A framework for effective management of water and sewer infrastructure

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Abstract. From a municipal operational and maintenance perspective water and sewer infrastructure systems are complex systems with numerous components leading to recurring water pipe bursts and sewer blockages. This prompted the study to assess, analyze and quantify the characteristics of factors that compromise water distribution and sewer services reliability around Johannesburg (used as a case study). The aim of the study was firstly to investigate water and sewer infrastructure challenges by researching the relationship between operations, maintenance, design and construction. To develop a short-term framework for improving the day to day operations process based on data highlighting common failures.
The common trend found in the literature case studies is the use of a water audit as a basis for assessing bursts, blockages, leaks and water losses. The water audit approach enables researchers to discover patterns in big data without formulating hypotheses by using a grading system (Lycett, A., 2013).This study considered various methods of managing water and sewer systems, developing a framework for addressing various types of infrastructure failures related to water and sewer. The study fills a gap by supporting effective project management of water leaks and sewer blockages by implementing quality management systems during construction to prevent recurring burst/blockages and post construction (maintenance plan linked to operations and complaint loggings from residents).
In order to simplify understanding a Model Based Systems Engineering (MBSE) approach was used to develop and present a proposed framework. Failure Modes and Effects Analysis (FMEA) was used as a method to identify potential failures of a design, construction operations, maintenance, product and process identified. The FMEA was used as a continuation from the data to create the Framework
The initial study focused on developing a short-term framework for improving the day to day operations process based on data findings. This is then to be escalated into a longer term framework over time.
Keywords: Model Based Systems Engineering, MBSE, water and sewer, water infrastructure, sewer infrastructure.

Terminology

The following terms are defined to ensure clarity:

- Flooding - A section of the area being full of water or sewer across properties or roads due to pipe bursts or blockages
- WSF - Water sewer framework
- C111 - Major burst flooding
- C112 - Minor burst no flooding
- C522 - Sewer blockages
- FMECA - Failure, Mode, Effects and Criticality analysis.

Introduction

The successful execution of all types of engineering construction projects and keeping them within estimated cost and prescribed schedules depend on a methodology that requires sound engineering management judgment. Government infrastructure projects, whether implementing new projects or operating and/or maintaining existing infrastructure, are highly complex due to stakeholders, technology changes, legislation and a wide range of services (Hamilton, 2013).

The problems highlighted at operations and maintenance level such as pipe bursts and manhole spillages due to old infrastructure, vandalism to pipelines and under-designed capacity (sizing) assisted in prioritizing the problems that lead to water/sewer infrastructure problems (Aecom, 2016). This prompted a study to assess, analyze and quantify the probabilistic characteristics of water infrastructure that may compromise water distribution and service reliability systems.

The aim of the study was to develop a single short-term (Emergency response) framework that will assist in effectively managing operations and maintenance challenges for water infrastructure systems from a design, construction and materials perspective. This was done by assessing and quantifying the characteristics, as well as establishing reliability and system engineering principles unfolding to solve and manage the identified problems.

Due to lack of forecasted demand data a study focused on addressing the short-term framework issues to improve the day to day operations process based on failure data findings.

According to Anderson the objective for effectively managing water and wastewater systems is to identify the major causes of water infrastructure problems and to assess the relative importance of these causes in the traditional type of contracts from the viewpoint of maintenance, contractors, engineers and project managers (Anderson, 1992). The main objectives of this study subsequently identified as:

- Identify common causes of pipe failure
- Identify materials used by operations department
- Review of operation and maintenance department’s procedures using different metro council frameworks as case studies
- Develop a short-term framework to be applied during operations and maintenance.

As inter alia indicated by Hellstrom, urban water systems should, without harming the environment, provide clean water for a variety of uses and remove wastewater from users to prevent unhygienic conditions (Hellstrom, 1999). In order to ensure effective operation and continued functionality of such systems it is very important for engineers and other involved professionals to have an in-depth understanding of the project management factors that affect water and sewer infrastructure(Alexander, 1987). This includes materials used, typical failures and possible prevention. Based on the above detailed literature study was performed of which the most important findings are listed below.

Based on the literature review findings, a study design framework was developed by observing, monitoring and categorizing data trends from the most to the least likely causes of water and sewer infrastructure failure. This was all plotted and calculated in Excel to produce an audit. An audit is an accounting of water in portable water and sewer systems resulting in a quantified understanding of the integrity of the water/sewer system and its operation (EPA, 2009).

Methodology followed

In this project, data was collected relating to all water and sewer mainline problems that have been previously recorded based on end users(consumers) complains for seven regions in Johannesburg. A Framework or Content analysis (examine findings with a pre-defined framework, which reflects on the aims, objectives and interests) and Thematic analysis (exploratory and observatory perspective) will be used in this project. A literature study was performed investigating other frameworks to determine the value of developing a framework. Various frameworks were identified. One example of such a high-level framework and strategy is the long term planning of water resources for Public Water Supply in England and Wales ("water-resources-long-term-planning-framework", 2016). It focuses on addressing long term benefits through forecasting future water demand vs. supply, population statistics and drought severity analysis in different regions and then generating solutions based on the forecasted data. During the study questionnaires were developed formulating questions to be addressed qualitatively and quantitatively in order to develop a suitable framework.

- *Qualitative* – Questionnaire setup gave the context of the problem and defined the problem based on literature. Feedback is based on experience and perception of the participants.
- *Quantitative* – Highlighted water demand vs. supply forecast for current and future scenarios as well drought severity within regions between years 2015 - 2065 on a long term basis together with some findings used to address current maintenance issues on a short-term basis for emergency implementation.

  Quantitative data findings included the following (Infra guide 2005):
  - Population statistic (Quantitative)
  - Water demand (Quantitative)
  - Water supply (Quantitative)
  - Drought based on historic data (Quantitative)

The study aimed at addressing four (4) key research questions:

1. Do we have a problem? (Qualitative)
2. How big is the problem? (Quantitative and qualitative)
3. What do we need to do to avoid/mitigate the problem? (Quantitative and qualitative)
4. What enabling actions are needed, by when and by whom? (Qualitative)

Quantitative data received via questionnaire feedback highlighted the following:

- Final decision making from stakeholders based on quantitative and qualitative data findings
- Generating solutions – Portfolio development and costing
- Making the case – consequence evaluation and analysis
- Identify enabling actions needed and timing
- Develop key conclusions and messages from analysis completed

Case studies of existing frameworks

The case study will give an idea of what other metro councils method of approaching water and sewer failure whether using a Long-term or Short-term framework refer to the two case studies below:

Case study 1: Australia framework for water systems
According to Auditor General Australia Water Corporation uses a risk based assessment, where the consequences are significant, proactive condition assessment work is carried out so that replacement decisions can be made prior to pipe failures occurring. The overall approach of the Water corporation is a long term framework (prevent problem from occurring in the sewer system).

Case study 2: Napa Sanitation District California Sewer framework
According to the Napa sanitation district a sewer system management plan focuses on the map of the sewer system, description of routine preventative activities by operations maintenance teams, developing a rehabilitation and replacement plan, training of staff and lastly providing of equipment and replacement part inventory. The overall approach of the Napa district is a combination of a long term framework (prevent problem from occurring in the sewer system). However, hotspots (high level frequency) problems are dealt with using a short-term framework, which rectifies urgently the sewer hotspot problem (NapaSan, 2017).

FMECA

Failure Modes, Effects and Criticality Analysis (FMECA) is a systematic method to identify potential failures of a design, construction operations and maintenance etc. It is a crucial reliability tool that helps avoid costs incurred from product failure and poor reliability.
The performance of mainline water and sewer pipe line before/after construction is primarily dependent on sound design and construction, effective capturing and management of the pipe burst/blockage loggings from a user point of view and the correct usage of the system by consumers. To ensure a reliable design, sound operating methods and material selection a FMECA was therefore performed to classify the occurrence, the severity and the impact of potential failure mechanisms on the framework proposed. It was then simplified to summarize the critical failures identified from data available for water and sewer infrastructure in the Johannesburg Water system.
Once implemented, a FMECA will once again be used as an engineering analysis to assist in reviewing the effects of probable failure of components and assemblies of the system and system performance resulting from the proposed framework.

Summary of causes of failures

The following were the main causes of pipeline leakages/spillages leading to water and sewer pipe bursts and blockages in the Johannesburg system:

- Sabotage of existing infrastructure: Vandalism
- Old infrastructure: Infrastructure has surpassed its useful life thus will deteriorate and cracks occur
- Exposure to sunlight: Damages certain plastic materials such as PVC and HDPE
- Water pressure: Creating stresses in the walls of pipes and fittings which led to cracks of pipe material
- Changes in momentum: Flow in pipes at bends, junctions, reducers, valves and other fittings which led to pipe accessories failure
- Excessive loads: Loads or forces that exceed the strength of a material can lead to failure through cracking or rupture.
- Defective materials: Flaws that were not identified in the manufacturing process

- Design sizing: Inadequate sizing of pipe material, pipe accessories, reservoirs and water towers due to population(densification/urbanisation)
- Cracks: Due to inadequate bedding (geotechnical soil layers- Insufficient soil bedding support) which also leads to excessive deflection leading to pipe to crack
- Tree intrusion: Due to incorrect placement of sewer lines and lack of inspection of the type of trees around the area prior to water/sewer line positioning
- Handling damage (especially small diameters): When delivering to site as well as poor handling on site for storage
- Improper construction or repair: During construction or repairs the system is open to the surrounding environment and thus the physical integrity is compromised especially on the following:
  - Joint misalignment especially spigot and socket joints
  - Welding jointing weakness due to misalignment
- Internal and external corrosion: Leading to material to deteriorate at a high rate which eventually leads to leakages

Material used for water and sewer distribution systems

Selecting the correct material requires detailed understanding of conditions and the strengths and weaknesses of each pipe material especially during design stage so that after construction the service delivered has no or little operational costs. The following are the most commonly used pipe material in water and sewer networks globally (Van Zyl, 2014):

- Asbestos cement: Cement and fibre glass used for water and sewer, but mostly water
- Bitumen or Epoxy: Petroleum (hydrocarbon substance) used for coating or lining pipe to prevent corrosion
- Cement and concrete: Aggregate or sand bound together by cement used for water and sewer pipes also buildings, foundation, chambers and anchoring encasement. Manholes – for sewer made mostly of concrete or steel or plastic
- Copper and Brass: Extracted from oxide and sulphide ores and brass allow of copper and zinc used for water
- Iron and Steel: Carbon and silicon content used for water and sewer
- Polyethylene-Plastic: Thermoplastic polymer consisting of long hydrocarbon chains used for water and sewer
- Polyvinyl chloride (PVC) Plastic: additives such as plasticizers used for water and sewer
- Rubber: Is an elastomer and thermoplastic that originates from trees or produced synthetically and used for water
- Glass Reinforced Plastic: Uses glass fibre in thermosetting resin in combination with other materials for desired properties

Table 1 shows the material (water and sewer) and construction method used in Johannesburg based on approved standard from the City of Johannesburg (Johannesburg Water standards, 2013).

Table 1: Material and construction method used in Johannesburg

Minimum size, type and class of pipe	Use and method of construction

25mm OD - **HDPE**, Class 12.5 P2 100 SDR 13.6	Water – Open trench or trenchless
32mm OD **HDPE**, Class 12.5 P2 100 SDR 13.6	Water – Open trench or trenchless
40mm OD **HDPE**, Class 12.5 P2 100 SDR 13.6	Water – Open trench or trenchless
63mm OD **HDPE**, Class 12.5 P2 100 SDR 13.6	Water – Open trench or trenchless
Mpvc Class 12 coupling system: High impact **Upvc** Class 16	Water – Open trench
Mpvc Class 16 coupling system: High impact **Upvc** Class 16	Water – Open trench
HDPE Class 16 PE SDR11	Water and sewer – Open trench or trenchless. Joined by electro fusion or butt welding using SAPPMA approved welder. Lengths to match existing material.
Welded steel -	Water and sewer – Open trench Internal lining with a solvent-free epoxy bitumen wrapped with or coated with a fusion bonded medium density polyethylene material

Current status – Data results

Complaint loggings from end users give operations department a direct indication of actual problems occurring on the ground. Loggings that were recorded and false alarms will not be considered. Filtering methods will be used to prioritize infrastructure data loggings.
The data for water and sewer was found from Johannesburg Operations field work reporting based on end user complains than operations department created Job cards to resolve end user complaints permanently or temporarily for water and sewer infrastructure.
Quantitative data highlighted the following with respect to water/sewer pipeline related failures, which were directly linked with literature findings:

Water:
- AC pipes leaking: Old infrastructure, cracks, design sizing, excessive loads and water pressure
- Leak on valve: Old infrastructure
- Contractor/external party damage water/sewer pipe: Sabotage/Vandalism
- Leaking meter: Old infrastructure and Sabotage/Vandalism
- Hydrant repaired/uncovered: Improper construction or repair
- Stopcock leaking: Old infrastructure and Sabotage/Vandalism

Sewer:
- Fat in the sewer main
- Infiltration: Roots, sand and stones
- Foreign objects in the sewer main: Paper, rags and other foreign material caused by sabotage/vandalism from end users

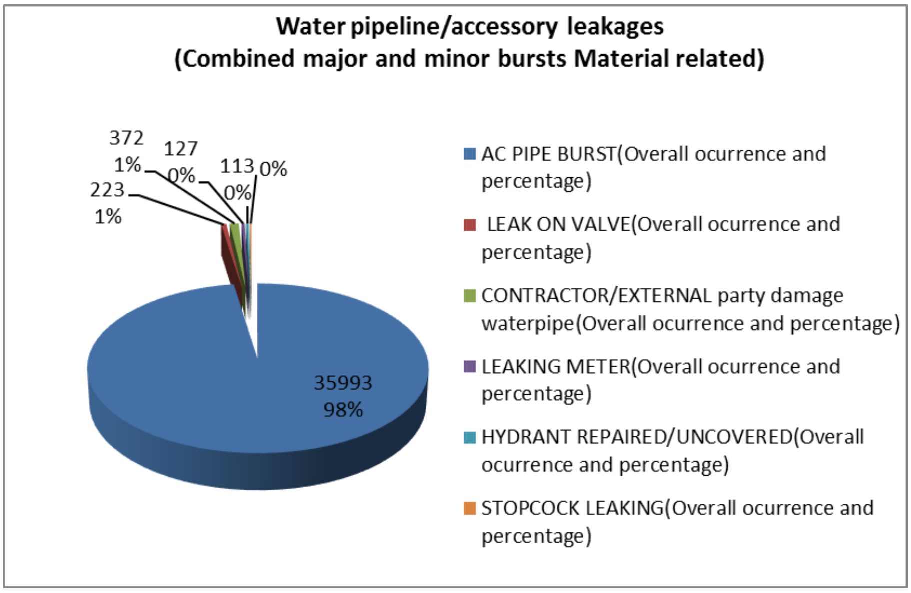

Figure 4: Combined C111 Water major and C112 minor bursts

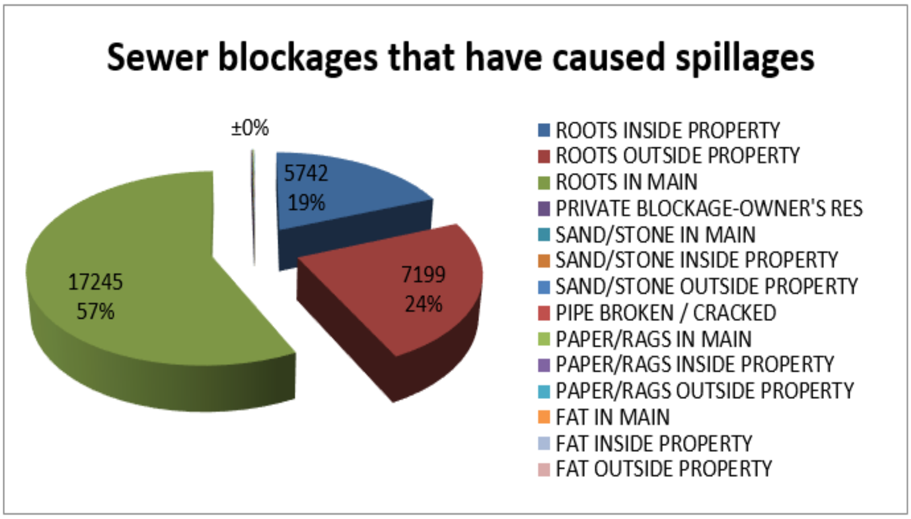

Figure 5: Combined C522 Sewer blockages

Figure 4 is combined water major and minor bursts caused in the pipe mainline and pipe accessories (meters, valves and hydrants). Asbestos cement (AC) pipes had the highest cause of water main major bursts. Contractors caused the new pipeline under the pipe replacement program e.g. HDPE, Upvc, etc. However minor water bursts were due to pipe accessories of hydrants, valves and meters. It highlights the ineffectiveness of the current framework to manage emergency bursts and to plan maintenance to prevent any bursts in the future although no water system can be perfect but can be well maintained to minimize water bursts. Below sewer blockages will be discussed.

Figure 5 is combined sewer blockages/spillages roots in the sewer mainline were the highest cause of sewer spillages with 17245 cases of roots and the rest were due to broken pipes, Fat Oil Grease (FOG) in main and Sand/stone in system. The sewer system highlights a lack of an effective maintenance and operation framework to regularly manage and plan for the system for CCTV (Closed Circuit Television), regular inspections, detailed hydraulic model analysis and decision making.

Table 2: Probability of failure for water systems (Derived from Johannesburg Water Operations 20 Month data collection, 2017)

Damage Cause Code	**Frequency of occurrence (%)**	**Failure Probability**	**Effect of occurrence**
AC pipe burst (overall occurrence and percentage)	97.56	>1 in 2	Very High
Leak on valve (overall occurrence and percentage)	0.60	1 in 80	Moderate: Occasional failures
Contractor/external party damage water pipe (overall occurrence and percentage)	1.00	1 in 80	Moderate: Occasional failures
Leaking meter (overall occurrence and percentage)	0.34	1 in 400	Moderate: Occasional failures
Hydrant repaired/uncovered (overall occurrence and percentage)	0.30	1 in 400	Moderate: Occasional failures
Stopcock leaking (overall occurrence and percentage)	0.176	1 in 400	Moderate: Occasional failures

Table 3: Probability of failure for sewer systems

Damage Cause Code	**Failure Probability (%)**	**Failure Probability**	**Effect of occurrence**
Roots inside/outside property and mainline	99.7	>1 in 2	Very High
Private blockage Owner's residence	0.04	1 in 2,000	Moderate: Occasional failures
Pipe broken/ cracked	0.02	1 in 2,000	Moderate: Occasional failures
Sands and stone inside/outside property and mainline	0.04	1 in 2,000	Moderate: Occasional failures
Paper/Rags inside/outside property and mainline	0.172	1 in 400	Moderate: Occasional failures
Fat inside/outside property and mainline	0.026	1 in 2,000	Moderate: Occasional failures
Severe overflow: Floods lack of design capacity(sizing)	0.007	1 in 15,000	Low: Relatively few failures

Tables 2 and 3 shows the probabilities of failure based on the data available Figure 4 and 5. The analysis performed indicated the effect of system failure due to the frequency of occurrence.

The highest probability of failure in the water system were asbestos cement pipes and sewer were pipeline structural integrity compromised due to roots in the sewer system. Section 3 will focus on a Short-term framework to effectively manage failure in water and sewer systems.

Proposed short-term solution framework

The development of the framework is based on the literature and data findings for water and sewer infrastructure problems identified than implementing solutions using a framework for different problems identified in the data .The information available proposed for implementation in Johannesburg Water in order to provide some guidance in effectively managing ad-hoc and recurring failures. It offers a first attempt at using systems engineering principles in developing a structured approach similar to approaches begin implemented globally in a Mobile Based System Engineering (MBSE) perspective. Figure 6 shows the high-level framework leading to more detailed framework similar to that shown in Figure 7-11 addressing the specific areas.

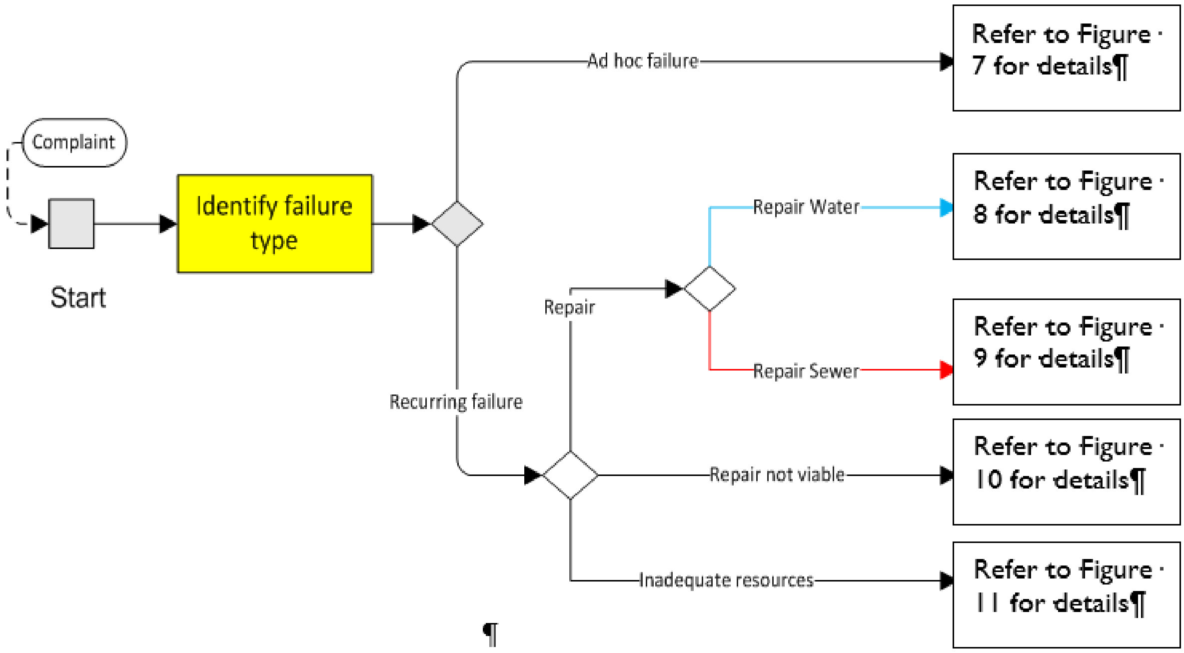

Figure 6: Main water management framework (short-term solution) WSF Model Based System Engineering Framework

Step 1: Adhoc failures

Figure 7: The adhoc failure is the infrequent failure that rarely occurs must be fixed within 1-3 days and documented.

Step 2: Regular water failures

Figure 8: The regular water failure is the frequent failure that occurs frequently must be fixed within 1-3 days (in extreme case 7 days) and documented. Be prioritized under Long term framework (future works) for replacement or operations/maintenance inspections.

Step 3: Regular sewer failures

Figure 9: The regular sewer failure is the frequent failure that occurs frequently must be fixed within 1-3 days (If extreme case 5 days) and documented. Be prioritized under Long term framework (future works) for replacement or operations/maintenance inspections.

Step 4: Regular repairs not viable by Operations

Figure 10: Regular repairs that the operations and maintenance depot departments cannot implement and have lack of personnel staff/skilled staff to deal with the magnitude of the problem. Time to fix this issue varies due to procurement procedures and waiting times for approval.

Step 5: Inadequate resources within metro council

Figure 11: Inadequate resources are the steps taken by the metro council to expand on employing more service providers and personnel staff to deal with water and sewer failure.

Similarities between existing and proposed framework

Similarities between the literature for existing long-term framework and the newly developed short-term framework

- Both existing and proposed frameworks are both qualitative and quantitative
- Data analysis was used to derive solution processes in the framework
- Both existing and proposed frameworks aimed at addressing water related problems although the short-term framework addressed sewer issues as well

Short-term framework – Low-level framework

- Regular failure for asbestos water line
- Occasional failure for pipe accessory and external party failure

Long-term framework

- Water demand and supply for current and future scenarios between 20-50 years forecasting
- Severity of droughts in regions,
- Population statistics for current and future demand

Interpretation of the proposed framework short-term and data

Quantitative data findings show two distinct groups of failure i.e. ad-hoc failures and recurring failures. Ad-hoc failures are failures that occur infrequently and can be repaired within 1- 3 days. Recurring failures are then grouped into one of three system failures including:

- Failures than can be repaired economically.
- System failures that cannot be repaired economically thus requiring a new/upgraded system.
- Failures due to resource issues.

The new and resource issue lines are similar for water and sewer although the repair lines are slightly different. As the activities for resolving recurring failures vary depending on the type of failure the lines distinguish between the different failures types as per literature and the available data for Johannesburg Water.

Short-term (Lower level) framework

The short-term framework focuses on improving the day-to-day water and sewer failure management and developing operational, maintenance and design procedures of effectively managing water and sewer infrastructure failure (refer to Figure 6). The framework highlighted the following:

- Integrated managing water framework and sewer basic framework
- Benefit Short-term Day to Day running of the implementation infrastructure failures based on the data findings
- Implement procedures – for managing the day to day running of water infrastructure

Improving key performance indicators

Consider combining a water and sewer framework as a long term (higher level) and short (lower level) term solution with the following data information to develop one main framework:

- Water demand data be integrated to determine current and future drought occurrences for different regions
- Population statistics current and future forecast for the whole of South Africa with forecasting data
- Water demand vs. supply statistics for past, current and future scenarios. Water demand and supply data be integrated to determine current and future drought severity for different regions
- Develop detailed severity analysis based on pipeline/fittings failure for water and sewer failures recorded for past 10-20 years, current scenarios and future scenarios to build up a holistic framework for the whole of South Africa (Carlsson,2010)

Benefits of framework

The benefits of the framework are the following:

- Assist in identifying water and sewer main line infrastructure failure
- Proving guidance in identify solutions based on the failures identified
- Allow decision makers to decide whether to solve problems through operations (day to day services) or to apply an alternative solution
- Develop detailed water and sewer operating information based on end user loggings (consumers)

Conclusion

The framework findings highlighted water bursts for Asbestos Cement pipes at 30871(most frequent) and 105 major bursts caused by leaking valves in the suburbs (medium to high income group). Similarly for minor bursts 5122 water bursts were recorded for Asbestos cement and 118 minor bursts were recorded for leaking valves also in the suburbs. Highlighting water major/minor bursts were directly linked to material, age and installation method (from contractors).

In contrast sewer problems were not material based but highly based on external factors that intrude into sewer mainline a total of 30186 root intrusion(Most frequent) cases were reported that caused sewer blockages in the suburbs. However a total of 35 sewer blockages by depositing of foreign object such as rags, paper, tampons, etc. In the mainline this occurred in the townships. This highlighted the negative social economic factors in the townships of a lack of education to use infrastructure technology. Water had the most failures due to major and minor pipe bursts caused by old infrastructure material and poor maintenance which are linked to the literature findings especially for pipe material failure.

In this study a complex short-term framework has been proposed to manage water and sewer infrastructure issues with different types of failure modes referring to FMECA and literature review. For the development of the framework a literature review and data found using Johannesburg was used to develop the short-term framework. The study was very helpful for managing water and sewer infrastructure failures that are economically viable and not economically viable. The purpose was to show that there was two main lines based on the quantitative data findings i.e. ad-hoc failures and recurring failures. The new and resources lines were similar for water and sewer although the repair lines are slightly different. As the activities for resolving recurring failures vary depending on the type of failure the lines then distinguishes between the different failures types as per literature and the Johannesburg Water data found. It is a new detailed procedure for maintaining and operating the current water and sewer infrastructure failures. Furthermore the proposed framework enhances decision making for engineers, clients and planning departments for water and sewer infrastructure for implementing new projects.

RECOMMENDATION

The main recommendation is to develop a holistic framework for water and sewer as a long term solution with software technology integration e.g. frameworks integrated within smartphones and tablets for staff working in operations and maintenance. Developing detailed dataset models from the data loggings should be developed in future.

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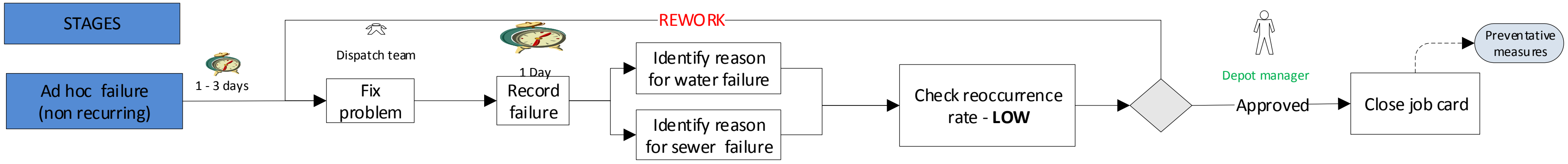

Figure 7: Adhoc failure steps for resolving the problem occurred under the short-term framework WSF (Adhoc failures are infrequent type of water and sewer failures that can be solved within 1-3 Days)

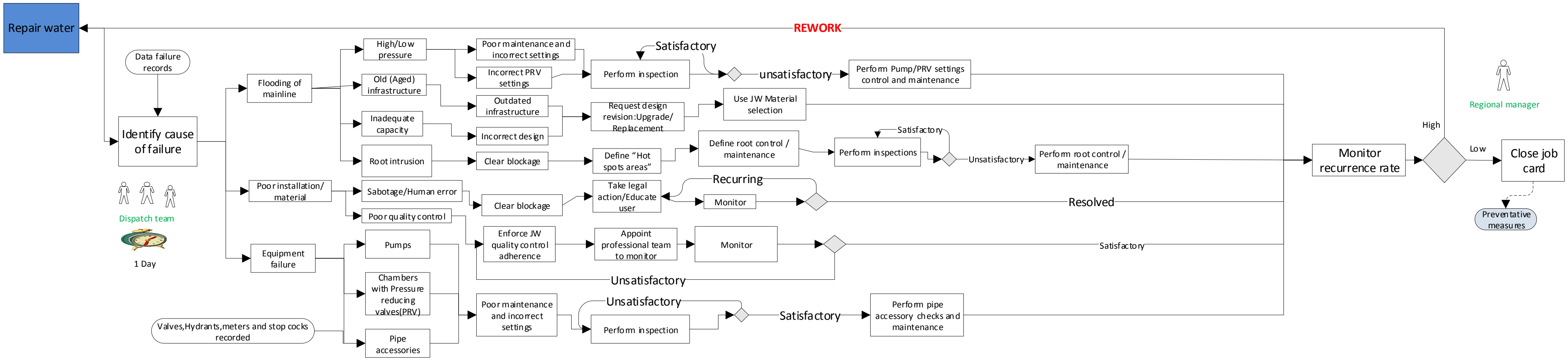

Figure 8: Repair of water regular failure steps for resolving the problem occurred for the short-term framework WSF (Regular water failures: Frequent water failures that can be solved within 1-3 Days or longer depending on severity)

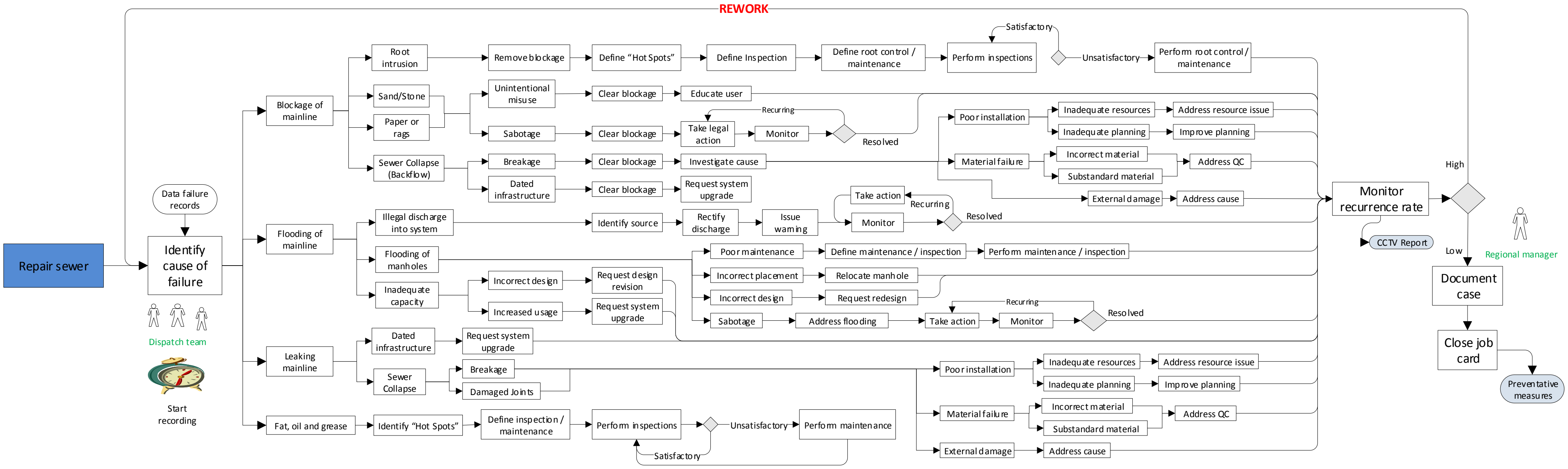

Figure 9: Repair of sewer regular failure steps for resolving the problem occurred for the short-term framework WSF (Regular sewer failures: Frequent sewer failures that can be solved within 1-3 Days or longer depending on severity)

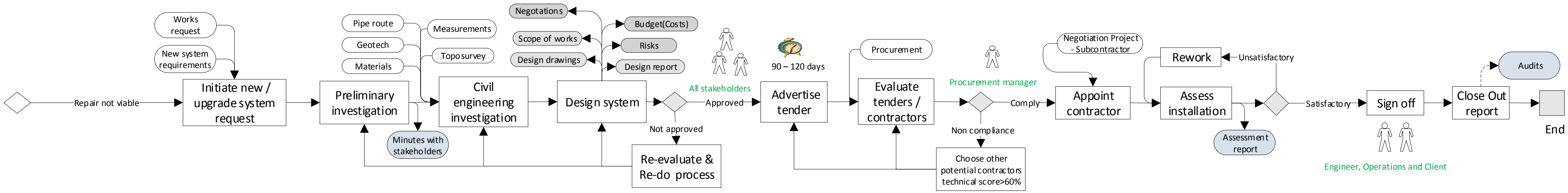

Figure 10: Repairs of regular failure not viable steps for resolving the problem occurred for the short-term framework WSF
(Regular repairs not viable by Operations: A full on project will need to be implemented with consultants, project managers, contractors, etc to solve project.)

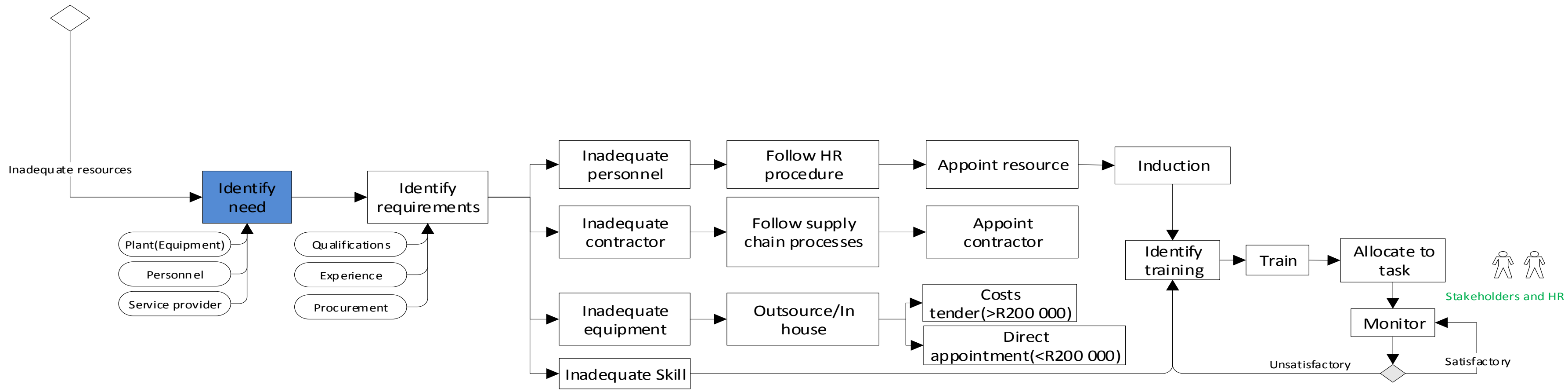

Figure 11: Inadequate resources steps for resolving the problem occurred for the short-term framework WSF
(Inadequate resources within metro council: A full on process to expand resources to achieve service delivery goals)

Biography

Dr Botha started his engineering career as systems engineer at Denel in 1992 and registered as professional engineer with ECSA in 1994. He joined Potchefstroom University in 1995 where he lectured at both under and post graduate level till 2008. In parallel he acted as consultant to PBMR and quality manager to M-Tech Industrial. He completed his Ph.D. in Engineering in 2003 at the North-West University. In 2008 he joined PBMR full-time as Senior Systems Engineer. After the closing of PBMR in 2010 he joined the University of Pretoria lecturing in Reliability Engineering, Reliability Based Maintenance and Mechanical Design as part of the Maintenance Engineering programme. He then joined SNC-Lavalin as Design Manager until SNC-Lavalin closed their South African office due to the slump in the mining industry. He is currently a lecturer in Mechanical Engineering Sciences at UJ where he lectures in Design and provides study guidance at postgraduate level in both Mechanical Engineering and the Postgraduate School of Engineering Management. Further information can be obtained from Dr Botha at bwbotha@uj.ac.za or from the website of the Department of Mechanical Engineering Sciences at the University of Johannesburg.

Oarabile Mawasha obtained his BEng bachelors in Civil Engineering degree from the University of Johannesburg in 2014. Thereafter he started working as an engineer for the city of Johannesburg Metro under Johannesburg Water implementing water and sewer infrastructure capital projects. In 2016 he enrolled for his Masters in Engineering Management majoring in System Engineering and completed his studies in 2018. Oarabile is passionate about innovations especially in the water and sewer sector. His hobbies include watching rugby, soccer and reading. His favorite reads are the richest man in Babylon by George Glason and the alchemist by Paulo Coelho.