Including Pipe Replacement Prioritization in the Dynamic Master Planning Process

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Introduction

GLS Consulting has pioneered the Dynamic Master Planning Process for water distribution and sewer reticulation networks in South Africa and applied successfully to major cities, including Pretoria, Johannesburg & Cape Town and is now extending their expertise into the associated Asset Management field. Extending the Dynamic Master Planning Process to include Pipe Replacement and Refurbishment Prioritization ensures that upgrades and replacements of infrastructure are planned and implemented in an efficient and cost effective manner. Studies have been completed for the water distribution network of the City of Tshwane (Pretoria) the City of Ekurhuleni (Eastern Gauteng) and a number of smaller municipalities and results show the advantage of combining above strategies.

Dynamic Master Planning Process

In South Africa, water and sewer master planning has traditionally taken the form of establishing a model of existing infrastructure followed by the preparation of a master plan defining future improvements to the system to meet the requirements for expected developments. The master plan typically includes a capital expenditure program that is used for budget purposes and project prioritization by the service provider. Traditionally the process is repeated and updated every two to five years, depending on the rate of development in the study area.

GLS developed a system to manage, capture and utilize information, in order to keep the models up to date, to plan for the future and to regularly revise the planning given any new information. The system has been implemented so that up to date information is available from the model at any time to facilitate decision making for both the existing and future systems, allowing for prompt and accurate responses to queries and applications for new developments. Figure 1 illustrates the data flow during this dynamic master planning system.

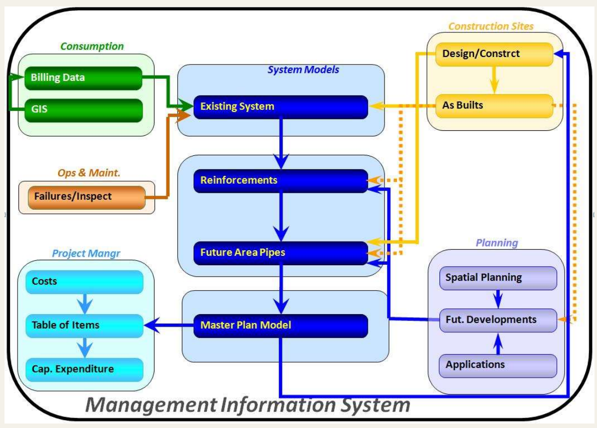


Figure 1: The Dynamic Master Planning Process

Infrastructure refurbishment programs should be designed to be integrated with the dynamic master planning process. With extensive GIS-based information available as part of the dynamic master planning process, GLS has developed a Pipe Replacement Prioritization methodology specifically suited for South African conditions taking cognisance of the available information and reliability thereof.

Pipe Replacement Prioritization - Methodology

The risk associated with replacing infrastructure can be quantified in monetary terms by the product of the Probability of Failure and the Consequence of Failure. Intervention to replace infrastructure before failure, reduces risk, but finding useable statistical information to perform such an analysis is difficult.

GLS decided to perform an analysis based on fundamentally independent factors to assess the pipe replacement potential (PRP) for any one modelled pipe in the water distribution model by combining four critical factors

- *Likelihood of failure (LF)*
- *Consequence of failure (CF)*

Various independent variables contribute to each of these factors using a simplified scoring system from 1 to 5 out of 5 (F_i). The information required to determine these variables are available if comprehensive and integrated management information systems have been adopted by the authorities.

The contributing variables are then summated using different weights (Q_i) to give total *LF* and *CF* factors. The total Pipe Replacement Potential (*PRP*) is then calculated for each pipe as the product of these factors (see Figure 2) which is then ranked for all pipes in the model to give the *PRP%* (in the range of 0 to 100%).

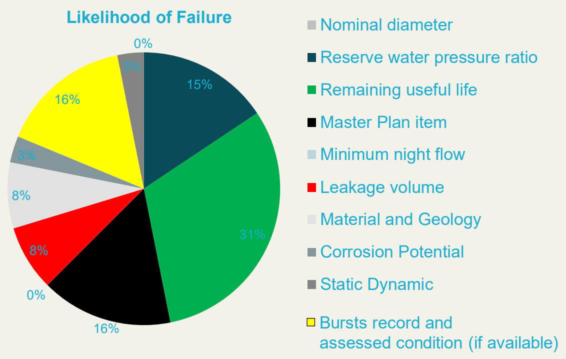
$$LF_{total} = \sum_{i=0}^{n-1} \mathrm{LF_i} \times \mathrm{QL_i} \qquad CF_{total} = \sum_{i=0}^{n-1} \mathrm{CF_i} \times \mathrm{QC_i}$$

$$PRP = LF_{total}\ x\ CF_{total}$$

Figure 2: Calculating PRP for one modelled pipe

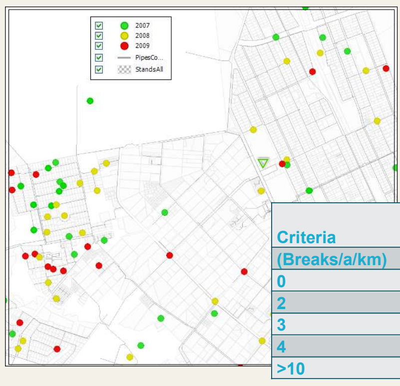
In addition the actual replacement cost for every pipe is calculated. The pipes with high *PRP* or *PRP*% can then be visualized graphically. The pipes can be aggregated in various ways to provide the weighted average, maximum or minimum PRP for various collections, such as per suburb or reservoir zone. The analysis is performed as an add-in to the *Wadiso* (GLS Software, 2020) GIS-based hydraulic analysis software.

Likelihood of Failure Variables & Typical Weights



Bursts record and assessed condition

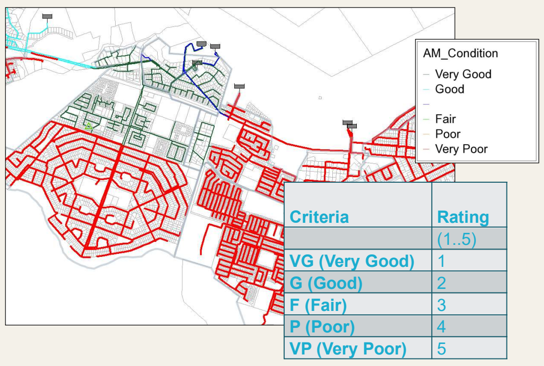
Recorded pipe bursts are an important source of information to identify where pipe failures are likely to occur in future. Although a section of the failed pipe would have been replaced by a new pipe, the underlying reason for failure might not have been resolved and future failures are likely to occur again in adjacent sections. Figure 3 shows a geographical record per year and typical rating table.



Criteria (Breaks/a/km)	Rating (1..5)
0	1
2	2
3	3
4	4
>10	5

Figure 3: Geographical pipe burst record and typical rating table

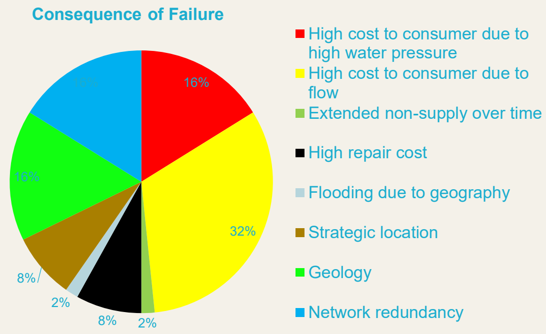
Assessed pipe condition through pipe inspection technologies or excavation provides the best source of reliable condition assessment. Figure 4 shows a geographical presentation and typical rating table.



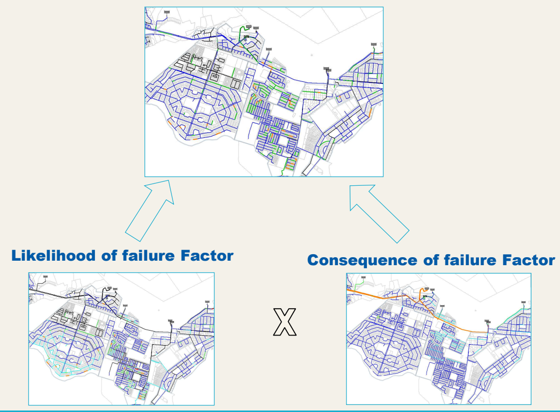
Criteria	Rating (1..5)
VG (Very Good)	1
G (Good)	2
F (Fair)	3
P (Poor)	4
VP (Very Poor)	5

Figure 4: Geographical pipe assessed record and typical rating table

Consequence of Failure Variables & Typical Weights



Final Assembly of PRP



Graphical Results

Results are reported in generic GIS format or in a dedicated module of the *IMQS* Reporting System (IMQS Software, 2020). It can for example be seen (Figure 5 shows a sample geographical view) how the pipe identified in blue has a relative low PRP score of **0.19**. The short pipe identified in magenta has a PRP score of **0.50** mainly attributed to its high failure frequency and location under the tarred road.

Figure 6 shows the weighted average PRP% per "Roll-up" Area (a combination of suburbs and reservoir zones) for the City of Tshwane water mains as reported in IMQS.

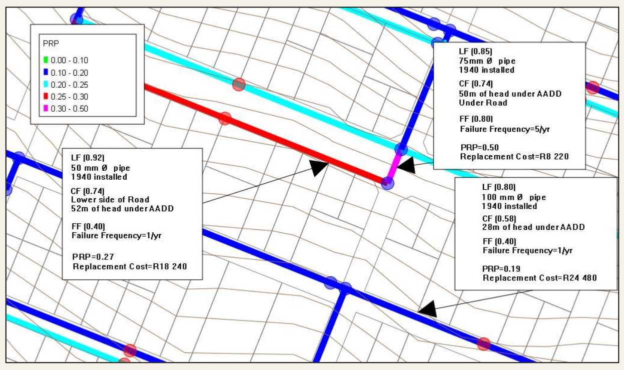


Figure 5: Geographical result from typical PRP analysis

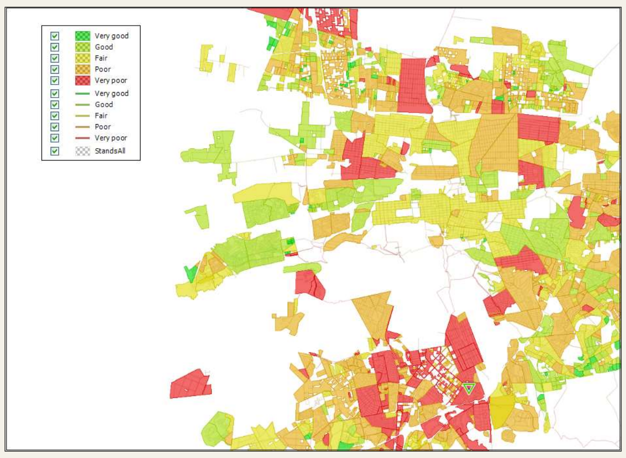


Figure 6 Weighted average PRP% per "Roll-up" area for the City of Tshwane as reported in IMQS

Conclusion

Combining the pipe replacement programme with the required infrastructure programme ensures that asset upgrades and replacements are planned and implemented in an efficient and cost effective manner. With the extension of the dynamic master planning process to include the assessment of infrastructure replacement and refurbishment it is now possible not only to generate a list of costs for infrastructure requirements to accommodate the future scenario but to also assess the cost and priority to maintain the current infrastructure.

The PRP model provides the best approach to identify areas where pipeline inspections should commence to confirm pipe refurbishment or replacement, especially in the absence of assed condition data.

The weighted PRP per "Roll-up" area is a more practical indicator than individual pipe PRP values as it shows which areas should be considered for pipe replacement or refurbishment and does not identify pipes located randomly all over the city.

An asset management aligned approach has now also been developed which calculates an adopted Remaining Useful Life for each pipe.

References

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