	0.550	39%
12	0.05	0.27	0.29	0.28	0.71	1.24	1.45	0.37	0.56	0.83	0.607	53%
14	0.06	0.30	0.32	0.30	0.77	1.35	1.58	0.41	0.62	0.93	0.664	68%
16	0.06	0.32	0.35	0.33	0.84	1.46	1.71	0.45	0.69	1.03	0.723	83%

Table 5.17 Description of Roughness Index categorisations (Archondo-Callao, 1999)

Roughness								
Range (IRI)	Description							
1.5 to 2.5	Recently bladed surface of fine gravel or soil surface with excellent longitudinal and transverse profile (usually found only in short lengths).							
3.5 to 4.5	Ride comfortable up to 80-100 km/h, aware of gentle undulations or swaying. Negligible depressions (e.g. < 5mm/3m) and no potholes.							
7.5 to 9.0	Ride comfortable up to 70-80 km/h but aware of sharp movements and some wheel bounce. Frequent shallow-moderate depressions or shallow potholes (e.g. 6-30mm/3m with frequency 5-10 per 50m). Moderate corrugations (e.g. 6-20mm/0.7-1.5m).							
11.5 to 13.0	Ride comfortable at 50km/h (or 40-70km/h on specific sections). Frequent moderate transverse depressions (e.g.20-40mm/3m-5m at frequency 10-20 per 50m) or occasional deep depressions or potholes (e.g. 40-80mm/3m with frequency less than 5 per 50m). Strong corrugations (e.g. > 20mm/0.7-1.5m).							
16.0 to 17.5	Ride comfortable at 30-40 km/h. Frequent deep transverse depressions and/or potholes (e.g. 40-80mm/1.5m at frequency 5-10 per 50m); or occasional depressions and/or potholes (e.g. 40-80mm/1.5m at frequency 5-10 per 50m); or over deep depressions (e.g. 80mm/1-5m with frequency less than 5 per 50m) with other shallow depressions. Not possible to avoid all the depressions except the worst.							
20.0 to 22.0	Ride comfortable at 20-30 km/h. Speeds higher that 40-50 km/h would cause extreme discomfort and possible damage to the car. On a good general profile: frequent deep depressions and/or potholes (e.g. 40-80mm/1.5m at frequency 10-15 per 50m) and occasional very deep depressions (e.g.> 80mm/0.6-2m). On a poor general profile: frequent moderate defects and depressions (e.g. poor earth surface).							

The operating costs for a short distance (say 10m) may amount to:

Operating costs as stated are R1.44 per km, total operating costs then are R0.0144 per distance of 10m, with an 80% increase this yields R0.02592 per 10m.

If 100 vehicles per day travel past the conflict area the total cost for all vehicles is R2.592, or R78.84 per month or R7.63 for a 3 day period – the time JRA states it takes to repair damage after reported (JRA, 2014).

This will increase as the road surface further deteriorates.

5.4.3 Electrical costs of neglected maintenance (City Power)

Damages to cables, sub stations and other electrical equipment require emergency repair in most cases. Costs of cables and other necessary materials may be large depending on the type of cable and the extent of damage to the cable. Labour and sub-contractor costs are often escalated for emergency repairs. Data in the asset files provided by City Power includes only Medium Voltage cables. Costs for damages to Light Voltage cables are ignored in this research.

User costs can be significant. Downtime in manufacturing plants can have high costs; not only through lost production, but also due to partly manufactured goods being thrown out due to defects caused by electrical outages or supply inconsistencies.

In City Power's annual financial report of 2011 quoted figures for repairs and maintenance expenses for City Power as R293 million (City Power, 2011). By 2013, this figure had risen to R419 million (City Power, 2013).

5.4.3.1 Direct costs: Electrical

Direct costs of electricity outages or inconsistent supply include:

- Repair and replacement costs
- Loss of Revenue
- Need for temporary supply

Repairs and Replacement

The research assumes that costs will arise from damages done during construction works on other services. For example, a contractor excavating a trench for maintenance works on a water line hits an electrical cable. No costs associated with opportunistic theft are taken into account. The direct costs then will be replacement of sections of cable including materials, plant and labour. Costs of repairs to MV cables are in the order of R1,200 per metre as stated by City Power in an interview on 29 September 2014. With approximately 5m needing repair on either side of a damaged section, the total amount that may be applied to repair work is R12,000.00. No additional amount is added for labour.

After rigorous literature review; the probabilities of an event, relating to damage caused to assets during other MOE's maintenance, could not be determined. This research attempts to calculate the chances of an event of damage to the cable. Initially, a risk may be thought of as a 50/50 chance: either the cable is hit or it is not hit. However, a number of factors influence the chances of damage. Firstly, no contractor wants to hit an electricity cable. The expense of repairing is normally passed on to the contractor so most contractors take precautionary measures to avoid damage to other assets. There are other factors: if the asset is marked on way leaves, the contractor knows that it is there. However, if databases are not up to date, there is a possibility that the contractor is not informed of the service as it is not displayed on way leaves. Another important factor is the accuracy of current plans and drawings: an asset shown in a specific location but existing elsewhere may be as bad, or worse, than an asset not shown. Further factors include soil conditions: soft soil makes locating a service easier while a dense rocky soil can force a contractor to exert more force while digging and consequently the risk of

damage increases. Finally, the depth at which an asset is located affects the chance of damage. Assets near the surface are located easily by hand excavation, greater depths encourage machine excavation and the possibility of damage to assets becomes greater.

Assuming that a damage event occurs 1 in 50 times during maintenance works (see section 5.4.1), there is a possible cost of R500.00 for every point of conflicting assets.

Loss of Revenue

City Power's Annual report of 2011-2012 shows an annual consumption of R12 billion for a customer base of 422 367 (see Table 5.18). This is an average of R28,621 per customer. No allowance is made for any variations of consumption due to the properties of the Robertsham/Southdale areas. The area is fairly densely populated with a mix of industrial, business, shops, offices, and residential units. The usage charge per customer in the study area is therefore deemed to be R3.27 per hour.

Table 5.18 Electricity sales and purchases for 2009_10 to 2011_12

Sales				
Measure Indicator	Unit	2011/12	2010/11	2009/10
Electricity sales	MWh	10 129 226	11 272 961	11 633 380
Growth in electricity sales	%	-10.15	-3.1	3.74
Revenue	R'000	12 088 478	9 786 301	7 235 256
Growth in revenue	%	23.52	35.26	31.3
Number of customers	No.	422 367	407 906	345 523
Gross margin	%	36.73	40.22	32.6
Purchases				
Measure Indicator	Unit	2011/12	2010/11	2009/10
Bulk purchases	MWh	13 064 152	13 116 388	12 117 250
Direct costs of bulk purchases	c/kWh	56.71	47.7	36.45
% reduction in electricity consumption	%	37	40	33

There are 3,891 domestic customers and a further 365 large power users in the study area and 92 load centres as determined from data received from City Power in October 2014. If one load centre is damaged, the number of customers affected may amount to 43 customers. This number is obtained by dividing the total users, domestic and other, by the number of load centres. Large power users account for approximately 70% of the revenue due to City Power as stated by City Power in an interview on 29 September 2014 and so the costs that follow may be considered to be conservative.

If 43 customers are affected by an outage caused by contractors' works, and the outage lasts 4 hours, then the cost of lost revenue amounts to R562.44 (i.e. 43 x 4 x 3.27). Converting this to a 1 in 50 chance (see section 5.4.1) the risk cost per incident is R11.25.

Need for Temporary Supply

The research does not allow any costs for temporary supply of electricity. It may be assumed that any breaks in power can be rectified in a short time and therefore the need for temporary supply is negligible.

5.4.3.2 User costs: Electrical

Users are made up of Industrial, Business, Shops, Offices and Residential users. The research limits the study to Industrial, Business and Shops and Offices.

Users face losses or additional costs at the time of electricity outages due to the following causes:

- Loss of production (manufacturing processes)
- Loss of revenue (all sectors)
- Damage to equipment and consequential repairs (all sectors)
- Damage to goods in manufacturing process – discarding defect items
- Lost leisure time, social costs
- Need for alternate supply – may involve relocation, or alternate systems
- Need for standby or redundant systems
- Traffic delays and accidents (no traffic signals)
- Increases in crime (opportunistic theft and other crimes – no lighting, no alarm systems)

Loss of Production, Revenue and Damage to Equipment

Loss of production means that manufacturers incur the normal expenses of overheads such as rent, insurances, wages and salaries without the benefit of sales.

Case Study 1: One particular case study of a scenario applied to the model APOSTEL (Austrian Power Outage Simulation of Economic Losses) identifies the scenario where Austria is affected by a power outage lasting 1 hour. Losses total €287 million (Reichl, Schmidthaler and Schneider, 2013).

A comparison between Austria and South Africa gives some indication of costs. Comparing the Austrian GDP of US$394.46 billion in 2013, (Trading Economics, 2014) to the South African GDP of US$382.34 billion in 2013 (Trading Economics, 2014) a ratio of

1.03 is determined. Reichl, Schmidthaler and Schneider's 287m Euros converted to US$ is US$373.1million (1 Euro is approximately 1.3US$). This figure divided by the GDP yields a ratio of 0.00094585. Applying this ratio to SA's US$382.34 billion GDP shows losses are calculated at US$361.64 million. At a conversion rate of R1 to US$0.094, this amounts to R3.847billion. If 16% is attributable to Johannesburg (Mercer, 2008) then the costs of outages in Johannesburg is R615.52million. If 0.25% (based on area ratios) is attributable to the study area, then the costs of outages in the area are R1538800. If 1% is due to neglected maintenance, costs for neglected maintenance are R15388 and if the chance of an incident is 1 in 50 then the risk cost is R307.76 per incident lasting one hour. Our scenario is based on the assumption that the break will last four hours and so the resultant risk cost is R1230 per incident

Case Study 2: A second study was examined to ascertain costs of electricity outages. A thesis by Kaseke (2011) shows studies performed in Zimbabwe to estimate the cost of electricity outages.

According to Kaseke (2011) costs of lost output, labour, damaged goods, equipment damage repairs associated with outage are US$7,444,795 in 2009. This cost is for 260 surveyed firms. That means an average cost of US$28,633 per user per annum.

Of the 260 firms the average outages per week are 3 to 4. Roughly translated, that's 182 outages per annum. The cost then, for one outage per user is US$157.33. The duration of outages is predominantly in the region of 2 to 3 hours, giving a cost of US$62.93 per user per hour.

As outlined in 5.4.2.1 the number of customers affected by an outage in Robertsham and Southdale is on average equal to forty three. Assuming that an outage lasts for 4 hours, a cost of US10,823.96 (i.e. 62.93*4*43) is derived. If the chances of an event occurring are 1 in 50 (see section 5.4.1), the cost per event is US$251.73. At a conversion rate of $1=R10.77, the costs is R2,710.89. Allowing for the effect of inflation ($FV=PV \times (1+i)^n$) on this 2009 figure, the resultant risk cost is R3,422 per incident.

Case Study 3: There are no definite studies done in SA to show costs of outages. A method for determining losses which may be used in South Africa is "the production function" approach. This approach equates the loss during a power outage with the full value that an organisation may have gained, without the break, during the outage period (de Nooij, Koopmans and Bijvoet, 2007). Production Function connects electricity use to the organisation's output and/or cost of leisure time in the case of residential users (Leahy and Tol, 2011).

Electricity consumption in 2011_12 in Johannesburg was 10,129,226 MWh (see Table 5.18). The South African GDP of 2013 was R3,385,369 billion, (Statistics South Africa, 2014). 16% of this is attributable to Johannesburg (Mercer, 2008) which equals R541.659billion. Drawing a comparison based on area, the study area accounts for 0.25% of the electricity costs for Johannesburg, i.e. R1.354 billion per annum, or R154,583 per hour.

The consumption in Johannesburg can be set to an hourly consumption of 2.89 MWh per annum. So 2.89 MWh gives R154,583 output – or 1kWh = R53.49

If consumption is 10,129,226MWh per annum for 422,367 customers then average consumption is 23,982kWh per annum, or 2.74kWh per hour.

For 50 customers experiencing a break lasting 4 hours, costs are calculated as the equivalent monetary value of 548 kWh (50 x 2.74 x 4 kWh). This amounts to R29,312.52. With only a 1 in 50 chance of construction work damaging cables, the risk cost is R586.26 per incident.

To summarise: Three studies offer three different values for costs of outages. This is expected with the different variables relating to the outages. The research takes an average of the three values as the risk cost.

Based on the average of the three studies:

- Austrian comparison R1,230.00
- Zimbabwean case study R3,422.00
- Production Function R586.26

Average cost (rounded to nearest rand) is R1,750

Loss of Leisure Time, Social Costs

We use the same social reward (cost of leisure time) as calculated in Costs of Time Delays in Roads Costs (section 5.4.1.2), for passenger cars, i.e. R64.29 per hour (Gao and Zhang, 2013). This does vary from the study performed by de Nooij, Koopmans and Bijvoet (2007) in which the leisure time cost is calculated at half of the average wage or salary.

In an outage lasting 4 hours, this is a figure based on current outage times of load shedding (City Power, 2014), where 43 users are affected, leisure time costs are a minimum of R64.29 x 4 x 43, i.e. R11,058 per outage. Assuming a chance of 1 in 50 (see

section 5.4.1) the cost of the risk is R221.16 per incident. This is a minimum cost as one user of electricity may include several persons or organisations.

Residential users of electricity subjected to outages may face additional costs created by the:

- Need to make use of alternate energy supply (generators, gas, etc.)
- Need to substitute other means for processes (e.g. Cooking may be replaced with purchasing ready-made meals)
- Loss of foodstuffs reliant on freezing powered by electricity

Other Causes (Traffic Delays and Accidents, Increase in crime)

Users may face costs through traffic delays caused by non-working traffic lights.

Users may be subjected to additional crime. Thieves take advantage of the drop in security measures. In areas of power failures, electric fencing, alarm systems and lighting cease to function. Additional costs due to other causes are not included in this research but are very real and further studies can be performed to determine the nature and extent of these costs.

Need for Alternate Supply, Standby or Redundant Systems

Some users of electricity have resorted to installing stand-by and back-up systems to operate in times of outages or to monitor and stabilise inconsistent flow of electricity. These systems are costly. The research assumes that alternate supply generators are not installed due to an event that may occur as a result of damage caused by contractors but rather in response to the likelihood of ongoing load-shedding. The cost of alternate energy supplies is therefore ignored in this research.

5.4.4 Water and Sewer costs of neglected maintenance (Johannesburg Water)

5.4.4.1 Direct costs: Water and Sewer

Direct costs of water outages or inconsistent supply include:

- Water losses
    - Damage from burst water lines, claims against the MOE or Council
    - Loss of revenue
- Repair and replacement costs
- Need for supply of temporary water supply

Direct costs due to damage to sewer networks include:

- Repairs to pipelines and other equipment
- Provision of alternate drainage equipment

With the diverse water network and myriad of valves, reservoirs, pump stations and other equipment which may get damaged through work by others in the vicinity of Johannesburg Water's assets a definite figure for repairs is difficult to quantify.

The figure for repairs and maintenance in the annual report for Johannesburg Water for 2012 is R7.9 million.

Repair Costs of Water pipes and equipment

Costs of repairs to pipes and property damaged by construction works may vary considerably due to the nature and extent of damage to pipes, equipment and surrounding property. In a bad case scenario damage may run into millions of rands. Such risks should give rise to some insurance protection.

This research assumes fairly conservative damage, possibly to pipes that have diameters of less than 200mm. The costs of installation of pipes with diameters of less than or equal to 200mm are approximately R600 to R1000 per metre. The cost of 200mm diameter uPVC Class 16 pipes is R267.75 per metre as quoted by a supplier, Paul Bayvel Eyethu Sales in March 2013. Allowing plant (an excavator costs approximately R275.00 per hour as quoted by CATS Plant Hire in September 2014) and labour and mark-up costs (minimum wages per hour as per SAFCEC (2013) is R22.56 per entry level labourer per hour, see section 5.4.1.3), it is reasonable to assume a minimum cost of R800.00 per metre.

The standard length of pipe sold by suppliers is 6 metres in length. If damage results in a standard length (6m) of pipe needing to be replaced, costs will amount to R4800.00 per incident. Using an estimate of a 2% (see section 5.4.1) attributable to damages caused by the works of other MOEs performing maintenance the direct costs for repairs to water pipes is R96.00 per incident.

Damage to surrounding property is ignored for this research.

Repair Costs of Sewer Pipes and Equipment

Costs of the installation of sewer pipes may range from R500.00 per metre to over R1,000.00 per metre depending on various factors. When emergency repairs are carried out this figure may increase substantially due to other factors; overtime rates, removing

water/sewer logged earth, removing other obstacles, the type of pies and equipment to be replaced, the depth of the pipes.

The cost of a 160mm diameter underground uPVC Class 34 sewer pipe is R82.00 per metre as quoted by a supplier, Paul Bayvel Eyethu Sales in March 2013. Assuming plant, labour and mark-up costs are in the region of R400.00 (see section above on repairs to water pipes), it is reasonable to assume an estimate of R500.00 per metre. If a standard length of 6 metres needs to be supplied and installed, the costs of replacement are in the order of R3,000.00 per incident. Assuming 2% (see section 5.4.1) of this figure is attributable to other MOEs works then the direct costs of sewer repair amount to R60.00.

No amount is allocated here to the clean-up operations which are essential in cases of sewer discharges; an amount is included in the section, Water and Sewer: User Costs.

Loss of Revenue

Water is priced at approximately R12.87 per Kilolitre (CoJ, 2014).

According to the Johannesburg Water Guidelines and Standards for the Design and Maintenance of Water and Sanitation Services (Johannesburg Water, 2013) average water demand figures are as shown in Table 5.19.

Table 5.19 Average Water Demand (Johannesburg Water, 2013)

Description of Consumer	**Demand**
Low cost housing schemes (5 persons per unit)	
Standpipes not more than 200m apart	30 litres / capita / day
Yard connections	250 litres / unit / day
House connections	300 litres / unit / day
Other Consumers - by zoning	
Low income ≤ 500m^2	600 litres / unit / day
Residential1: > 500m^2 - 1750m^2	800 litres / unit / day to 2600 litres / unit / day
Residential 2 and 3 (per 500m^2 of gross floor area)	800 litres / unit / day to 2700 litres / unit / day
Residential 4: (per 500m^2 of gross floor area)	2900 litres / day
Business and Commercial per 500m^2 of the floor area	1650 litres / day
Industrial Developments	10kl - 25kl / ha gross site area

From table 5.19, it is possible that damage to a water pipe may cause losses of water in excess of 3000 litres per day. On average, Johannesburg attends to and repairs water

outages caused by pipe bursts within 6 hours of reporting (Ncube, 2012). If the repairs are effected within 6 hours of the leak being reported, it is reasonable to assume that the break in the pipeline will cause losses of 750 litres ([3000 / 24] x 6).

A loss of 750 litres each time a line is damaged equates to R9,652.50 per incident. If 2% (see section 5.4.1) of this damage is attributable to other organisations' maintenance works, this means that R193.05 is the cost of loss of revenue at a point of conflict.

Need for supply of temporary water supply

The need for temporary water supplies in the form of water tankers, temporary water tanks, temporary pipes, etc. is not envisaged as necessary for most damage situations caused by the works of other maintenance activities. It is therefore ignored in this research.

5.4.4.2 User costs: Water and Sewer

Users may be faced with additional costs due to water supply outages and inconsistent or unreliable supply. Sewers that cannot be used due to breaks in lines and blockages caused by other organisations' works can cause costs to users. Users are made up of industrial organisations (factories, warehouses, workshops, etc.), organisations with offices and shops, and residential consumers and other organisations such as churches, schools, recreational facilities, etc. For the different users, different sets of costs are encountered.

Water

A break in the supply of water may affect different users in different ways. Residential users use water for watering gardens, cleaning, filling swimming pools, and health and hygiene reasons. Offices, shops, and entertainment facilities use water for the same health and hygiene reasons, and cooking and cleaning. The hardest hit users in a water outage are the industrial users who require water for their manufacturing processes. Costs here can escalate to millions due to loss of production and damage to equipment. Stand-by systems are expensive. Most manufacturing plants do have built-in safety mechanisms to protect equipment in cases of water outages and those costs are ignored here. Production losses are difficult to quantify. No studies were found to verify user costs in relation to water cuts; the same user cost for a power outage is assumed to apply to water outages, i.e. 1750 rands per incident.

Sewer

A break or a blockage in a sewer system can adversely affect industry, business, and residential customers.

- Entertainment facilities can be adversely affected, where customers turn away from facilities due to the stench and perceptions of an unhealthy environment
- A lack of waste removal facilities can affect residential, business and industry in terms of occupants of buildings needing to make alternative arrangements for washing and toilet facilities
- Any damaged sewer left unattended may be the cause of the spread of disease. There are many forms of disease associated with raw sewerage.
- Sewerage spills will need to be contained and cleaned and removed.

The costs of disease may include:

- Absence from productive work - lack of productivity due to time taken to recover
- Medical costs; ranges from minor treatment to hospitalisation
- Fatality costs

Costs therefore include:

- Production losses
- Business closure
- Medical
- Cleaning operations

It is not envisaged that a break in sewer by contractors' works will cause extensive damage and disease. However, it may cause inconvenience and temporary shutdowns to businesses and factories, and residents may need to make alternative measures to attend to day-to-day health and hygiene requirements.

There exists a possibility that sewage spillage near rivers and lakes may cause harmful effects to the environment which may affect drinking water and the health of people and animals. Johannesburg has several rivers which flow through or into drinking water catchments and they are often the source of water related activities and entertainment. Rivers in Johannesburg include the Braamfontein Spruit, the Klip River, the Vaal River, the Jukskei, Sandspruit, and the Klein Jukskei. Newspaper reports indicate sewer problems in these rivers from time to time. Sources of such problems are normally not related to construction faults but to insufficient capacity of systems and blockages through other causes.

User costs, therefore, for sewers damaged by construction by MOEs during maintenance are limited to inconvenience costs. The inconvenience cost may be calculated by applying the cost of a person's time (opportunity cost) by the duration of the break. This cost of people's time is similar to social reward described in the section on the Cost of Time Delays on traffic. Taking the minimum wage as outlined in the section on Time delays, as an opportunity cost and multiply this by 12 hours (break in sewer service) the result is a cost of R336.00 per event.

5.4.5 Summary of Costs

Costs are calculated and displayed for each MOE. The costs are entered into the program as a cost to be applied to each incident. Different events occur in different circumstances and with different damages for the type of asset. The figure may be seen then, as a guide to determining possible costs. Further studies may include a more detailed approach to allocating costs per asset types and categories and locations. The following tables show costs for the different MOEs and a summary of these costs separated into direct costs and user costs.

5.4.5.1 JRA

Table 5.20 Costs of damage to JRA's assets due to other MOEs' maintenance work

	Rands (rounded to nearest rand)
Vehicle Accident – Fatality	164
Vehicle Accident - Medical / Serious	140
Vehicle Accident - Vehicles only	38
Vehicle damage - rims, tyres, etc.	90
Time delays	3 656
Alternative routing	2 119
Damage to goods in transit	Omitted
Costs of extra emissions (CO2 etc.)	72
Additional Operating Costs	8
Total User costs	**6 287**
Direct Costs	**9 212**
Total costs	**15 499**

5.4.5.2 City Power

Table 5.21 Costs of damage to City Power's assets due to other MOEs' maintenance works

ELECTRICITY	Rands (rounded to nearest rand)
Direct Costs	
Repairs and Replacement	500
Loss of Revenue	11
Total direct costs	**511**
User Costs	
Loss of production, revenue, other	1750
Leisure time and social cost	221
Total user costs	**1971**
Total Costs	**2482**

5.4.5.3 Johannesburg Water

Table 5.22 Costs of damage to Johannesburg Water's assets due to other MOEs' maintenance works

WATER	Rands (rounded to nearest rand)
Direct Costs	
Loss of Revenue	193
Repair	96
Indirect Costs	
User costs	1750
Total (water costs)	2039
SEWER	
Direct Costs	
Repair	72
Indirect Costs	
User costs	336
Total (sewer costs)	408
Total Direct costs (Water and Sewer)	361
Total User costs (Water and Sewer)	2086
Total (all water and sewer costs)	2447

5.4.5.4 Summary of all Municipal Owned Entities (MOEs) costs

Table 5.23 Summary by MOE of costs of damage due to maintenance works

MOE	Direct Costs (R)	User Costs (R)	Total costs (R)
JRA	9 212	6 287	15 499
City Power	511	1 971	2 482
Johannesburg Water	361	2 086	2 447

5.5 EXPERIMENT RESULTS AND FINDINGS

The experiment comprised a simulation of maintenance planning and implementation tasks of IAM for each MOE. Data was collected from MOEs for two suburbs, Robertsham and Southdale, in the south of Johannesburg. The size of the study area was approximately 0.25% of the area of Johannesburg. The area included a diverse selection of zoning and services (see section 5.1).

The simulation program generated lists of assets requiring maintenance for each year of the study period, based on the asset's RUL value. Only when an asset's useful life had reduced to one year, was the asset marked for maintenance (see section 5.3). A 30 year period for the simulation was chosen and certain assumptions made (see section 5.3). When all maintenance tasks were identified and listed, the location of these assets was checked against the location of other assets to determine whether work performed on that asset may affect the integrity of another MOE's assets. These points, where one asset is in the vicinity of another asset, were called conflict points.

A set of parameters was chosen (see table 5.24) to determine conflicting points. The figures were selected after a series of manual checking of intersections of cables and roads (see table 5.2).

Table 5.24 Parameters input into simulation program

New RUL period (years)	50
Period at which asset needs maintenance (i.e. within the last *x* years)	1
Database of costs	
Cost of damage to Johannesburg Water assets (rands)	2,447
Cost of damage to JRA assets (rands)	15,499
Cost of damage to City Power's assets (rands)	2,482

Table 5.25 displays the summary output from the simulation program showing possible costs associated with risks at conflict points for a 30 year period involving maintenance of all JRA, Johannesburg Water, and City Power assets. The full results are listed in Appendix C.

Table 5.25 Resulting total costs per annum of risks at conflict areas (output from simulation program)

MOE	Total risk costs (rands)
JRA	2,343,449
City Power	335,401
Johannesburg Water	502,043
Total for all MOEs	3,180,893

For some of the MOEs, job cards were significantly more in some years than in others. This is due to forcing maintenance to occur only when the RUL value is equal to one. In practice, maintenance may be planned to occur before or after the RUL is reduced to a single unit. Prioritisation of maintenance tasks may allow some tasks to be brought forward and some to be delayed for a later time. A form of aggregate planning (Bloomsbury Business Library, 2007) is needed to maintain efficiencies, make the best use of available resources and provide least cost strategies for the CoJ Council. Programming the prioritisation is not part of this research. However, it is assumed that this balancing will take place. The average figures for the maintenance tasks are considered in the analysis of costs.

From this summary, it appears that costs of risk of damage are R3.18million per annum. This may be divided into direct costs (costs to CoJ and its MOEs) and user costs as shown in table 5.26. The base unit split between direct and user costs is illustrated in table 5.23.

Table 5.26 Cost of risk of damage separated to show direct costs and user costs

MOE	**Direct Costs (rands)**	**User Costs (rands)**	**Total costs (rands)**
JRA	1,392,854	950,594	2,343,449
City Power	69,053	266,348	335,401
Johannesburg Water	74,065	427,978	502,043
Totals	1,535,973	1,644,920	3,180,893

There are several ways that these figures may be generalized to the entire Johannesburg metropolitan area. Table 5.27 shows comparisons between various asset lengths and areas in Johannesburg.

Table 5.27 Comparisons of study area and Johannesburg parameters

Service / item	**Robertsham / Southdale**	**Johannesburg**	**Study area assets as a percentage of Johannesburg's assets**
	Length of assets (km) as measured in data files	**Length of assets (km)** as per literature or interviews noted	**(%)**
Sewer (CoJ, 2014)	47.112	9,000	0.52%
Water (CoJ, 2014)	66.85	9,500	0.70%
Roads (CoJ, 2014)	40.891	9,247	0.44%
	Area of study area (km2)	**Area of Johannesburg (km2)**	
Area (CoJ, 2014)	4	1,664	0.24%
Average percentage			**0.48%**

Following on from table 5.27 the savings are calculated using the average percentage ratio of Johannesburg to the study area and displayed in monetary values in table 5.28

Table 5.28 Potential cost savings for the whole Johannesburg metropolitan area

MOE	**Direct Costs (rands)**	**User Costs (rands)**	**Total costs (rands)**
JRA	291,736,309	199,103,987	490,840,296
City Power	14.463.301	55,787,170	70,250,471
Johannesburg Water	15,513,076	89,640,926	105,154,002
Totals	321,712,686	344,532,082	666,244,978

There are many assumptions made in this research, whether or not the results may be generalised to include Johannesburg using the area ratios or any other means is questionable. More studies need to be conducted to assist in determining more accurate potential savings.

The research only looks at 3 of the 15 MOEs in Johannesburg. All MOEs and other organisations with assets on Council property are listed in Table 5.29. Extending the analysis to include savings for all the organisations may result in more savings.

Table 5.29 List of MOEs and organisations with assets on Council property in Johannesburg

1	City Power
2	Johannesburg City Parks
3	Joburg Theatre Complex
4	Johannesburg Development Agency
5	Johannesburg Fresh Produce Market
6	Johannesburg Property Company
7	Johannesburg Social Housing Company
8	Johannesburg Roads Agency
9	Johannesburg Tourism Company
10	Johannesburg Water
11	Johannesburg Zoo
12	Metrobus
13	Metro Trading Company
14	Pikitup
15	Roodepoort Theatre
16	Neotel
17	Dark Fibre Africa
18	Telkom
19	SASOL
20	ESCOM
21	Egoli Gas
22	Rand Water
23	MTN

CHAPTER 6 COSTS OF IMPLEMENTATION

The preceding chapter illustrates the possible savings that may be achieved through employment of a cross-enterprise integrated effort in IAM in the Robertsham and Southdale suburbs of Johannesburg. These savings are significant over a 30 year period based on the assumptions made. However, there exist expenses that come with the implementation of new systems. These expenses must be determined to properly check the viability of the integration.

Costs that are associated with the introduction of Integrated Systems are:

- Customisation of existing software and/or writing new software
- Setting up Organisational structures to run the new systems
- Training of existing and new personnel
- Offices, furniture and equipment
- Additional day-to-day costs not covered by current systems

In the projection of costs over a 30 year study period, costs do not change, as figures are maintained as provided for the base year of 2013. No escalation is applied here or in other projections concerning savings and expenses of new cross-enterprise systems.

6.1 INTRODUCTION TO THE INTEGRATED SYSTEM

The scenario for calculating expenses was based on the following: Each MOE will maintain and be responsible for their databases and assets. They will collect data and capture it. They will be responsible for the updating of existing data, inspections of assets, recording of events concerning assets, and repairs and maintenance of assets. The difference with the cross-enterprise system is that now overall planning and co-ordination of maintenance will be performed at a central location. This operation will involve input from MOEs, and they will be obliged to follow an encompassing plan of maintenance. This plan will coordinate maintenance and other works on assets with a view to conducting maintenance in an efficient manner thus minimising risk to assets on Council property.

This research makes the presumption that the new system involves a central department that will produce initial programs of maintenance based on input and engagement from stakeholders. These programs are sent to the participating MOEs for comment. MOEs return programs with comments and recommendations. These are considered by the central department before new programs are again compiled and issued for further comment.

The process is one of iteration and eventually must reach finality where issues which have stalemated are resolved by the central department.

The central department must monitor the progress of MOEs with regard to their performance in terms of the maintenance plan.

6.2 SOFTWARE DEVELOPMENT

Computer programmers and Information Technology analysts are highly skilled personnel and are expensive to employ. Tasks associated with this profession are often outsourced. Necessary software is developed and commissioned before day-to-day operating of systems is taken over by in-house staff. Contracts are often established with companies specialising in this area to maintain software and provide support and training to users. There may be a period during which the system is handed over entirely to trained in-house personnel.

The size of a team may be assumed to be seven personnel with two additional staff performing management and administration functions. This follows the Agile methodology for software development as outlined in section 2.9.3. However, the traditional resourcing of a software development team may be viewed in figure 6.2; this configuration does not deviate significantly in numbers, from the Agile staffing complement. Figure 6.1 illustrates the organisational chart for the development of software from executive level to programming and testing levels. Costs shown in table 6.1 refer only to the persons involved directly with development of software. Steering committees' and executive committees' costs are detailed in section 6.3.

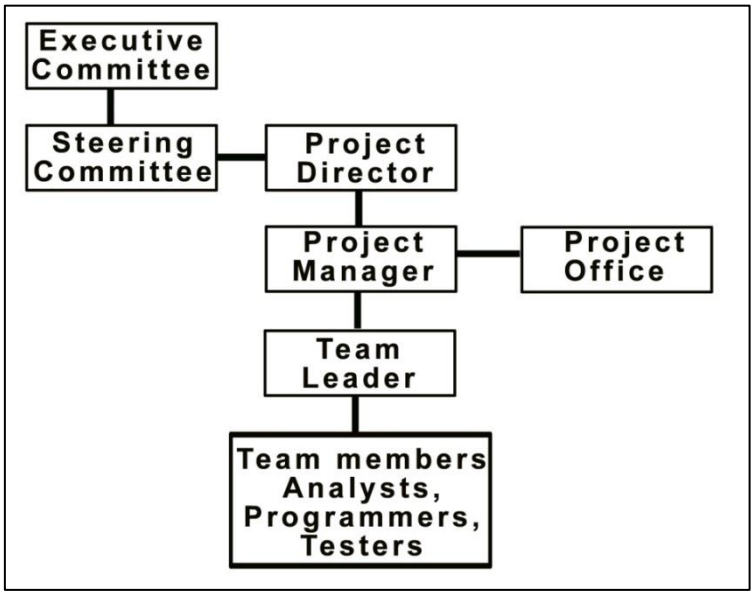


Figure 6.1 Example of Software development team (Wallace, 2014)

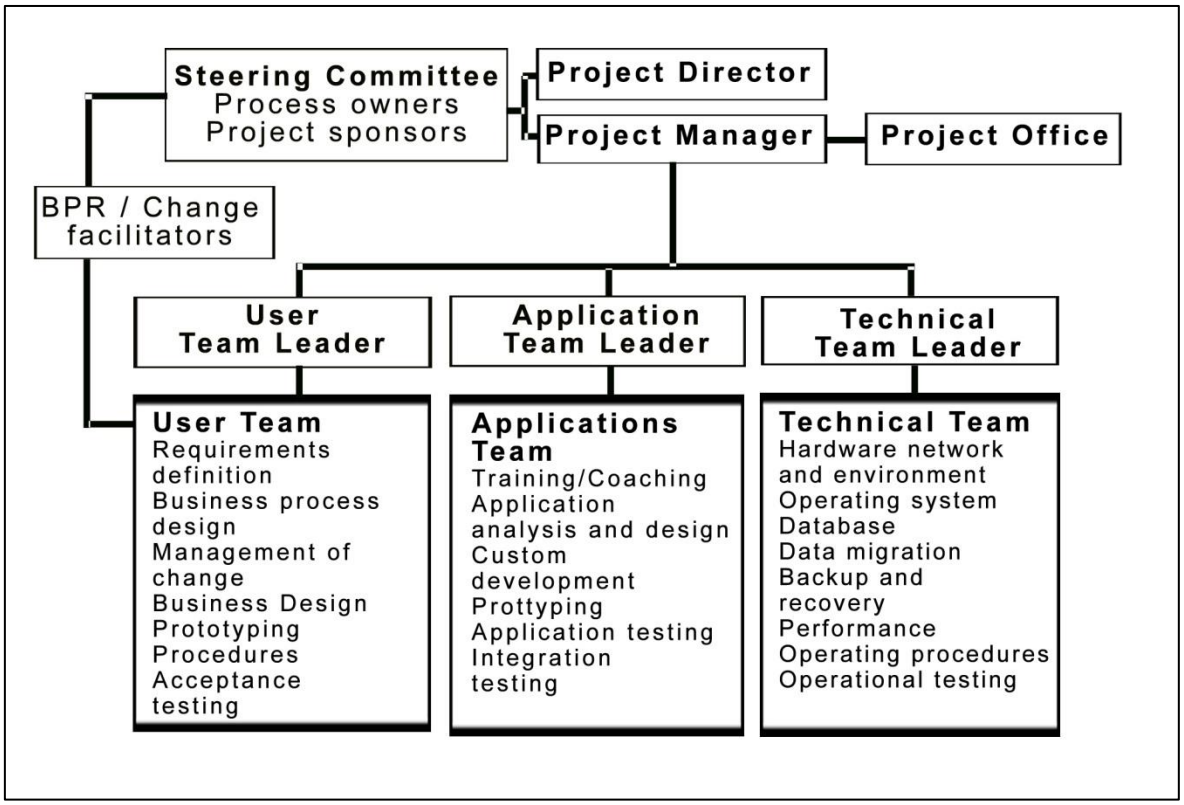


Figure 6.2 Software development resource pool structure (Wallace, 2014)

The remuneration for the personnel involved in the software development process is estimated as R7.89million per annum (payscale.com, 2014). An administration post is also included with the expenses. Costs will vary for different suppliers. There is a risk that scope of works is not clearly defined; this may lead to costs in excess of budgets. From the literature review (see section 2.9.3) an optimal software development team size may be between 3 to 7 members. Allowing for the inclusion of office overheads and mark-up table 6.1 shows the costs of software development.

Table 6.1 Software development costs (payscale.com, 2014)

Category	Annual Salary (Cost to Company)	No. employed	Time employed (%)	Total costs
Project Manager	2 506 774	1	100%	2 506 774
Analysts	858 770	1	100%	858 770
Programmers	566 255	2	100%	1 132 511
Testers	390 896	1	100%	390 896
Support staff	249 102	2	100%	498 204
Administration	249 102	1	100%	249 102
Sub Total				5 636 256
Office overheads	563 626	1	100%	563 626
Mark-up and other costs	1 690 877	1	100%	1 690 877
Total				7 890 759

6.3 ORGANISATIONAL COSTS

A project of this nature must have the full commitment and backing of senior and executive management across all participating organisations. This means having senior management with the necessary authority heading up boards and/or committees and/or working groups controlling the process.

IAM is a process involving many professions. The make-up of the controlling body should include people with expertise in:

- Engineering
- Finance
- Human Resources
- Business Administration
- Information Technology
- Project Management

These people may already exist in the City Council of Johannesburg. A cost must be allocated for time for meetings, research, and other works. The group will need to meet regularly with MOEs to plan, implement and monitor the integrated system. Some form of administration must exist; cost centres need to be created, budgets determined, accounting records maintained, etc.

Costs are calculated based on a collective committee of 7 people each spending four days per month on meetings and other works (see Figure 6.3). This figure is based on interviews with JRA (2014). Salaries for these personnel are estimated as R2.5million per

annum (payscale.com, 2014). A full time administration post is also included with the expenses.

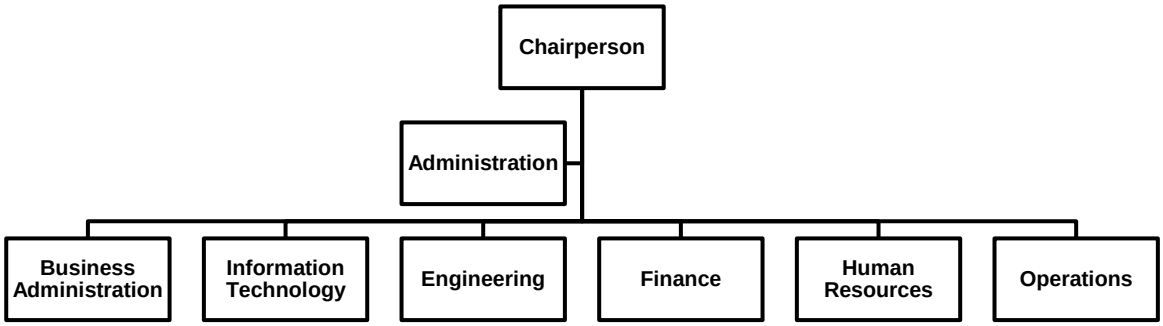


Figure 6.3 Example of Infrastructure Central Committee Organisational Structure (JRA, 2014)

Table 6.2 Costs of organisational structure of new IAM committee (payscale.com, 2014)

Position on Committee	Average Annual Salary (rands)	Amount apportioned to IAM duties 4 days per month (rands)
Chairman	2 506 774	38 566
Engineering	2 506 774	38 566
Finance	2 506 774	38 566
Human Resources	2 506 774	38 566
Operations	2 506 774	38 566
Information Technology	2 506 774	38 566
Business Administration	2 506 774	38 566
Administration (full time)	378 996	378 996
	Total	**Cost per month**
	17 926 414	**648 956**

6.4 TRAINING

Training is an ongoing process. At first, personnel from the CoJ Council and MOEs need to understand the intentions of the City and the requirements of the new systems. Employment of a team of IT professionals must then take place. These people will need to attend briefing sessions where the Council spell out requirements. As the systems are developed, the IT professionals will train MOEs in the operations of systems.

The Council will need to ensure that MOE staff are conversant with the needs of the integrated IAM system. Guides and instruction manuals need to be compiled and distributed to relevant departments and staff.

A focused and detailed training needs analysis should be performed before training commences (Ofluoglu and Cakmak, 2011). Ofluoglu and Cakmak (2011) states that the following issues must be addressed during training needs analysis programs:

- analysis of the organisations strategic objectives
- competencies required for the work to be learnt and performed and competencies within the organisation
- demographic analysis – what parameters affect training and work performance (e.g. age, gender)
- Job and task analysis
- Knowledge and skills assessments

This is a process which should be followed in further examination of cross-enterprise systems and in the very early stages of planning for any pilot studies as it is a vital factor in implementing the systems. A needs analysis of this type is beyond the scope of this research. For the report estimated requirements are drafted after consideration of the number of disciplines at executive level as shown in figure 6.3.

Types of training vary from highly technical operations and understanding of computerised systems for personnel chosen to support the software in-house to routine on-site training of staff using only the front house functions of the software.

Costs of some SAP courses (e.g. asset accounting) relating to their asset management systems are in the order of R21500 (SAP, 2014) for a five day course, that is R4300.00 per day. Training on other accounting software such as Pastel Accounting costs in the region of R2000.00 per day (Sage Pastel Accounting, 2014). Courses in basic computing skills are in the region of R4500.00 for a three day course or R1500.00 per day (leadingtraining.co.za, 2014).

If there are six sections of management (see section 6.3) and assuming each of these require two personnel to be trained in the high-end skills of IAM systems and the new cross-enterprise integration methods, costs are calculated using costs associated with SAP training, allowing 2 courses per candidate. The resultant costs are shown in table 6.3 under the “Specialised” type of training.

Further to the high-end skills required, there are requirements for personnel within MOEs and the central control facility to possess technical skills. The research estimates that the

central control committee will induct two personnel for each discipline and the MOEs will train three personnel each. Using the training costs of Pastel Accounting and allowing for 21 personnel to be trained on four courses, each lasting 3 days the resultant costs are shown under the “Support - Technical” field in table 6.3.

Finally each MOE will need personnel to be trained on the general day-to-day operations of the new systems. The research h estimates that each MOE will train 10 personnel approximately two times a month. The costs of such training are in line with basic computer skills courses of R1500.00 per day.

Table 6.3 Costs of training (SAP, 2014; Sage Pastel Accounting, 2014; leadingtraining.co.za, 2014).

Type of Training	No. of Personnel	Duration (days per annum)	Cost per day (rands)	Totals (rands)
Specialised	12	10	5 000	600 000
Support - Technical	21	12	2 000	504 000
General program operation	30	24	1 500	1 080 000
Totals				2 184 000

6.5 OFFICES, FURNITURE AND EQUIPMENT

Working space and equipment will be required by the new central department. A rough estimation of offices needed and equipment is shown in Table 6.4. Figures have been obtained from several estate agency web sites (The Business Centre, n.d.), (Abland, n.d.), (Broll, n.d.) and computer sales are estimated on past purchases of the researcher. Rentals for offices may vary from R50 per square metre in the Johannesburg CBD to more than R200 per square metre in Sandton and Rosebank. A figure of R150 per square metre was selected for this study.

Table 6.4 Office, furniture and equipment rates (The Business Centre, n.d.; Abland, n.d.; Broll, n.d.)

Basic Needs for offices				
Office Room type	**Sq metres required**	**Rates**		**Total cost (rands per month)**
Boardroom	40			
Reception	9			
Toilets	8			
Kitchenette	6			
Offices	90			
Storage	60			
Total	213	150		31 950
Furniture		**Rates**	**Write-off period (years)**	**Total cost (rands per month)**
Boardroom table and chairs	1	50 000	6	694
Reception desk and chairs	1	20 000	6	278
Office desks and chairs	10	15 000	6	2 083
Shelving and other	1	25 000	6	347
				3 403
Equipment		**Rates**	**Write-off period (years)**	**Total cost (rands per month)**
Computers including processors, drives, monitor, keyboards etc.	20	10 000	6	2 778
Network routers etc.	1	10 000	6	139
				2 917
Total costs per month (rands)				38 269

6.6 DAY-TO-DAY COSTS

New tasks will be established. In the new integrated system personnel will be required to submit plans to a central department for discussion. They will attend meetings with a central department in addition to their current internal IAM meetings. They will need to review plans where before their internal plan was accepted without query. They may need to review plans and programs more than once.

As the workload will increase to a certain extent and the nature of works change, new personnel may need to be employed and existing personnel may be given different work scope. An estimation of the costs of the changes is based solely on the assumption that

10 personnel will have jobs created for them in some way or another. An approximation of the average annual cost to company for these people is proposed as R400 000.00.

6.7 SUMMARY

The costs for the expenses of a new integrated IAM system are summarised in Table 6.5.

Table 6.5 Summary of costs for integrated systems

Costs of New Systems for Integrated IAM (rands per annum)	
Category	**Costs (Rands)**
Software Development	7 890 759
Organisational Costs	7 787 475
Training	2 184 000
Offices, Furniture and Equipment	459 233
Additional Day-to-Day costs	4 800 000
Totals	23 121 467

CHAPTER 7 BENEFITS

In a cross-enterprise integrated system risk costs should be significantly reduced. With improved communications between MOEs and other relevant organisations, maintenance work to one MOE's asset should no longer influence the integrity of another MOE's asset. Risk costs will decrease. The potential economic benefits of cross-enterprise integration can then easily be calculated by subtracting the expenses of implementation of cross-enterprise integrated systems from the risk costs. There are other benefits that may be derived from cross-enterprise integration which cannot at this stage be valued in terms of monetary value, namely:

- Way leaves. Greater efficiency in producing way leaves to relevant authorities.
- Motivation to maintain up-to-date databases. Through a central department MOEs are motivated to update their database regularly.
- Efficient use of skills. Pooling of resources promotes better use of scarce skills.
- Improved communication. A central department may pull together relevant personnel from MOEs and other organisations to discuss relevant IAM topics.

The following chapter discusses the benefits of cross-enterprise integration and list recommendations based on the benefits.

7.1 ECONOMIC BENEFITS

Based on the simulation carried out in Robertsham and Southdale, possible savings to be generated from the employment of cross-enterprise integrated IAM systems amount to R321 million per annum as direct costs to the Johannesburg Council and a further R344 million per annum as user costs (table 6.5).

Expenses for the implementation of the system are approximately R23 million per annum (table 6.5).

This yields a net saving to the Council of R298 million per annum and savings of R344 million to the users. It is noted that this applies to 3 MOEs only, systems may be extended to include all organisations with assets on Council property and savings may increase.

Table 7.1 Economic benefits of cross-enterprise integration in Johannesburg

	Costs/Expenses (rands)	Benefits (rands)
Savings through integration (elimination of unnecessary repairs and consistency of levels of service)		666,244,978
Costs of implementation of new systems	23,121,467	
	23,121,467	666,244,978
Net savings		**643,123,301**

Economic Benefits of this magnitude cannot be ignored. Further work or feasibility studies should be conducted to add detail to this research.

These benefits will not be realised within the short term. Implementation of systems of this nature and magnitude and complexity require pilot studies, implementation and testing on smaller areas of Johannesburg before final cross city application (see section 10.1).

7.2 SPIN-OFFS

There are some notable spin-offs that are benefits of the proposed integrated system.

7.2.1 Way leaves

Presently, way leaves are compiled by JRA. Any contractor wishing to execute works on Council property must apply for way leaves. An application is submitted to JRA for the necessary way leaves. JRA request feedback from all organisations with assets in the vicinity of the works. Among the organisations needing to confirm services for way leave applications are Telkom, Neotel, City Park, Johannesburg Water, JRA, Egoli Gas, Dark Fibre Africa, and ESKOM (CoJ, 2014).

It is a time consuming process and one which is open to error. A spin off of Integrated IAM systems is that the issue of way leaves becomes a seamless almost instantaneous operation without the need of correspondence between at least eight organisations.

7.2.2 Motivation to maintain up-to-date Asset Databases

In the system to be described in section 8.5, MOEs will be monitored with regard to their IAM performance. With a central department, MOEs can be encouraged through the focussed efforts of all to get IAM databases up to date. The department may also assist MOEs with the tasks surrounding IAM.

7.2.3 Efficient use of skilled personnel

A concentrated department of highly skilled personnel supplying services to many organisations makes good use of skills. Currently, certain operations are duplicated across different MOEs. Some of these tasks involve skilled personnel such as IT and financial personnel.

7.2.4 Improved communications

An integrated system informs organisations beforehand of planned work in the vicinity of their assets. This allows organisations to be on alert for damage to their assets and have contingency plans in place to deal with possible faults. They may also plan to inspect their own assets during and after works. In some cases, certain levels of service of assets are critical to surrounding operations and persons. Warnings of work at those assets may improve reaction time to faults if they occur.

CHAPTER 8 REQUIREMENTS FOR THE IMPLEMENTATION OF CROSS-ENTERPRISE INTEGRATION SYSTEMS

8.1 STANDARDISATION AND INTEGRITY OF DATA

The need for standards in data is clearly advocated by literature (Halfawy, 2010). However, the systems in place and working for the three MOEs in this study are enormously complex. To attempt to modify these systems to work in the same manner is monumental. Tools need to be developed to adapt data from these systems for readability by other systems.

Literature indicates that AI tools (see section 2.6.2) are available for the writing of software to import and export data in various formats. Trends in cross-enterprise integration are to use a set of AI tools to act as an interpreter between systems (Themistocleous, 2004) (see figure 9.1).

If a cross-enterprise integrated system is to be installed, then it is not only standardisation of data that must be tackled, other areas need to be addressed:

- Asset databases need to be up-to-date
- The integrity of databases must be sound
- Assets and events must be flagged in some way to show their vulnerability to outside damage and their ability to damage other assets (e.g. crack sealing of roads has little impact on pipes and cables buried underground)
- Positioning of assets needs to be better defined to accurately predict conflict points between assets.
- Periods between maintenance tasks and life expectancies require definition.
- JRA inspects assets before developing plans. This system has to be incorporated into new systems for aligning JRA's maintenance needs and tasks with other MOEs and organisations.

8.2 ORGANISATION STRUCTURE

There are challenges getting data from three different MOEs and manipulating it to fit into an Integrated IAM system. These challenges increase when attempting to involve all organisations with assets on council property in the process. The project requires coordination, clear instruction and focussed unambiguous direction coming from an

authoritative source. There may be a general reluctance to accept change, ownership and control of data are not easily relinquished (Wihlman et al, 2008).

The MOEs do not need to release control over their assets. Systems can run as they do now. The suggestion from this research is to implement AI software to adapt output from the different MOEs for input to a single maintenance co-coordinator. This is done with co-operation between MOEs. Data is still controlled by the individual MOEs.

It is vital that a solid structure be established to drive the implementation of cross-enterprise integration.

8.3 THE PROCESS

The coordination of the maintenance tasks of all MOEs is performed by a department dedicated and reserved to this purpose. In interviews conducted with City Power (2014) and JRA (2014), the best location for the new control should be within JRA as JRA acts as custodian of the road reserve and already controls processes which involve cross-enterprise integration such as compilation of way leaves. MOEs still maintain control over their own data and are responsible for their own maintenance (see figure 9.1).

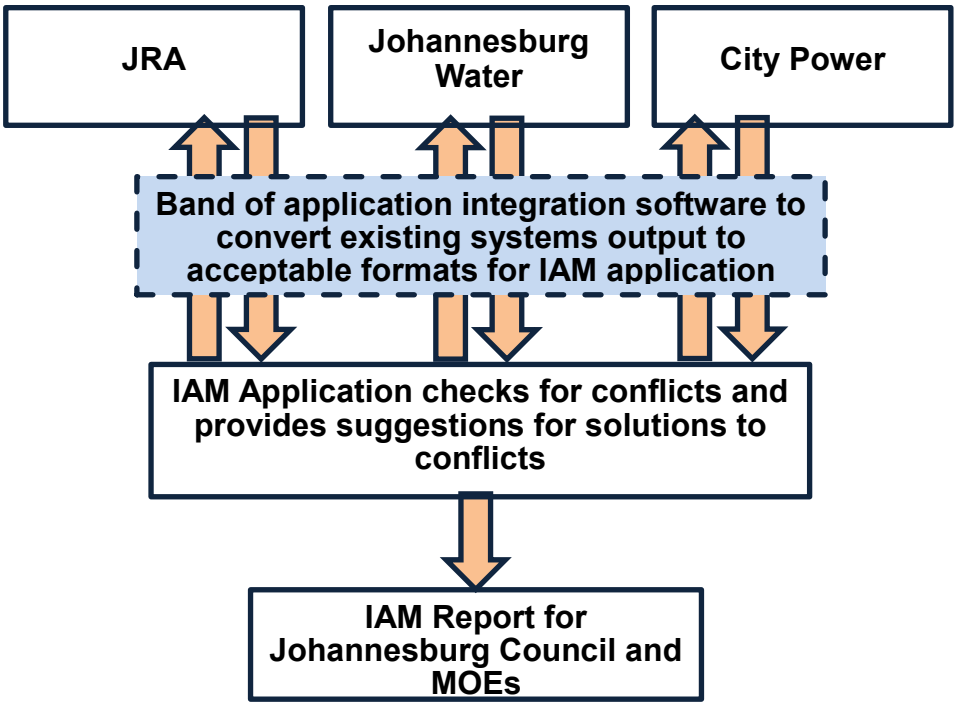


Figure 8.1 Diagram showing the use of AI software as translator / interpreter

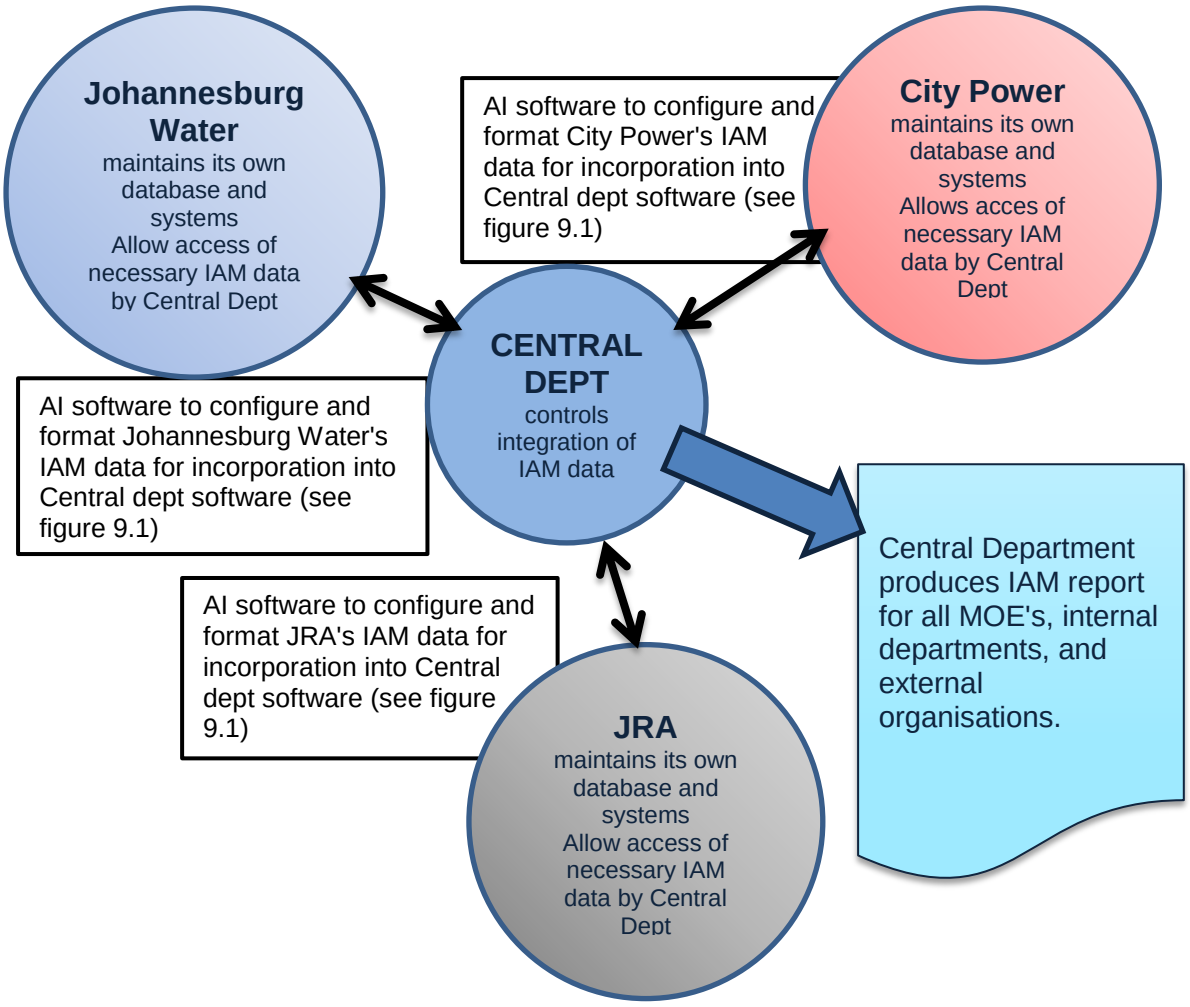


Figure 8.2 Diagram of processes of integrated systems

With a dedicated department it becomes possible to pool scarce, costly and skilled resources especially in the fields of engineering, and IT.

At start up, the department gets IAM programs from each MOE. They then check for conflicts and they propose changes. These changes are returned to the MOEs for comment and suggestions. New programs and plans are returned to the central department and checked again for conflicts. Conflicts are resolved and a program is given to each MOE (see figure 9.2).

The process is iterative and at some point, it needs to be halted with the overriding say, concerning disagreements with schedules, residing with the central department.

CHAPTER 9 CONCLUSIONS

The research presented in this report deals with cross-enterprise integration between three MOEs, Johannesburg Water, City Power and JRA. Results from a simulation exercise creating maintenance tasks for MOEs based on ages of assets, indicates that there are significant benefits to be realised with cross-enterprise integration.

The three MOEs employ large complex systems, most are stand-alone systems and data sharing within the MOEs is sometimes subject to manual intervention. There is no cross-enterprise data sharing or integrated effort present in Johannesburg. It will be extremely difficult to bring 'across the board' standards to bear on MOEs in terms of data formats.

There have been advances made in the IT industry. Current trends show a move toward departments and organisations keeping the most applicable software for applications instead of attempting to get one software application to fit all operations. Departments then share data through interpreting software formed with Application Integration software tools. The tools allow manipulation of data between different applications.

Cross-enterprise integration can take place between the MOEs by developing an Application Integration system to transfer data to a central maintenance scheduling package that allows co-ordination of IAM plans. This way, MOEs retain their identities while costs are lowered for the MOEs, CoJ Council and the users of assets.

Johannesburg MOEs have fairly advanced data sets concerning infrastructure assets. Some data needs updating. Bringing the data together for input to a scheduling package requires effort; some development work needs to be done to provide more accurate data.

The benefits of cross-enterprise integration in the long run are enormous, but so too, are the challenges involved in implementation of such systems. Cooperation and commitment of executive management in the process is vital.

Benefits valued in this research indicate possible savings in excess of R700 million to Johannesburg with the majority of these savings on the side of the consumers: the users of roads and services, and the rate payers. Benefits from cross-enterprise systems are not limited to the financial arena. Some other benefits include streamlining of existing processes such as the issue of way leaves, efficient use of resources (especially skilled personnel), and improved integrity of data concerning infrastructure assets.

Further study with regard to the procedures of implementation and more definitive costs is warranted in order to achieve holistic cross-enterprise integration in Johannesburg.

CHAPTER 10 RECOMMENDATIONS

The potential savings of cross-enterprise integration in the long term far outweigh the implementation costs of such systems. The implementation of cross-enterprise integration within the CoJ does warrant further study.

Various means can be employed to accurately determine the benefits of cross-enterprise integration and section 10.1 defines a number of steps which may be employed for the implementation process. A pilot study on a small area of Johannesburg is recommended to fully determine potential problems with the development, implementation and monitoring of systems. The pilot project may also indicate, more fully, the benefits of cross-enterprise integrated systems.

It is important that implementation follow strict project management procedures which are discussed in section 10.2.

10.1 STEPS TO THE IMPLEMENTATION OF INTEGRATED SYSTEMS

Step 1 – DATA REQUIREMENTS
Get data up to date with integrity and sufficient minimum detail

Step 2 – COMMUNICATIONS
Get organisational structures in place to facilitate integration. Decide on what structures are needed, whether they exist in Johannesburg and who can run the project.

Step 3 – PERSONNEL
Get necessary personnel with relevant skills on board. Identify necessary skills. Decide on employment of internal and/or external personnel and outsourcing of tasks.

Step 4 – IT HARDWARE AND SOFTWARE
Ensure the correct hardware is in place. Create policies for security issues (protection of data, backups). Decide and implement methods for electronic communication, and transfer of data. Build systems software and perform testing.

Step 5 – PILOT STUDY
Implement the process on a small section of Johannesburg and find ways to measure successes and failures possibly over a period of one to two years. Measure the performances of the organisation and effect of organisational structures. Ensure quality control of software with all necessary checks. Check on ability to adhere to the programs. Develop quality assurance controls.

Step 6 – PROJECT EXPANSION TO GREATER JOHANNESBURG
Expand the pilot study (if successful) to the greater Johannesburg region

Step 7 – PROJECT EXPANSION TO OTHER ORGANISATIONS
Expand the program to include other MOEs and external services/suppliers

Step 8 – PROJECT EXPANSION TO PROVINICIAL AND NATIONAL ORGANISATIONS
Expand the program to include infrastructure feeds from Provincial and National organisations that interface with Johannesburg's infrastructure.

10.2 PROJECT MANAGEMENT

The implementation of integration must follow the basic rules of Project Management (PM) by addressing all nine areas of PM as defined in A Guide to the Project Management Body of Knowledge (PMBOK) (Project Management Institute, 2008). The system must be run with a competent Project Manager having proper authority and the backing of the executive of the CoJ Council. The following list describes the areas of project management:

i. Scope

For the success of any project the Scope of Works needs to be clearly defined up front. Methods need to be in place to allow for reasonable changes to the scope.

ii. Time

Milestones must be created. Progress must be measured. Any deviance from program needs to be analysed. Projects of this nature may easily drift from program.

Preliminary estimates used in previous costing exercises show a period of 6 years for the phasing-in of systems.

iii. Cost

Budgets are to be created. Expenses are to be monitored regularly. Reports should be directed to the head of the steering committee or workgroup.

iv. Quality

There are 3 areas of concern with regard to Quality Assurance (QA) and Control.

The Organisational Structure: Performances of this group must be measured.

The Application: The PM team needs to draw up a QA system for the application.

The Assets: Although there should already be QA controls to check levels of service of assets it is important that these are addressed (monitored and reported) by the new department.

v. Risk

Risks must be identified.

For example:

- Lack of skills
- Lack of commitment
- From senior/executive management
- From MOEs
- Lack of co-operation
- Poor management of the process
- Scope of works poorly defined – may lead to high costs, poor quality, and extensions to time
- No buy-in by organisations not directly linked to the CoJ Council

vi. Personnel

Personnel need to have the right skills for the work. Authority and responsibilities must be defined. Personnel need to be allowed to conduct their business without undue interference and with cooperation of other personnel and organisations.

vii. Communications

Protocols for communication are to be defined. Schedules for meetings compiled.

viii. Procurement

All legal contracts are to be in place, Decisions made to employ external or internal personnel must be made. Outsourcing of task needs to be discussed and tenders should be drafted. This should follow Johannesburg's specifications and policies.

ix. Integration

Project Management follows an integrated process. Each of the above areas of PM may have influence over other areas. For e.g. time schedules have direct

impact on budgetary constraints. Any changes to the time schedules need to set off alarms for checking impact to other areas of the PM.

CHAPTER 11 FURTHER RESEARCH

11.1.1 Automation of cross-enterprise integration

The simulation program only determines conflict areas. Further study may be conducted to produce alternative plans for maintenance based on researched algorithms. This may enable automation of the creation of new IAM plans.

11.1.2 Reduction of asset life and investment due to incomplete maintenance

When one MOE performs work on their assets causing damage to another MOE's assets, the life of the other assets is negatively affected. Despite repair works carried out, the life of the asset will be diminished. An example is a road crossing: the join at the road crossing becomes a weak point in the road. Through normal use, this may develop into a crack allowing ingress of water which damages the layers below the surface. More repair works are then required before the end of the expected life (RUL) of the asset, or further scheduled maintenance may need to be brought forward to an earlier date.

11.1.3 Effect of Power outages on Traffic Delays, Accidents and Increase in Crime

During power outages, businesses and residents may be subject to unforeseen expenses due to traffic delays caused by non-working traffic lights and additional crime. Thieves may take advantage of the drop in security measures. In areas of power failures, electric fencing, alarm systems and lighting cease to function. Costs to business and private households may be significant. These costs are not included in this study.

11.1.4 User Costs of Water Outages

No data was discovered on the costs to users when water supply is interrupted. User costs may include many items. Some items are included, but not limited, to the list below:

- Health and hygiene - costs for alternative means
- Loss of production
- Loss of revenue (egg. Restaurants, Entertainment facilities, Gymnasiums, Saunas may not operate)
- Damage to plant and equipment
- Lost leisure time
- Costs for alternative means of supply (tanks, alternative locations)

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APPENDIX A QUESTIONNAIRE NUMBER 1

QUESTIONNAIRE NO. 1

Integration of Infrastructure Asset Management Systems

To: <insert name and address here>

Date: 2 April 2013

My name is James Doyle. I am writing a research project for the purpose of obtaining a Master's degree in Engineering through the University of the Witwatersrand. The title of the project is "In Preparedness for an Integrated Infrastructure Asset Management System for the City of Johannesburg".

The thrust of my research is to determine the feasibility of Integration across departments and disciplines in the application of Infrastructure Asset Management (IAM) in Johannesburg.

Only 5 minutes needed to complete the questionnaire

Please complete the following questionnaire to aid me in the research. It should not take more than 5 minutes. If there are questions that you feel cannot be answered, tick the "don't know" box or leave them out. Any comments will be greatly appreciated.

Confidentiality

The answers to the questions here will be treated as confidential in that names and/or job titles of participants will not be specifically mentioned unless permission is obtained.

Please tick one of the following boxes giving/not giving permission for your name to be used in the report (if no box is ticked it will be assumed that permission is NOT given)

I give ☐ do not give ☐ permission to have my name used in the report.

General Asset Management

1.	Does the entity have an Asset List?	YES	☐	NO	☐	Don't Know	☐
2.	Are the assets valued?	YES	☐	NO	☐	Don't Know	☐
3.	Are assets componentised (broken into smaller units)?	YES	☐	NO	☐	Don't Know	☐
4.	Are the components valued separately?	YES	☐	NO	☐	Don't Know	☐
5.	Is the condition of assets captured?	YES	☐	NO	☐	Don't Know	☐
6.	Are life expectancies of components captured?	YES	☐	NO	☐	Don't Know	☐
7.	Is data spatially represented (eg. GIS)	YES	☐	NO	☐	Don't Know	☐
8.	Does this spatial data (GIS or other) help personnel in	YES	☐	NO	☐	Don't Know	☐

	operating the system?					
9.	Does the software allow for recording and tracking of service calls?	YES		NO	Don't Know	
10.	Does the IAM system produce job cards?	YES		NO	Don't Know	
11.	Does the system prompt follow up procedures on outstanding jobs?	YES		NO	Don't Know	
12.	As far as you are aware, does Johannesburg have an Asset Management Policy?	YES		NO	Don't Know	

13. What level of data is already captured?

Simple (minimum, required to meet regulations and laws)		
Core	(Corporate policy in place, data to meet policy requirements only)	
Intermediate	(Detailed action plans in place to meet policies and strategies. Plans reviewed annually)	
Advanced	(Policy and strategy integrated into the organisation's business. Subject to periodical audit and review)	
Not Known		

Please write any comments below

Software

14. What is the name of the software used for IAM?

SAP	
CITYWORKS	
Other	

If "Other" Please specify the name

……

15.	Does the software allow for integration across departments?	YES		NO	Don't Know	
16.	Does the software allow for integration across disciplines (eg. Financial, Engineering, etc.)?	YES		NO	Don't Know	

17. Where is data stored?

Central data repository	
Individual locations in depts./MOEs	
Not known	

18.	Does the IAM software have functionality to export data in different formats?	YES		NO	Don't Know	
19.	Can it read in data from other systems?	YES		NO	Don't Know	

Please write any comments below

Integration

20. Does Integration exist in your Infrastructure Asset Management system?	YES		NO		Don't Know	
21. If YES to Question 20, on what level does Integration exist?						
There is integration between disciplines Input is required by several departments (such as financial, engineering departments) to develop the asset management plan	YES		NO		Don't Know	
Software accepts input from different disciplines and analyses the data in order to develop an asset management plan	YES		NO		Don't Know	
Integration is performed in a manual manner with meetings taking place between personnel to develop a plan	YES		NO		Don't Know	
22. Can different departments enter data directly to the Asset Management system?	YES		NO		Don't Know	

Please write any comments below

Organisational Structures and Skills

23. Is the IAM process controlled by a separate department in the City of Johannesburg?	YES		NO		Don't Know	
24. Within your particular MOE – do you have a separate department that controls the IAM process?	YES		NO		Don't Know	
25. Does the department/MOE have an organisational chart showing general reporting / authority / responsibility levels?	YES		NO		Don't Know	
26. In your opinion, do employees clearly understand the hierarchies involved with IAM?	YES		NO		Don't Know	
27. In your opinion: Are there sufficient skilled staff to operate an IAM system efficiently?	YES		NO		Don't Know	

28. If the answer to 30 is NO, what sector, and by what percentage, do you think skills need improving?

Financial	0%	25%	50%	75%	100%
Engineering	0%	25%	50%	75%	100%
Information Technology	0%	25%	50%	75%	100%
Operations	0%	25%	50%	75%	100%
Other: Specify ……	0%	25%	50%	75%	100%

Please write any comments below

APPENDIX B QUESTIONNAIRE NUMBER 2

QUESTIONNAIRE NO. 2

Integration of Infrastructure Asset Management Systems

To: <insert name and address here>

Date: 25 September 2013

Dear <insert name here>

I thank you for your time and input on our previous interview and in completing previous questionnaires. I hope I can trouble you some more to provide some more information and data so that I can conclude my research on the above topic.

Request for Data.

In order to finalise my research project I need to:

- Ascertain the information needed to run an integrated Infrastructure Management System in Johannesburg
- Run IAM systems in simulation mode with the current non-integrated manner, and also a proposed integrated model.

To do this I ask that you please provide answers to the following questions in the questionnaire below. And if possible, provide data as outlined after the questionnaire.

Confidentiality

The answers to the questions here will be treated as confidential in that names and/or job titles of participants will not be specifically mentioned unless permission is obtained.

Please tick one of the following boxes giving/not giving permission for your name to be used in the report (if no box is ticked it will be assumed that permission is NOT given)

I give ☐ do not give ☐ permission to have my name used in the report.

Note: Integration as stated in this request refers to the integration along departmental / MOE lines. In other words, the communications between different MOEs and the consequent rescheduling of maintenance based on a whole co-ordinated plan.

1.	Do you currently generate maintenance plans/programs based on your Infrastructure Asset databases?	YES		NO		Partially					
2.	Are these maintenance programs for the entire Johannesburg Area?	YES		NO		Don't Know					
3.	If not, for what percentage of Johannesburg do you provide maintenance programs?										
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
4.	For what periods does the MOE plan? (*please tick – there can be more than one period*)										
	1 year		2 to 5 years		6 to 10 years		11 to 20 years		20+ years		
5.	What level of detail is planned for each period?										
	1 year (*Please tick most appropriate selection, High Medium Low, or N/A*)							High / comprehensive plans for specific maintenance including allocation of all resources (plant labour materials)			
								Medium			
								Low			
								Not applicable			
	2-5 years							High / comprehensive			
								Medium			
								Low (Broad brush plans)			
								Not applicable			
	6-10 years							High / comprehensive			
								Medium			
								Low (Broad brush plans)			
								Not applicable			
	11 – 20 years							High / comprehensive			
								Medium			
								Low (Broad brush plans)			
								Not applicable			
	20+ years							High / comprehensive			
								Medium			
								Low (Broad brush plans)			
								Not applicable			
6.	What percentage of jobs, associated directly with the asset maintenance program, are successfully completed?										
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
7.	Are the jobs that are not completed carried forward to the next planning period?	YES		NO		Don't Know					
8.	Is work done (as on job cards) inspected by qualified personnel to determine IAM considerations?	YES		NO		Don't Know					
9.	Is work done (as on job cards) and changes to relevant parameters of assets recorded on the IAM database?	YES		NO		Don't Know					
10.	Does your asset data have <u>start</u> and <u>end</u> x-y coordinates, or <u>start</u> and <u>end</u> longitude-latitude parameters?	YES		NO		Don't Know					
12.	If the answer to 8 is NO – is it easily possible to obtain start and end coordinates?	YES		NO		Don't Know					

13. Please provide an estimate of time delay in attending to emergency repairs (in calendar days)		days

Please make any notes that you feel necessary to clarify answers or that may be helpful to the research

CURRENT INFRASTRUCTURE DATA – Request for data file

Other data requested:

- A sample maintenance program for an area
- An example of job cards
- Copy of the organisational structure relevant to IAM

If possible, please provide me with a copy of data concerning an area in Johannesburg. (preferably in Excel, MS-Word, Text, CSV, or other editable format) The area need not be very big – all I need is an area which has several different services.

It may be beneficial for purposes of research to get hold of data for an area common to all MOEs (City Power, JRA, Johannesburg Water). I propose looking at the area close to Cresta. However, if data is not available for the area around Cresta, please provide some other region – as long as I have an example of the format and type of data I may still complete the experiment. A map of the data will be beneficial.

I thank you for your time and cooperation.

Kind Regards

James Doyle

APPENDIX C PROGRAM OUTPUT TABLES

Table C. 1 Program output showing Job Cards

MOEs	CP	JR	JW	Totals
Total number of infrastructure assets	1 113	488	1 270	2 871
JOB CARDS				
Maintenance Year	**CP**	**JR**	**JW**	**Total assets needing maintenance**
2 013	20	12	76	108
2 014	15	5	39	59
2 015	27	7	0	34
2 016	24	13	40	77
2 017	10	11	18	39
2 018	16	7	0	23
2 019	28	13	5	46
2 020	22	8	0	30
2 021	25	8	0	33
2 022	24	8	0	32
2 023	22	7	0	29
2 024	27	8	1	36
2 025	17	11	0	28
2 026	26	12	241	279
2 027	23	11	2	36
2 028	18	11	0	29
2 029	23	5	0	28
2 030	18	11	62	91
2 031	23	5	7	35
2 032	13	5	7	25
2 033	33	8	0	41
2 034	25	6	0	31
2 035	17	10	8	35
2 036	16	13	11	40
2 037	23	10	14	47
2 038	23	16	5	44
2 039	23	18	5	46
2 040	27	13	100	140
2 041	25	9	0	34
2 042	19	7	0	26
Total number of assets maintained over 30 years	652	288	641	1 581
Average number of assets maintained per year over 30 years	22	10	21	53

Key: CP=City Power; JR=JRA; JW=Johannesburg Water

Table C. 2 Parameters for input to program

period for resetting RUL	50	
period at which asset needs maintenance (i.e. within the last *x* years)	1	
	Database of costs	
Damage caused to Johannesburg Water	R2,704	cost of risk per incident
Damage caused to JRA	R15,499	cost of risk per incident
Damage caused to City Power	R2,482	cost of risk per incident
percent overlap	50%	necessary for determination of intersection
maximum length of asset	0.187	km

The following abbreviations are in use over page to describe conflict points

- JR-JW = Conflict between JRA asset on maintenance list and assets belonging to Johannesburg Water
- JR-CP = Conflict between JRA asset on maintenance list and assets belonging to City Power
- CP-JW = Conflict between City Power asset on maintenance list and assets belonging to Johannesburg Water
- CP-JR = Conflict between City Power asset on maintenance list and assets belonging to JRA
- JW-CP = Conflict between Johannesburg Water asset on maintenance list and assets belonging to City Power
- JW-JR = Conflict between Johannesburg Water asset on maintenance list and assets belonging to JRA

Table C. 3 Program output showing Conflicts

	JR	CP	JW				
CONFLICTS							
Maintenance Year	**JR - JW**	**JR - CP**	**CP - JW**	**CP - JR**	**JW - CP**	**JW - JR**	**Totals**
2013	139	40	53	0	298	0	530
2014	48	7	63	28	217	157	520
2015	91	48	92	10	0	0	241
2016	183	88	208	70	323	67	939
2017	128	37	48	10	42	0	265
2018	70	25	59	42	0	0	196
2019	127	44	199	123	44	26	563
2020	98	29	64	17	0	0	208
2021	70	29	188	68	0	0	355
2022	66	28	80	46	0	0	220
2023	78	24	50	21	0	0	173
2024	134	29	76	27	0	0	266
2025	85	30	110	66	0	0	291
2026	146	25	149	73	1 496	2 456	4 345
2027	129	60	116	93	5	0	403
2028	168	42	80	48	0	0	338
2029	69	40	97	67	0	0	273
2030	152	46	41	29	195	103	566
2031	46	13	51	7	7	0	124
2032	33	14	21	12	36	0	116
2033	60	22	174	85	0	0	341
2034	38	21	119	57	0	0	235
2035	112	34	56	30	33	0	265
2036	114	27	36	0	21	6	204
2037	140	53	57	9	109	0	368
2038	293	86	78	43	19	0	519
2039	242	88	98	32	0	0	460
2040	208	57	174	29	239	256	963
2041	95	25	124	71	0	0	315
2042	45	18	68	12	0	0	143
Total number of assets maintained over 30 years	3 407	1 129	2 829	1 225	3 084	3 071	14 745
Average number of assets maintained per year over 30 years	114	38	94	41	103	102	492

(see previous page for abbreviations key)

Table C. 4 Costs of risk of damage caused by MOEs to other MOEs' assets

	JR		CP		JW		
Maintenance Year	**JR - JW (R)**	**JR - CP (R)**	**CP - JW (R)**	**CP - JR (R)**	**JW - CP (R)**	**JW - JR (R)**	**Totals (R)**
2013	2 154 361	619 960	131 546	0	729 206	0	3 635 073
2014	743 952	108 493	156 366	69 496	530 999	384 179	1 993 485
2015	1 410 409	743 952	228 344	24 820	0	0	2 407 525
2016	2 836 317	1 363 912	516 256	173 740	790 381	163 949	5 844 555
2017	1 983 872	573 463	119 136	24 820	102 774	0	2 804 065
2018	1 084 930	387 475	146 438	104 244	0	0	1 723 087
2019	1 968 373	681 956	493 918	305 286	107 668	63 622	3 620 823
2020	1 518 902	449 471	158 848	42 194	0	0	2 169 415
2021	1 084 930	449 471	466 616	168 776	0	0	2 169 793
2022	1 022 934	433 972	198 560	114 172	0	0	1 769 638
2023	1 208 922	371 976	124 100	52 122	0	0	1 757 120
2024	2 076 866	449 471	188 632	67 014	0	0	2 781 983
2025	1 317 415	464 970	273 020	163 812	0	0	2 219 217
2026	2 262 854	387 475	369 818	181 186	3 660 712	6 009 832	12 871 877
2027	1 999 371	929 940	287 912	230 826	12 235	0	3 460 284
2028	2 603 832	650 958	198 560	119 136	0	0	3 572 486
2029	1 069 431	619 960	240 754	166 294	0	0	2 096 439
2030	2 355 848	712 954	101 762	71 978	477 165	252 041	3 971 748
2031	712 954	201 487	126 582	17 374	17 129	0	1 075 526
2032	511 467	216 986	52 122	29 784	88 092	0	898 451
2033	929 940	340 978	431 868	210 970	0	0	1 913 756
2034	588 962	325 479	295 358	141 474	0	0	1 351 273
2035	1 735 888	526 966	138 992	74 460	80 751	0	2 557 057
2036	1 766 886	418 473	89 352	0	51 387	14 682	2 340 780
2037	2 169 860	821 447	141 474	22 338	266 723	0	3 421 842
2038	4 541 207	1 332 914	193 596	106 726	46 493	0	6 220 936
2039	3 750 758	1 363 912	243 236	79 424	0	0	5 437 330
2040	3 223 792	883 443	431 868	71 978	584 833	626 432	5 822 346
2041	1 472 405	387 475	307 768	176 222	0	0	2 343 870
2042	697 455	278 982	168 776	29 784	0	0	1 174 997
Total risk costs of maintenance over 30 years (R)	52 805 093	17 498 371	7 021 578	3 040 450	7 546 548	7 514 737	95 426 777
Average risk costs of maintenance per year over 30 years (R)	1 760 170	583 279	234 053	101 348	251 552	250 491	3 180 893
Total Average risk cost per MOE over 30 years (R)		2 343 449		335 401		502 043	3 180 893

(see previous page for abbreviations key)

APPENDIX E GLOSSARY

Aggregate planning	Planning the activities of an organisation to promote best efficiency and least cost strategies. A strategy for balancing output and production with available resources to achieve least cost and maximise profits for an organisation (Bloomsbury Business Library, 2007).
Cross-enterprise integration	Integration of activities across boundaries and/or borders of organisations. This integration may refer to the coordination of efforts between different branches of an organisation or even different organisations.
Data integrity	The consistent accuracy and reliability of data within systems which may access the data from different databases or export the data to other different systems.
Legacy systems	Old, outdated methods and systems - normally referring to computer applications.
Road crossing	A road crossing refers to a trench excavated across a road to install services. The excavation generally runs perpendicular to the flow of traffic but may run with the flow of traffic in some cases
Social reward	A measure of the value of time to road users
Way leave	Permission to work on Council property. Includes description and location of existing services.