PAPER 12

DATA MODELLING AND INFRASTRUCTURE PROFILING IN LOCAL MUNICIPALITIES

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ABSTRACT

With the introduction of MSCOA and GRAP compliance, many municipalities ensure that they have an asset register in place. These registers are compiled in such a way that certain mandatory calculations are possible. Calculations such as depreciation, useful life adjustments and condition grading are obtainable. Some municipalities also have geo-spatial data available for their assets. It has been found that many of the asset registers that are developed function as compliance mechanisms to satisfy audit requirements and result in significant shortfalls in terms of infrastructure profiling and reporting.

Using examples from practice, this paper presents the benefits of adopting appropriate asset data models for compiling asset registers and the implications of having inadequate data models. The impact of a data model on depreciation, useful life and condition grading are discussed, as well as the impact on infrastructure planning and maintenance. Developing and maintaining resilient infrastructure requires an accurate view of existing infrastructure and future needs.

The importance of the involvement of engineers in developing asset data models and assembling asset registers is underscored. Engineers are critical to the development of models that are fit for purpose. The nature of infrastructure asset data modelling requires a knowledge of the component parts of assets and their relationship to each other. It also requires a knowledge of deterioration mechanisms in order to accurately predict remaining useful life and condition grading. Examples from practice are used to demonstrate the advantages of having engineers being intimately involved in developing asset registers and specifically the data models that guide the componentisation of assets.

It is found that the application of appropriate data models can lead to the production of accurate information on asset condition, project cost estimation, maintenance scheduling and accounting practice. The aim of this paper is to motivate engineers to get involved in tasks that are ordinarily left to accountants, but have major implications on the work of engineers. Municipalities that have established good data models are able to develop better asset management plans and have a more solid basis to motivate for increased budgets, while satisfying audit and regulatory requirements.

INTRODUCTION

Municipal audit outcomes receive a lot of attention in the media. Much has been said about the need for financial audit compliance. It is perceived that poor financial management is a major contributor to the lack of municipal service delivery. The government has put in place a number of measures to ensure that municipalities achieve sound financial management. Annual audits are part of the established activities that take place in every municipality. Local government entities are required to comply with Generally Recognised Accounting Practice(GRAP) requirements.

GRAP 17 requires that municipalities establish asset registers. These asset registers are expected to contain certain minimum fields.

It has been found that mere compliance with GRAP does not necessarily result in improved infrastructure planning and service delivery. In other words, it is possible for a municipality to achieve financial compliance and emerge with a "clean" audit with regards to its asset accounting and yet have a register that does not enable it to practice good asset management. Assets are designed, developed and maintained by engineers. It would then follow that engineers should have a significant role to play in the establishment and maintenance of municipal asset registers. This paper will go through the steps involved in developing an asset data model, its application to an asset register and the influence of the final outcome on infrastructure planning and management.

The approach proposed for componentisation is based on the City Infrastructure Delivery Management System Toolkit(National Treasury and I@ Consulting, 2018) afterwards referred to as CIDMS.

Finally, the paper demonstrates that the activity of developing asset registers and their data models can be identified as engineering work according to ECSA's definitions.

ASSET REGISTER DEVELOPMENT STEPS

An asset register is simply a list of the municipalities assets and different columns reflecting the details of that particular asset. Many asset registers are presented in Microsoft Excel and maintained that way. Some municipalities have software that stores the asset data in SQL based databases.

In order to develop a good asset register, practitioners need to consider certain minimum requirements.

The following steps are recommended as a good approach to the development of an asset register.

1. Determine the level of component detail
2. Decide on the condition and asset performance grades to be used
3. Establish estimated useful life of the components
4. Determine the unit rates for each component

Each of these steps will be further elaborated below.

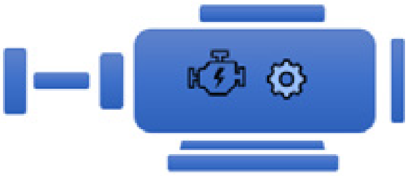
LEVEL OF COMPONENT DETAIL

The most important feature that makes an asset register worth the effort from an asset management perspective is the principles behind componentisation. Componentisation refers to the breaking down of infrastructure assets into their smaller constitutive parts.

The component detail should be guided by the level at which assets can be maintained or refurbished. In one municipality it was found that the practice of the operations staff was to refurbish an entire pump by sending it to a service provider whenever there was a problem. This practice presented a number of challenges as it was not known which components were replaced and what the remaining useful life of the asset would be. The representation of this asset on the asset register would not be reflective of its actual status with regards to condition and financial value.

It was decided that the pumps would be componentised to a level of detail that separated the Pump as a whole from the motor. Each motor would have a life of its own. It was found that some pumps are so small

FIGURE 1: *Componentised Pump*



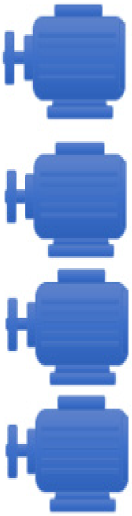


FIGURE 2: *Individual Pumps*

that it was impractical to componentise them further. It was the engineering team that needed to decide at which size a pump would be defined as large enough to need componentisation. It was a technical decision and not merely a managerial or financial choice.

This is an example of the value that an engineer would add to the development of an asset register. Determining the component detail for the pumps requires engineering knowledge. It requires a knowledge of the operation and maintenance of pumps and motors. An accountant or administrative professional may not be able to determine some of these factors without assistance. Yet in many municipalities they are custodians of asset registers and engineers are not involved since asset registers are considered to be a financial reporting tool.

In deciding on the component detail, one would also need to be guided by a hierarchy. For infrastructure assets the following hierarchy is suggested (CIDMS):

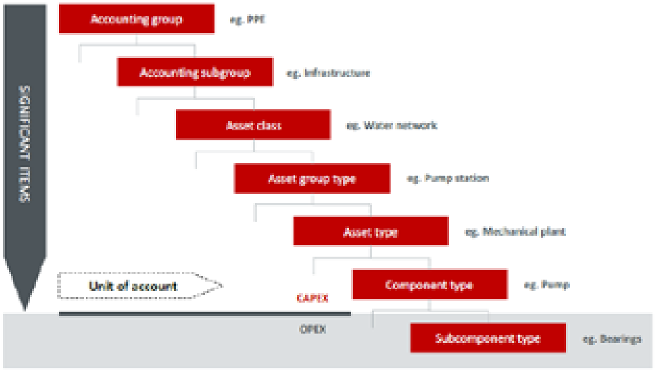


FIGURE 3: *Asset Hierarchy (Source: CIDMS)*

Engineers are key role players in defining which asset types specific infrastructure components belong to. Inappropriate classification can result in incorrect reporting and funding allocation for maintenance and capital investment.

Another example of the effects of using an insufficient level of componentisation is presented in the case of a fire station. A certain municipality reported its fire station as a complete unit on the asset register. This means, that the condition of the facility was reported on a facility level. It was found that there was a problem with the pipes on the facility and the auditors required that the facility should be impaired. The financial impact of such an impairment is significant and affects the municipality's financial reporting and status.

The municipality used the asset hierarchy in Table 1, we will refer to this as hierarchy A.

A more practical hierarchy would include more components as part of the facility. The hierarchy for these would look more like the table 2 and we will call this hierarchy B.

Hierarchy B allows for more accurate reporting on whichever level the municipality chooses. It is particularly useful for reporting at asset group level. The benefit however goes beyond reporting.

The componentised level allows the municipal engineer to define condition grades that are specific to different asset types.

IMPACT ON DEPRECIATION, CONDITION AND USEFUL LIFE

Consider the facility with the hierarchy defined in hierarchy A. The replacement value of the facility was based on an estimate related to the size of the facility. Simply size(m^2) x rate/m^2. The rate was obtained from the AECOM building and pricing guide.

For a facility that uses hierarchy B, the cost of the facility is the sum of individual unit rates for the different components.

This approach enables the municipality to request a maintenance budget that is realistic and addresses the specific components in need of maintenance. Further to that, as discussed in CIDMS, there are a number of benefits that emerge from componentising assets.

The most significant of these are:

1. Capex and Opex can be more accurately defined
2. Lifecycle renewal needs are easier to plan for each facility and facility type
3. The review of the useful life of the components in a facility become more meaningful and accurate.

The impact on depreciation is illustrated in the figures below from CIDMS. It can be seen that Hierarchy A would produce a depreciation that is not consistent with the reality of what is happening at the facility.

TABLE 1: *Hierarchy A with single component for a facility*

Accounting Group	Asset Category	Asset Sub Category	Asset Group	Asset Type	Component Type
Property, Plant and Equipment	Community assets	Community facilities	Fire / ambulance stations	Buildings	Building - complete installation

TABLE 2: *Hierarchy B with componentised facility*

Accounting Group	Asset Category	Asset Sub Category	Asset Group	Asset Type	Component Type
Property, Plant and Equipment	Community assets	Community facilities	Fire / ambulance stations	External facilities	Carport
Property, Plant and Equipment	Community assets	Community facilities	Fire / ambulance stations	Land	Land
Property, Plant and Equipment	Community assets	Community facilities	Fire / ambulance stations	External facilities	Perimeter protection
Property, Plant and Equipment	Community assets	Community facilities	Fire / ambulance stations	Pavements	Road surface
Property, Plant and Equipment	Community assets	Community facilities	Fire / ambulance stations	Pipe work	Plumbing
Property, Plant and Equipment	Community assets	Community facilities	Fire / ambulance stations	Brickwork	Walls
Property, Plant and Equipment	Community assets	Community facilities	Fire / ambulance stations	Civil structures	Floor
Property, Plant and Equipment	Community assets	Community facilities	Fire / ambulance stations	Civil structures	Roof

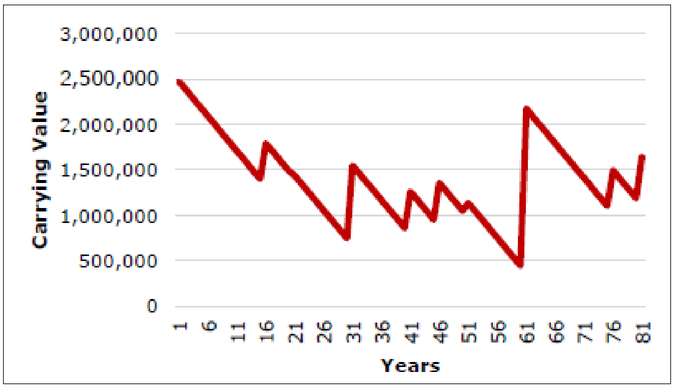


FIGURE 4: *Depreciation of a componentised Facility(Source: CIDMS)*

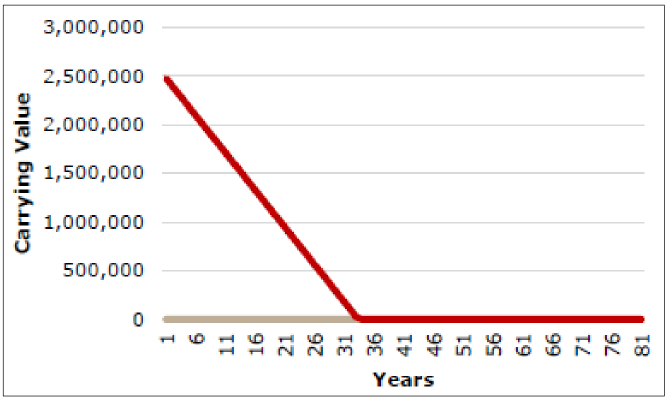


FIGURE 5: *Depreciation of a facility represented as a single asset (Source CIDMS)*

INFRASTRUCTURE PROFILING

When assets are broken down into components the maintenance and capital planning and scheduling can be more detailed and take on a wholistic view of the organisation's assets. The figure below presents the all the wastewater treatment assets of a metropolitan municipality for the year 21/22. It can be seen that the treatment works have bioreactors that need attention within the 10-year planning period. These bioreactors represented a noticeable proportion of the total replacement cost of the treatment works of the entire city.

Due to this level of componentisation, the municipality is able to prioritise the maintenance of those specific assets in the 10-year period and budget for the rest of the assets appropriately. The focus is shifted from reactive maintenance to planned and routine maintenance. An engineer is best suited to decide how to componentise a waste water treatment facility appropriately and define its functional areas.

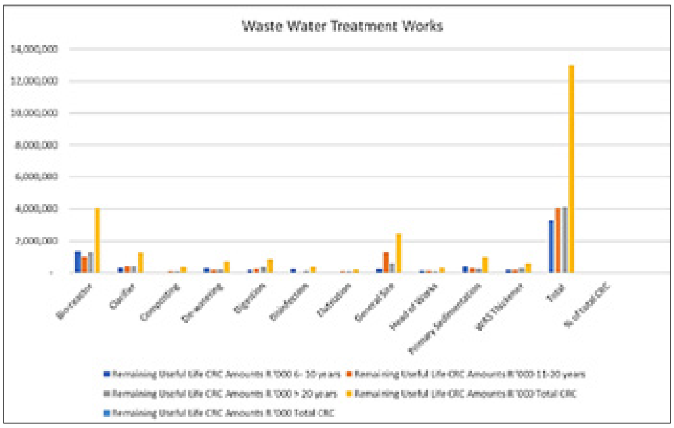
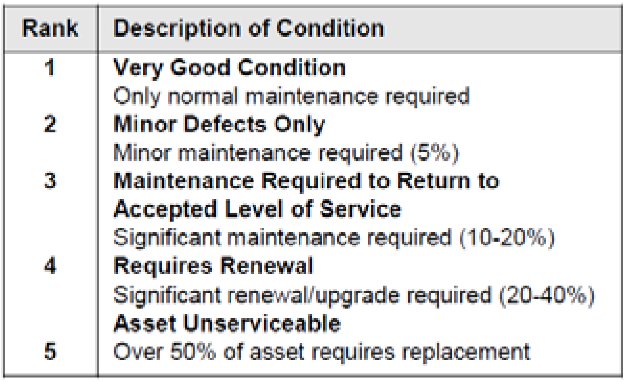


FIGURE 6: *Remaining useful life of components for metropolitan Waste Water Treatments Works for all facilities*

DETERMINE CONDITION AND ASSET PERFORMANCE GRADES TO BE USED

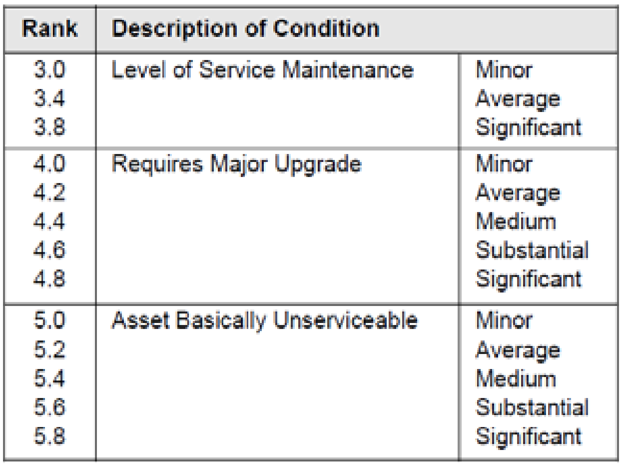
ondition data is used to determine a organisation's infrastructure capital and maintenance requirements. Condition data can be very useful in timing and optimising infrastructure expenditure.

There are numerous condition grading scales that can be used on infrastruture projects. The choice of condition grading is determined by the level of complexity that is desired and that would perhaps bring more value for money in terms of the municipality's available resources. The Institute of Public Works Engineering Australia (IPWEA, 2010) gives examples of the following grading scales:



Rank	Description of Condition
1	**Very Good Condition** Only normal maintenance required
2	**Minor Defects Only** Minor maintenance required (5%)
3	**Maintenance Required to Return to Accepted Level of Service** Significant maintenance required (10-20%)
4	**Requires Renewal** Significant renewal/upgrade required (20-40%)
5	**Asset Unserviceable** Over 50% of asset requires replacement

FIGURE 7*: Condition grading system for a simple approach(IPWEA)*



Rank	Description of Condition	
3.0 3.4 3.8	Level of Service Maintenance	Minor Average Significant
4.0 4.2 4.4 4.6 4.8	Requires Major Upgrade	Minor Average Medium Substantial Significant
5.0 5.2 5.4 5.6 5.8	Asset Basically Unserviceable	Minor Average Medium Substantial Significant

FIGURE 8: *Condition grading system for an intermediate approach(IPWEA)*

The choice of grading scale is a technical decision that would require the knowledge of the deterioration mechanisms and and the most important failure modes of the assets under consideration.

For asset management purposes, the condition grading should be augmented by other criteria such as performance, utilisation and criticality. Each of these measures should have a grading scale. The following measures are recommended by IPWEA:

- Business and Technical Performance
- Capacity or Utilisation
- Functionality/Suitability

The engineering professional should select the metrics that are appropriate for the municipality. The choice will affect future condition assessments and the deliverables that will be required from experts who are appointed to conduct annual asset "verification", which involves a condition assessment.

ESTABLISH ESTIMATED USEFUL LIFE OF THE COMPONENTS

The useful lives of assets is an estimate that is often based on manufacuturer's specification or industry norms. Various assets such as pumps and motors have useful lives that can be based on make, model and capacity. Other assets such as civil infrasturcture would be based on the construction materials used and their exposure or loading conditions. Concrete deterioration presents a good example. Alexander and Beushausen (2019) and others have demonstrated that service life of concrete structures should be adjusted based on local conditions. There are equations governing the service life of concrete based on carbonation depth and other deterioration mechanisms. These equeations can be adapted to local conditions in order to predict the estimated useful life and to adjust it yearly based on the deterioration curves derived.

Accounting standards require that the useful lives should be re-evaluated annualy and a remaining useful life should be established. It is vital that the remaining useful life is based on expert opinion and has a rational basis.

DETERMINE THE UNIT RATES FOR EACH COMPONENT

The unit rates various assets will be based on the replacement costs of the assets. The rates need to take into account the nature of the material being used. The design and construction methods required to install or construct components. The overhead costs involved as well as the municipality's internal costs.

Such information requires a knowledge of construction methods, equipment, mateirials and rates build up. Accurate unit rates lead to more effecient municipal budgeting and to financially viable projects.

An example of unit rate breakdown is given in Figure 9. The example presents the construction costs only, but additional costs need to be considered such as a percentage of the preliminary and general costs as well as design fees, environmental impact assessments and escalations, if any, on the project. Cost estimating is not an exact science and there needs to be a consideration of variances in estimates based on the assumption that had to be made and the economic conditions at the time of estimation.

IDENTIFICATION OF ENGINEERING WORK

It has been demonstrated so far that much of what goes into an asset register has a direct bearing on the work that will be planned for engineers. This article takes it a step further and argues that a lot of what needs to be done to assemble a good asset register should be identified as engineering work.

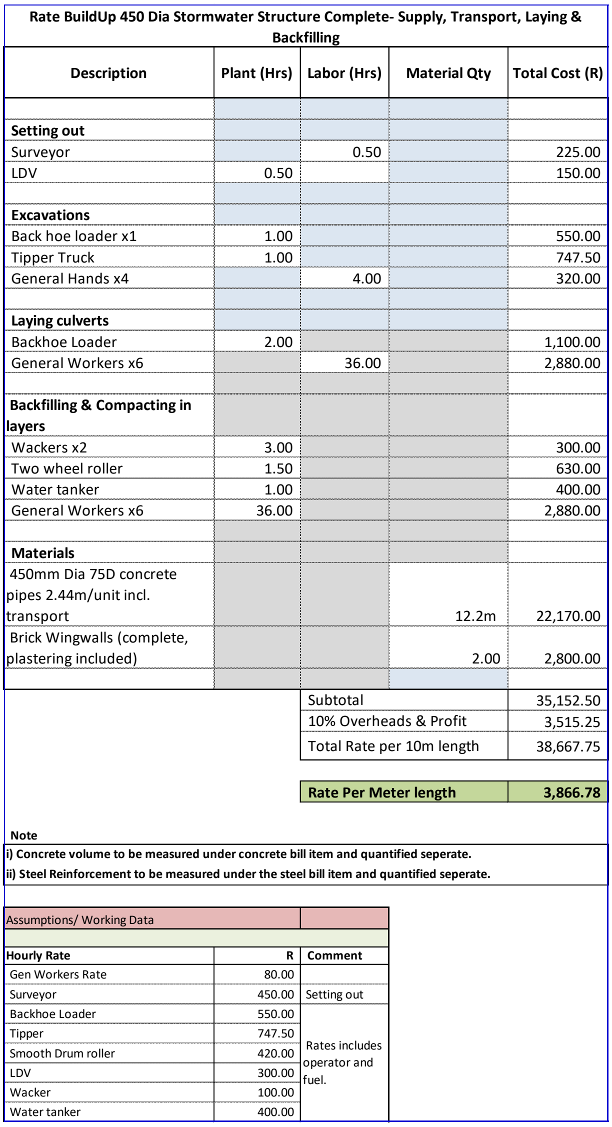
It can be demonstrated that some of the key activities involved in establishing and maintaining an asset register meet the outcomes for registration as a professional engineer.

Engineering work is defined as:

"The process of applying engineering and scientific principles, concepts, contextual and engineering knowledge to the research, planning, design, implementation and management of work in both the natural and the built environments." (ECSA, 2022)

According to the Engineering Council of South Arica an engineering problem is a problem that is amenable to analysis and solution using engineering sciences and methods. Engineering sciences are defined as a body of knowledge based on the natural sciences and using a mathematical formulation "where necessary" …to solve problems and provide a knowledge base for engineering specialisation.

ECSA does not define what the "natural sciences" are but the Merriam webster definition seems to consistent with most definitions in literature. The natural sciences are said to be sciences such as Physics, chemistry or biology) some definitions include geology.



Rate BuildUp 450 Dia Stormwater Structure Complete- Supply, Transport, Laying & Backfilling

Description	Plant (Hrs)	Labor (Hrs)	Material Qty	Total Cost (R)
Setting out				
Surveyor		0.50		225.00
LDV	0.50			150.00
Excavations				
Back hoe loader x1	1.00			550.00
Tipper Truck	1.00			747.50
General Hands x4		4.00		320.00
Laying culverts				
Backhoe Loader	2.00			1,100.00
General Workers x6		36.00		2,880.00
Backfilling & Compacting in layers				
Wackers x2	3.00			300.00
Two wheel roller	1.50			630.00
Water tanker	1.00			400.00
General Workers x6	36.00			2,880.00
Materials				
450mm Dia 75D concrete pipes 2.44m/unit incl. transport			12.2m	22,170.00
Brick Wingwalls (complete, plastering included)			2.00	2,800.00
		Subtotal		35,152.50
		10% Overheads & Profit		3,515.25
		Total Rate per 10m length		38,667.75
		Rate Per Meter length		**3,866.78**

Note

i) Concrete volume to be measured under concrete bill item and quantified seperate.

ii) Steel Reinforcement to be measured under the steel bill item and quantified seperate.

Assumptions/ Working Data		
Hourly Rate	**R**	**Comment**
Gen Workers Rate	80.00	
Surveyor	450.00	Setting out
Backhoe Loader	550.00	Rates includes operator and fuel.
Tipper	747.50	
Smooth Drum roller	420.00	
LDV	300.00	
Wacker	100.00	
Water tanker	400.00	

FIGURE 9: *Example of unit rate build up for a stormwater pipe*

In developing an asset data model, as a first step the engineer needs to determine which level of componentisation best represents the assets essential features. The "essentiality" of the components is based on its value, size and criticality to the operation of the parent asset, to which it is a component. Making this determination requires an understanding of the factors that influence the performance and operation of the component. This is the work of engineers, and it requires a knowledge of the physics and operating environment of the asset.

Group A outcomes for ECSA registration deals with engineering problem solving. The engineer is required to identify, analyse and solve complex engineering problems.

The development and maintenance of asset registers can be defined as a complex engineering problem. The classification of the exercise as an engineering problem was discussed above. What about the complexity? According to the ECSA competency standards a complex engineering problem can be one that is ill-posed, under or over specified and requires identification and refinement.

In developing an asset register the problem is ill posed for a number of reasons. The development of an asset register requires the engineer to address the following problems:

1. What level of component detail is appropriate for a particular asset?

2. To which asset category should the asset be allocated? This can be influenced by the spatial segmentation of a service.
3. What is the expected useful life of the asset?
4. What depreciation method should be recommended that more favourably aligns with the deterioration mechanisms of the asset?
5. Which unit rates are most appropriate for the construction methods involved in creating the asset?
6. What criteria will be used to determine the performance measures and grading of particular assets?

The answers to the questions above will require the solving of sub-problems such as deterioration mechanisms, construction methodology, material characterisation and may also require the utilisation or development of geographical information systems.

In addition to the requirements above a complex engineering problem can also be defined as involving wide ranging and or conflicting issues such as technical and engineering issues and interested and affected parties. The problem is wide ranging and has impact beyond the local scenario because the budgets that are received come from national treasury and perhaps other funding agencies. The service delivery challenges, though local may often impact bulk infrastructure that is provided by a provincial or national agency.

The development of an asset register with its associated data model and hierarchy involves wide ranging and or conflicting issues. The engineer has to balance the requirements of accounting practice, the budgetary and operational restrictions of municipalities and the capacity of the municipality to maintain the asset register and data at specific level of detail.

The designing and development of an asset register and its asset data model and hierarchy meets the requirements of outcome 2 of the ECSA requirements because an asset register solves a planning and maintenance challenge for engineering infrastructure.

CONCLUSION

In conclusion it has been demonstrated that the development of an asset data model and an asset register requires certain decisions to be taken that require engineering knowledge and judgement. These decisions are influenced by the nature of their assets and their operating environment and the ability of the personnel at the municipality to maintain that data at a specific level.

It has also been shown that the development of an asset data model has a significant impact on the profiling of assets and maintenance and capital investment planning. These activities are easily identified as engineering work. Some of them can be accurately described as meeting the criteria for complex engineering problems.

It is imperative that engineers are involved in the work of developing asset registers as this ultimately has a service delivery impact and a bearing on the quality of lives of individuals and society at large.

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