LIFECYCLE ASSET PORTFOLIO RENEWAL OPTIMISATION AT DRAKENSTEIN MUNICIPALITY

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ABSTRACT

All municipalities in South Africa have to manage large portfolios of infrastructure assets. The optimisation of service levels, risk and expenditure for all assets over the entire asset lifecycle, within ever-present budgetary constraints, presents a unique challenge for these organisations.

Drakenstein Municipality is the largest local government in the Western Cape Province of South Africa after the City of Cape Town. It delivers infrastructure support services to more than 260 000 people with an infrastructure asset portfolio comprising more than 32 000 individual infrastructure assets.

The municipality's capital budget is typically in the order of 6% of the replacement value of the infrastructure and this amount must cover both the renewal of existing assets, as well as network expansions necessary to provide and improve services to customers. The asset managers at Drakenstein Municipality therefore face a significant challenge in apportioning the limited capital budget so as to maximise service delivery whilst maintaining asset condition and minimising the risk of asset failures.

The solution developed by Drakenstein Municipality is based upon asset portfolio optimisation models typically used to plan renewal programmes for road networks. This approach was extended to cover all of the other infrastructure categories typically managed by them.

This has enabled the Drakenstein Municipality to optimise the performance of the entire asset portfolio, within specific risk and budgetary regimes. The model uses a sophisticated risk model which considers the social, environmental and economic risks associated with infrastructure services to prioritise capital renewal interventions.

1. INTRODUCTION

Drakenstein Municipality is one of the leading local governments with regards to the implementation of advanced asset management initiatives. The municipality was one of the first to complete comprehensive infrastructure asset registers along with the business processes required for the updating and maintenance of the registers. Whilst this has enabled the municipality to achieve compliance to the requirements of Generally Recognised Accounting Practice in terms of the financial treatment of its infrastructure assets, it also provides the municipality with a very good data set to be used for modelling the renewal requirements of the asset portfolio, and the techniques described in this paper were subsequently developed based upon the asset register originally compiled for financial compliance. The asset renewal needs for the infrastructure categories of electricity, road transport, sanitation, solid waste disposal, stormwater and water supply were covered in the modelling.

2. THE MODEL

The high-level process followed to complete the asset renewal modelling is illustrated in the accompanying Figure 1, which will be used as the basis for this document.

Primary inputs to the lifecycle portfolio model are:

- Asset data (Section 3)
- The asset renewal treatments and tactics (Section 4)
- A risk- and impact of failure model (Section 5)

The lifecycle model (Section 6) is then used to optimise renewal and maintenance expenditure based upon certain budget scenarios and, if affordable, will enable the production of a prioritised 20 year asset renewal project list.
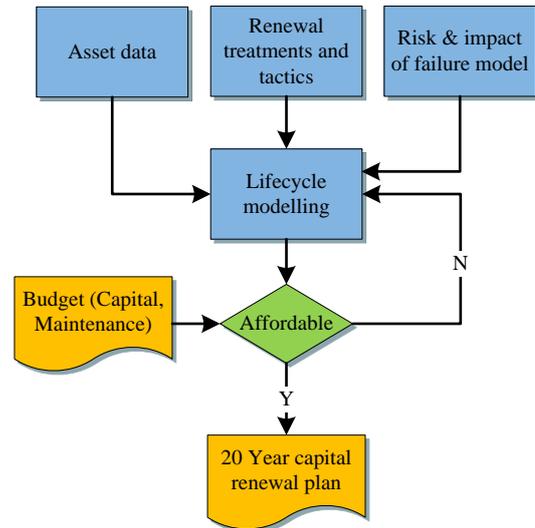

Figure 1: Asset portfolio renewal modeling process

3. ASSET DATA

Existing asset data is the foundation for the renewal model. It is therefore important to ensure that the following attributes are collected for each of the infrastructure assets to be modelled.

- Asset description, quantity and quantity unit.
- Current Replacement Cost (CRC), the cost to replace the asset with a similar asset at current prices.
- Construction date, in order to determine the age of the asset.
- The Expected Useful Life (EUL) and Estimated Remaining useful Life (RUL) of the asset in years. The operating conditions, e.g. environment and usage of the asset should be considered in determining these values.
- Asset condition expressed as an index, where the condition of a new asset is 100%.

In addition, an assessment of the confidence level of the asset information is useful. In some cases, such as buried assets or where original design information is no longer available, it is necessary to estimate some of the above attributes, and an awareness of the accuracy of the data will enhance the modelling process.

The asset types included in the Drakenstein renewal analysis is listed in Table 1.

Table 1: Types of assets included in the analysis for Drakenstein Municipality

Service Type	Facility Type	Description of typical assets
Electricity	High Voltage	HV Overhead Line; HV Underground Cable
	High Voltage Substation	Auxiliary Transformer; Battery; Circuit Breaker; Current Transformer; Earth Switch; HV Switchgear; Neutral Earthing Resistor; Other Assets such as fences, access roads and buildings; Outdoor AIS Isolator; Panels; Power Transformer; Voltage Transformer
	Low Voltage	LV Underground Cable
	Low Voltage Network	Consumer Connection Cable; Street Light Cable
	Medium Voltage	Distribution Transformer; Mini Substation; MV Overhead Line; MV Underground Cable; Ring Main Unit
	Medium Voltage Substation	Battery; MV Switchgear
Water Supply	Bulk Water Pipeline	Pipes

Table 1: Types of assets included in the analysis for Drakenstein Municipality

Service Type	Facility Type	Description of typical assets
	Dam	Civil Structure; Other Assets such as fences & access roads
	Pump Station	Civil Structure; Electrical Plant; Mechanical Plant; Other Assets such as buildings & fences
	Reservoir	Civil Structure; Electrical Plant; Other Assets such as fences & access roads
	Water Pipeline	Pipes
	Water Treatment Works	Civil Structure; Electrical Plant; Mechanical Plant; Other Assets such as fences & access roads
Storm water	Channel	Civil Structure
	Culvert	Civil Structure
Solid Waste Disposal	Landfill	Civil Structure; Other Assets such as fences & access roads
	Transfer Stations	Civil Structure; Other Assets such as fences & buildings.
	Bulk Sewer Pipeline	Pipes
	Pump Station	Civil Structure; Electrical Plant; Mechanical Plant; Other Assets such as fences, buildings & access roads
Sanitation	Sewage Treatment Works	Civil Structure; Electrical Plant; Mechanical Plant; Other Assets such as fences & access roads
	Sewer Pipeline	Pipes
	Road	Civil Structure
Road Transport	Structure	Civil Structure
	Taxi Rank	Civil Structure; Other Assets such as fences

4. ASSET RENEWAL TREATMENTS AND TACTICS

Because different assets deteriorate in different ways, the determination of appropriate asset renewal treatments *("…what must be done to the asset and when…")* for each asset is an important input into the renewal model. Appropriate asset renewal tactics *("…what are the appropriate treatments for the type of asset…")* need to be defined as inputs to the renewal model along with the timing of when in the asset life that treatment will be appropriate.

4.1 Asset deterioration
The condition of an asset will deteriorate over its life, from a condition of 100% ("as new") up to the point where it loses its ability to provide the intended service. The deterioration of an asset goes through a number of phases, depending on the asset type. These phases are based upon a typical asset life as illustrated in the accompanying Figure 2.
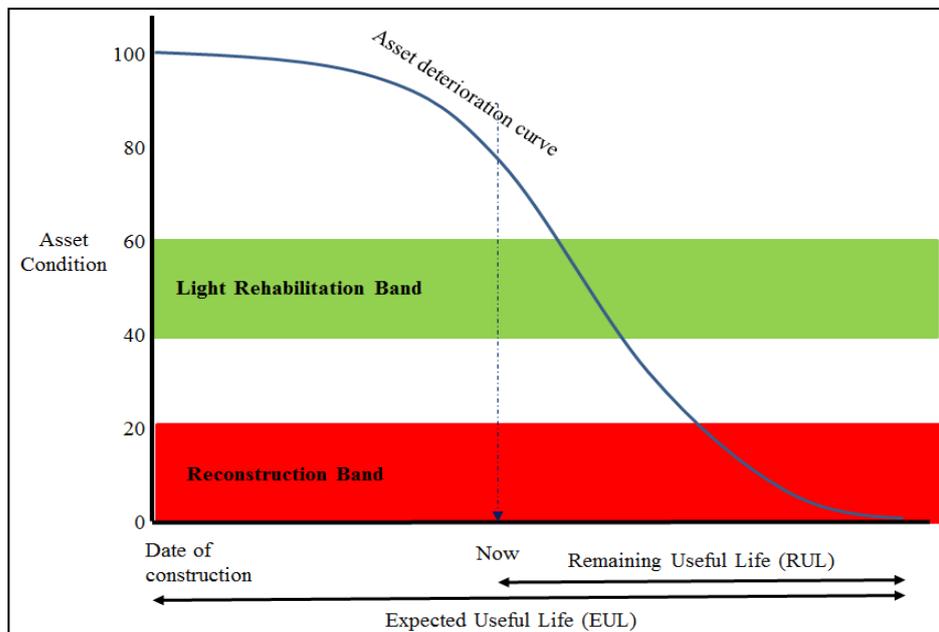
Figure 2: Asset deterioration

An initial phase where the asset provides a good service, and where any asset renewal work is not cost-effective. (Condition 100 to 60 in Figure 2).

A phase where it is cost-effective to do a light rehabilitation of the asset. (Condition 60 to 40 in Figure 2). This phase is called the "Light Rehabilitation Band".

A phase where the asset still delivers a service, but where the condition has deteriorated to such an extent that it is not cost-effective to spend money on the renewal of the asset. The asset is therefore allowed to deteriorate up to a point where it does not provide the service anymore. (Condition 40 to 20 in Figure 2).

A phase where the asset does not deliver the intended service anymore and needs to be reconstructed (Condition 20 to 0 in Figure 2. This phase is called the "Reconstruction Band".

The asset deterioration curves are unique for different asset types and such deterioration curves can be calibrated using asset specific variables.

4.2 Asset treatments
Appropriate asset treatments need to be defined for each asset type and the lifecycle characteristics of the asset. The cost of asset treatments is typically inversely proportional to the condition of the asset, i.e. as the asset deteriorates, the cost of returning the condition to "as new" increases.

4.3 Categorisation of assets
In order to simplify the modelling of the deterioration behaviour of different types of assets, they were grouped according to their deterioration characteristics, as follows:

- Pipelines
- Civil Structures and other assets
- Electrical & Mechanical Plant

Some of the asset deterioration characteristics considered for each group of assets were:

- Pipelines: Usually only full reconstruction treatments are possible because it is not really feasible to do minor repair treatments on pipelines, with some exceptions, such as steel pipelines where it is possible to install an in-situ lining in the pipeline.

- Civil Structures & other assets: Infinite light rehabilitation treatments at a reduced cost are possible. The underlying assumption is that civil structures can be maintained at a good condition with proper structural repairs and other assets without moving parts can be treated similarly.
- Electrical and Mechanical Plant: Light rehabilitation treatments are possible during the lifespan of the asset, but it can only be applied a limited amount of times.

4.4 Asset renewal tactics

The asset treatment programme for an asset will be determined by the renewal tactic adopted for a specific asset, and this is therefore a key input into the renewal model. The four main types of asset renewal tactics that can typically be adopted are as follows:

- RTF: Run to failure and do the full replacements at the end of the asset's lifetime. This tactic is appropriate for many types of municipal infrastructure, but must be supported by an inspection programme so that the failure of the asset can be detected. An example of an appropriate RTF strategy would be street lighting, where the lights are only repaired after failure. No treatments are triggered for assets where a RTF renewal tactic is selected.
- LLL: Perpetual light renewals. This tactic is suitable for assets for which the lifetime can be significantly extended through regular light renewals. An example would be building structures where regular repairs and painting will ensure a very long lifetime. Repeated minor repairs would therefore be done on assets with a LLL renewal tactic.
- LRL: Light renewals alternating with full replacements. A good example of assets where this renewal tactic is appropriate is lightly trafficked urban roads, where a programme of regular re-sealing of the road, and a major rebuild at the end of the road's lifetime is an appropriate approach. Alternating full- and minor repairs would therefore be done for assets with a LRL renewal tactic.
- DN: Run to failure and do nothing. This is a situation where there are insufficient funds available to do work on an asset. No treatments are triggered for assets where a Do Nothing renewal tactic is selected and the asset ceases to provide any service at the end of its useful life.

The typical asset deterioration curves for each of the renewal tactics is shown in Figure 3.
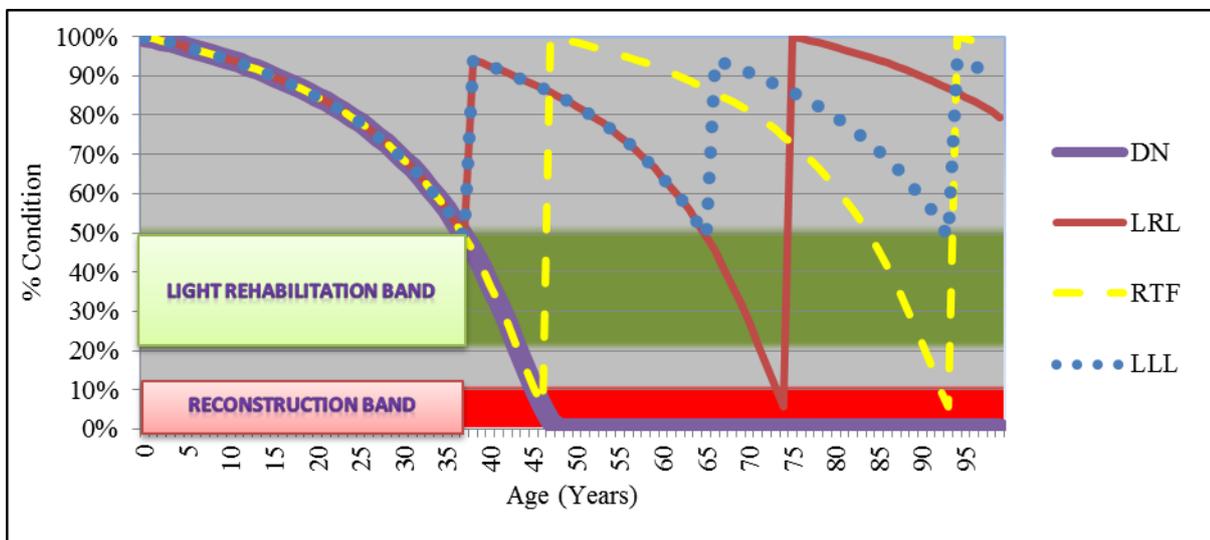

Figure 3: Asset deterioration curves for different renewal tactic options

5. RISK- AND IMPACT OF FAILURE MODEL

The renewal model uses a risk- and impact of failure model to select the most appropriate renewal strategies for each asset, based upon the available budget. A comprehensive risk model is therefore a primary input into the renewal model, where the risk associated with the failure of each asset in the asset register was calculated by multiplying the probability of failure with the consequence of the failure.

5.1 Probability of failure

The probability of failure of every asset was determined using the remaining life as a proxy variable so that as the asset ages, the probability of failure increases. It should be noted that the remaining life estimate already constitutes all the factors that may affect the asset and lead to it no longer being able to deliver the required level of service. Such factors may include usage, soil condition, breakage history and specific operating conditions.

5.2 Consequence of failure

Consequence of failure was determined by considering four different impacts:

- Environmental,
- Health & safety,
- Financial loss, and
- Service delivery impact.

The consequences of each of these were determined in conjunction with Drakenstein Municipality's departmental managers, using 10 point scales with agreed relative weightings between the factors.

Municipal infrastructure assets are typically located in facilities and networks, as follows:

- Networks: such as water-, sewer- & and electrical networks, or
- Facilities: such as mini substations, reservoirs, water treatment works, pump stations etc.

These facilities and networks have the inherent redundancies illustrated in Figure 4:
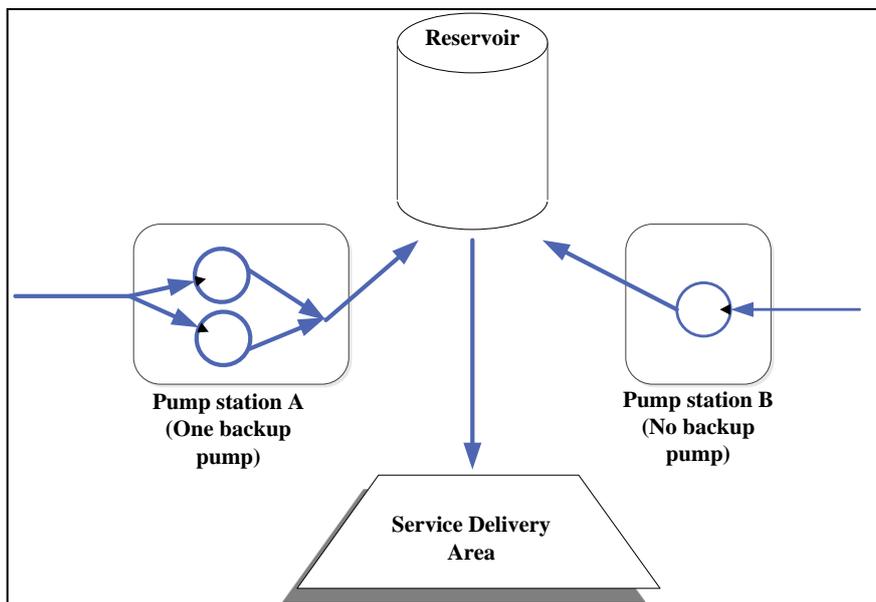

Figure 4: Facility and network redundancies

- The redundancy of assets within a facility. This is shown in the accompanying figure on the left hand side as pump station A with two pumps, a service pump and a standby pump.
- The redundancy of facilities within the system. This is shown in the accompanying figure on the right hand side as a duplicate pump station serving the same service reservoir.

The consequence of the failure of assets is therefore affected by the degree of redundancy of facilities and networks, and this was taken into account in the risk model.

6. LIFECYCLE RENEWAL MODELLING

In the last step the various inputs to the renewal model, viz the asset data, the asset renewal treatments and tactics and the risk- and impact of failure model can be combined with different budgetary scenarios to optimise the renewal of the asset portfolio.

6.1 dTims-CT modelling

The renewal modelling was done using the dTIMS-CT lifecycle analysis software solution, which is a powerful decision support tool for making consistent and informed decisions concerning the lifecycle of assets. The software uses a heuristic optimisation that is a combination of true optimisation and prioritisation methods. This enables the process to be computerised with calculations that can be done in an acceptable time frame on a large number of assets.

The software allows the user to configure the asset deterioration curves, treatment types and treatment costs for the different asset types. These parameters are used in lifecycle analysis for a specific budget to prioritise the treatment of assets in a logical way, based upon the minimisation of the risk to the organisation, in order to stretch the available budget as far as possible.

6.2 Incorporating budgetary constraints

Municipalities typically have limited financial resources for asset renewals. The most significant benefit from the renewal model is therefore the ability to prioritise the most critical renewals and treatments in a situation of limited funds.

The impact of reduced budgets on the following can be modelled:

- Municipal risk,
- Frequency of asset failures, and
- Asset condition.

In order to optimise renewal spend and identify the point of diminishing returns, a number of budget scenarios are usually modelled, as follows:

Firstly, an unconstrained budget (UCB) is used to determine the impacts if funding is unlimited. This is followed by the other extreme, the Zero Budget (ZB), where no funding is available.

The unconstrained and zero budgets represent the outer envelopes of the results. In order to obtain a number of options within these outer envelopes the performance of the portfolio is also modelled for an initial estimated budget, obtained by averaging the unconstrained budgets per year. The initial estimated budget plus 50%, (PLUS 50) and the initial estimated budget minus 50% (MIN 50) is then determined as additional parameter points. The current municipal budget (CB) is then plotted on this curve to identify where the municipality falls with their CB.

By plotting the six budget scenarios, a point of diminishing returns can be identified, as shown in Figures 5 & 6 with regards to the performance of the portfolio when measured through asset condition and risk exposure.

Figure 5 shows the impact of different annual budgets on the long term (20 year) average asset condition of all assets in the portfolio.
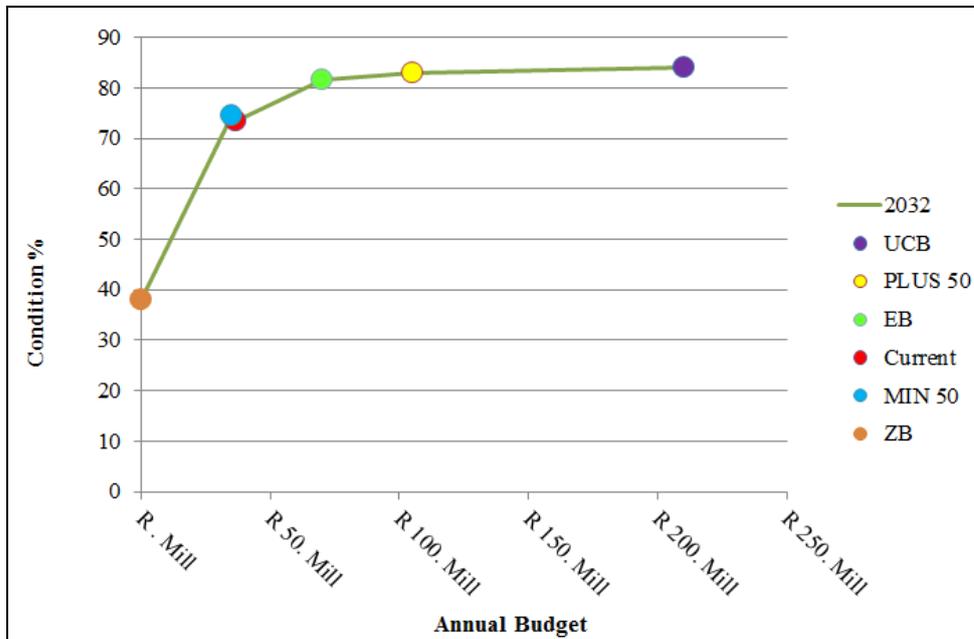
Figure 5: Twenty year impact on average asset condition of various budget scenarios

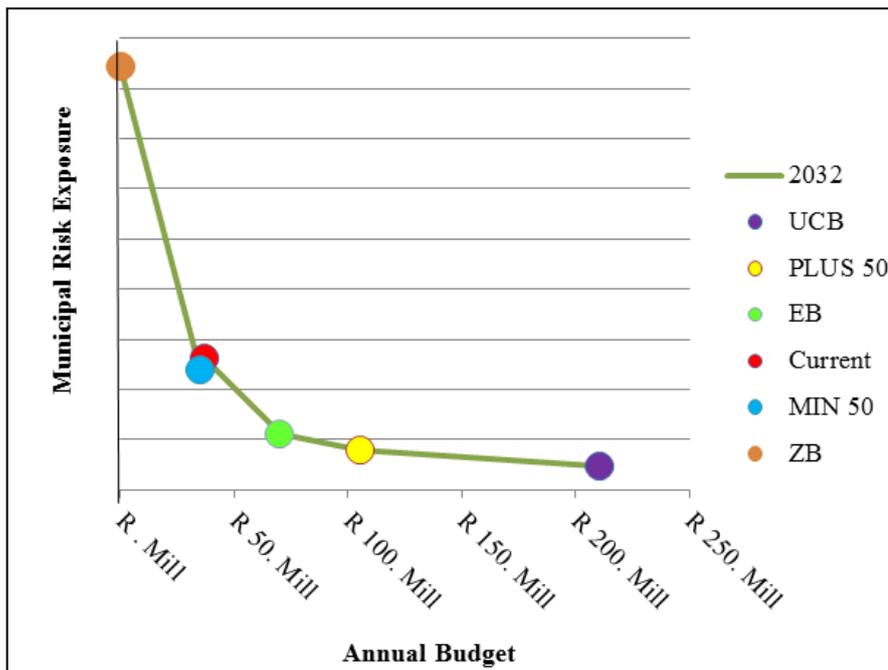Figure 6 shows the impact of different budgets on the long terms risk exposure to the organisation.

Figure 6: Twenty year impact on risk exposure of various budget scenarios

A point of diminishing returns can be identified from these graphs, where additional expenditure has a limited impact on condition improvement or risk reduction. This is represented by the estimated budget (EB). In the case above it is evident that there are benefits that can be acheived by increasing the budget above current levels, especially in terms of risk reduction.

6.3 Typical results from the renewal model

The renewal model produces a variety of reports to be used to assist with the budgeting process on an annual basis.

Using a selected overall budget level, the split in the budgets for the different asset classes (departments) can be calculated on an equitable basis, eliminating the typical approach of "silo budgeting". Because these budgets are based on actual asset condition, optimised renewal treatments and risk exposure to the municipality, they are a useful tool to guide the municipality and remove the "last year plus inflation" approach to budgeting which is sometimes encountered.

Since the portfolio analysis is based on actual asset treatments and renewals, the underlying information is an obvious starting point in the compilation of a renewal project list. An interim step where individual asset renewals are grouped into projects needs to be undertaken in order to programme the renewals in a logical way.

The long term impacts on average asset condition under different budget scenarios can be modelled as illustrated in Figure 7 to illustrate the long term effects of the different budgets on the performance of the asset portfolio.
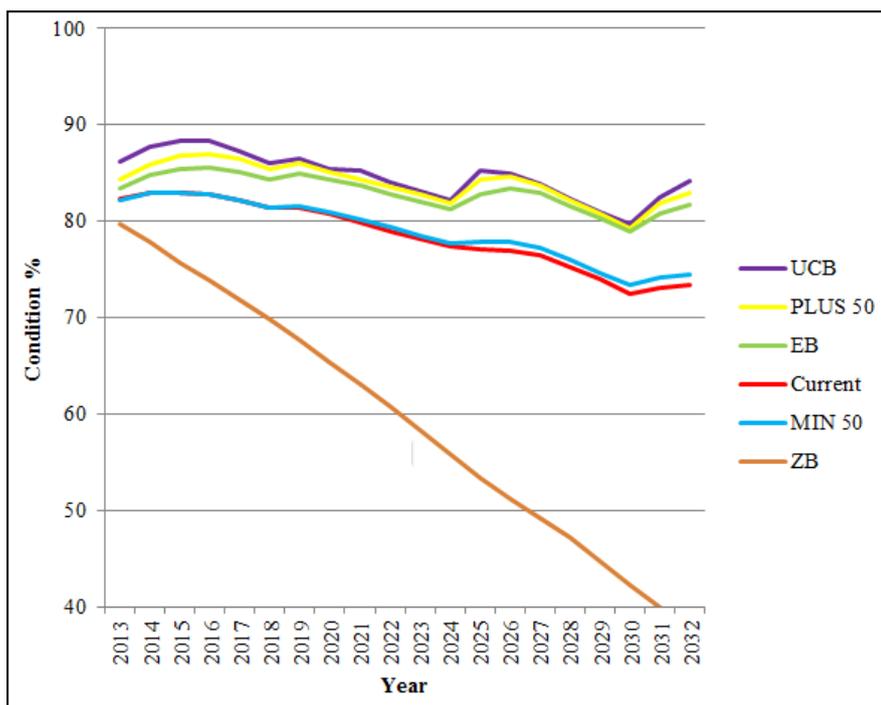

Figure 7: Twenty year impact on asset condition under various budget scenarios

Furthermore, the long term impacts on municipal risk exposure under different budget scenarios can be modelled as shown in Figure 8 to assist with the communication of the long term impact of funding levels on the risk to the municipality.
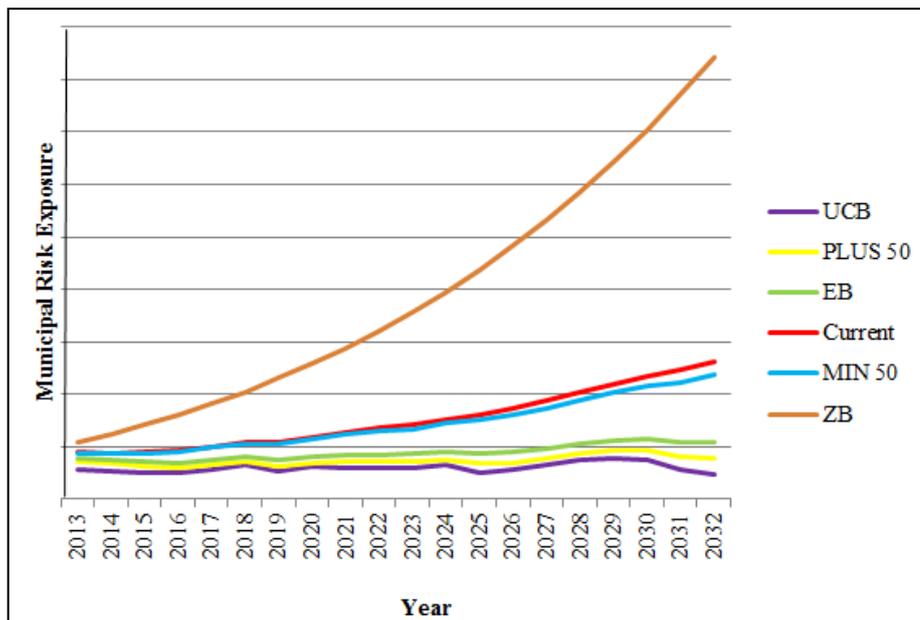
Figure 8: Twenty year impact on municipal risk exposure under various budget scenarios for the water supply service.

7.   CONCLUSION

Drakenstein Municipality has developed a risk-based asset renewal model to aid with the long-term planning of infrastructure investments. This tool has proved valuable in optimising budgets. It is based on the standard financial asset register that all municipalities are required to compile, and can therefore be replicated elsewhere.

In this regard, it is valuable to note some lessons learned and proposed improvements as a conclusion to this paper:

- Ongoing improvements in the accuracy of data in the infrastructure asset register need to remain a continuous process. An accurate asset register cannot be established within a short period, especially with hidden assets such as pipelines. Processes are required where maintenance and operating staff can continuously update the asset data as they work with the assets in the field. In this regard, Drakenstein Municipality has identified and documented all of the different processes that may affect its infrastructure assets, and have implemented steps to capture asset changes as they occur, in order to continuously improve the quality of its asset data.
- Asset condition assessments should be done at regular intervals on critical assets to ensure the risk of failure of these assets can be estimated with confidence.
- A comparison of the theoretical outputs to actual budgets and projects is very useful and insightful. The first iteration of the Asset Portfolio Analysis can be used to establish best-practice benchmarks, but these outputs should also be calibrated in order to accurately reflect actual conditions within the organisation.
- It is important to track the operational and maintenance expenditure to calibrate condition assessments, and to develop and implement formalised maintenance schedules in order to ensure infrastructure assets achieve their full expected lifespan.