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Building condition assessment: A performance evaluation tool towards sustainable asset management

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ABSTRACT

Most condition assessments are mere snapshots in time that end up gathering dust on a shelf because the value of consistent condition assessments is generally underrated and seldom fully utilised. Condition assessments should be the basis for management and maintenance decisions in the built environment towards sustainable construction.

Subsequent to the 1995 National Health Facilities Audit of hospitals in South Africa, condition assessments have evolved into a technology that adds a new dimension to strategic management and maintenance of buildings and related infrastructure. A five-point colour-coded rating system has been developed and refined through experience gained during the initial and follow-up assessments and sustained research and development. Value addition include converting condition assessments into condition-based maintenance budgets, eradication of backlog maintenance, performance assessment of effectiveness of maintenance/preservation interventions, and service life prediction.

This paper proposes a condition assessment system and process with examples of value addition towards sustainable construction.

Keywords: Condition Assessment, Backlog Eradication, Maintenance Budgets, Performance Tracking, Service Life Prediction.

1. INTRODUCTION

In our quest to meet "the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Report, 1987), consistent and continuous performance measurement of building materials and construction techniques is crucial to prevent the creation of an unsustainable artificial environment at the expense of our natural environment. Large volumes of natural and energy resources, many scarce and/or non-renewable, are consumed and waste generated by the construction sector during the life cycle of buildings, with a substantial impact on the environment. Sustainable construction is seen as an initiative by the building industry in response to this environmental impact towards achieving sustainable development (Agenda 21).

Building performance can be measured in many ways, the most common being condition. The building's condition "gives a measure of the effectiveness of current maintenance programmes because it determines the remaining useful life of components or systems and compares it with the full economic life expected, given good maintenance. These estimates become the foundation for establishing both the extent of deferred maintenance and the required maintenance and repair programmes." (NRCC, 1993). According to Varnier (2001) a condition assessment survey (CAS) "produces a benchmark for comparison, not only between different assets, but also for the same asset at different times."

Condition however changes over time as the physical and operational environments impact on the building, and regular, accurate and consistent condition assessments on a continuous basis are therefore required to update current information, provide for maintenance work done subsequent to the previous condition assessments and capture any significant changes in condition before they can impact on the performance of the building. Most condition assessments are however mere snapshots in time that end up gathering dust on a shelf because the value of consistent condition assessments is generally underrated and seldom fully utilised.

Central to a sustainable built environment is service life prediction, which depends on the ability to quantify the degradation rate of building fabric and components. Change in condition over time is a commonly accepted method to evaluate degradation (Morcous *et al,* 2003; CIB295, 2004; Lounis *et al,* 1998; and Madanat *et al,* 1995). According to CIB294 "an ability to understand what influences durability and service life of materials, components and structures, to develop more durable materials and components and to establish reliable methods for testing of durability and for prediction of the service life" could contribute towards addressing environmental problems in the context of sustainable development.

This paper proposes a condition assessment system and process with examples of condition assessment value addition towards sustainable construction.

1. CONDITION ASSESSMENT SYSTEM AND PROCESS

The Queensland Department of Public Works in Australia (1999) defines condition assessment as "the technical assessment of the physical condition of an asset, using a systematic method designed to produce consistent, relevant and useful information." ... "The condition assessment process for built assets should, as a minimum, rate asset condition, determine the risks associated with letting an asset remain in that condition, and identify maintenance work needed to restore to and retain an asset in its required condition."

Maintenance can only be effectively managed if the maintenance demand is properly quantified, and Then (1995) pointed out that "the quantification of maintenance demand is governed by the need to define the gap between current condition and the desired condition". The desired condition or condition standard can and should be clearly defined.

One of the three objectives for Agenda 21 for Sustainable Construction is "to create a global framework and terminology." Central to the achievement of this objective is the development and consistent interpretation of common terminology, especially for performance measurement, such as condition assessment ratings. A quick scan of international practice (DEE, 1999; DPW Queensland, 1999; IRC, 1993: Lounis et al, 1998; Madanat et al, 1995; and Morcous et al, 2003) reveals a great number of rating systems and interpretations of condition assessments. With the exception of roads and bridges, historical performance data in the built environment is scarce and inconsistent due to a number of reasons. One being the lack of common condition assessment rating systems, which complicates benchmarking and data mining unnecessarily.

1.1. System

Subsequent to the 1995 National Health Facilities Audit of hospitals in South Africa, condition assessments have evolved into a technology that adds a new dimension to strategic management and maintenance of buildings and related infrastructure. A five-point colour-coded rating system has been developed and refined through experience gained during the initial and follow-up assessments and sustained research and development.

A five-point scale proved to be the most effective. A three-point scale is too coarse for reliable results, while a seven-point or more scale is too fine and difficult for assessment staff to interpret consistently.

Colour adds another dimension to reporting by making reports more user-friendly and accessible to non-technical users of the information. Colour also makes graphic reports more effective and easier to interpret.

In Table 1 below, the proposed five-point colour-coded condition assessment rating is shown.

Table 1: Condition Assessment Ratings

CONDITION RATING	CONDITION	ACTION REQ'D	DESCRIPTION
5	Very Good	Planned Preventative Maintenance	The component or building is either new or has recently been maintained, does not exhibit any signs of deterioration
4	Good	Condition-based Maintenance	The component or building exhibits superficial wear and tear, minor defects, minor signs of deterioration to surface finishes and requires maintenance/servicing. It can be reinstated with routine scheduled or unscheduled maintenance/servicing.
3	Fair	Repairs	Significant sections or component require repair, usually by a specialist. The component or building has been subjected to abnormal use or abuse, and its poor state of repair is beginning to affect surrounding elements. Backlog maintenance work exists.
2	Bad	Rehabilitation	Substantial sections or component have deteriorated badly,suffered structual damage or require renovations. There is a serious risk of imminent failure. The state of repair has a substantial impact on surrounding elements or creates a potential health or safety risk.
1	Very Bad	Replacement	The component or building has failed, is not operational or deteriorated to the extent that does not justify repairs, but should rather be replaced. The condition of the element actively contributes to the degradation of surrounding elements or creates a safety, health or life risk.

Similar five-point colour-coded ratings have been developed for other performance evaluation criteria, such as functional suitability and risk. The above condition assessment ratings are also linked to the related maintenance actions and types as shown in Table 2 below.

Table 2: Condition Ratings and Related Maintenance Actions

RATING	CONDITION	ACTION REQUIRED	"MAINTENANCE" TYPE
5	Very Good	Preventative Maintenance	Normal Maintenance
4	Good	Condition-based Maintenance	
3	Fair	Repairs	"Backlog" Maintenance
2	Bad	Rehabilitation	
1	Very Bad	Replacement	

1.2. Condition Assessment Process

Condition rating, as illustrated in Table 1 above, is an often-misunderstood concept. The condition profile of a component, that is the percentage of the component in various condition categories, will change over time. In other words, different portions of a component could be in different conditions at the same point in time. Likewise, the extent of required maintenance actions would range from preventative maintenance to condition-based maintenance, repairs, rehabilitation and eventually replacement, increasing in severity and cost. The correct way is to rate each condition category as illustrated in Figure 1 below. In the example a single score would result in an average condition of 4, while the actual average condition is 3.5. By scoring each condition category small portions of a component in a bad condition (e.g. 10% in Condition 1) is not lost in the process.

CONDITION	Very Good	Good	Fair	Bad	Very Bad	
ACTION REQ'D	Planned Preventative Maintenance	Condition-based Maintenance	Major Repairs	Rehabilitation	Replacement	
CONDITION RATING	5	4	3	2	1	
ASSESSMENT RATING	a%	b%	c%	d%	e%	= 100%
EXAMPLE	0%	80%	0%	10%	10%	

Figure 1: Field Assessment of Condition

2. APPLICATIONS, REPORTING AND VALUE ADDITION

Due to the high cost associated with condition assessments (Kleiner, 2001) resulting mainly from the need for physical site visits, the assessment ratings and process should be designed to make value addition possible. Collecting data is only part of the process, how you use and interpret the data is what counts. The following paragraphs provide illustrations based on some case studies of typical applications and examples of value addition.

2.1. Condition-based maintenance budgets

The added advantage of the proposed condition rating is illustrated in Figure 2 below. The condition profile not only gives an insight in the actual condition of the component or building, but it is essential for maintenance budget calculations, because as the condition deteriorates the cost of the maintenance action increases. In Figure 2, the maintenance of the 50% in conditions 5, 4 and 3 will cost 4 times less than the 50% in conditions 2 and 1.

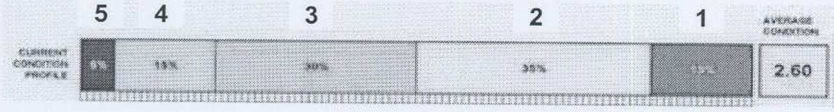

Figure 2: Typical Condition Profile

Maintenance and backlogs funding requirements are determined by the current condition offset against the current construction cost for a new facility, i.e. the amount required to bring the existing facility up to an 'as new' condition. The maximum provision is current construction cost plus, in the case of replacement, possible disposal or demolition costs.

Condition assessments are conducted at element or component level and the maintenance, rehabilitation and replacement costs associated with the maintenance actions related to the relevant condition ratings are calculated as illustrated in Table 3 below. The suitability of the element or component, the cause or reason for the current condition and the associated risk are also provided.

Table 3: Condition-based Maintenance Budget – Element Level

Building Number	Name of Building	Element Group	Estimated Current Construction Cost (1st Qtr 2006)	Weighted Average Condition	Condition 5 Preventive Maintenance	Condition 4 Condition-based Maintenance	Condition 3 Repair	Condition 2 Rehabilitation	Condition 1 Replacement	Suitability	Cause/ Reason	Risk Rating	MAINTENANCE BUDGET REQUIREMENT	REHABILITATION BUDGET REQUIREMENT	REPLACEMENT BUDGET REQUIREMENT	TOTAL BUDGET REQUIREMENT
B002	ADMINISTRATION	SPACE FABRIC: Floors and floor finishes: Internal floors and floor finishes	R 46,271	3.70	0	90	0	0	10	4.00	D	1.50	R 2,198	R -	R 5,090	R 7,288
B002	ADMINISTRATION	SPACE FABRIC: Plumbing	R 5,162	3.30	0	70	10	0	20	4.00	D	1.50	R 219	R 129	R 1,136	R 1,484
B004	GENERAL WARDS	SPACE FABRIC: Floors and floor finishes: Internal floors and floor finishes	R 456,827	3.10	0	70	0	0	30	4.00	D	1.50	R 15,532	R -	R 150,753	R 166,285
B004	GENERAL WARDS	SPACE FABRIC: Plumbing	R 67,954	3.90	0	90	10	0	0	4.00	D	2.83	R 2,582	R 1,359	R -	R 3,941
B004	GENERAL WARDS	SPACE MECHANICAL: Airconditioning and ventilation: Air conditioning: High wall split units	R 3,103	1.00	0	0	0	0	100	2.00	D	1.00	R 78	R -	R 3,413	R 3,491
B005	KITCHEN / LAUNDRY/ DINNING	BUILDING FABRIC: Doors: External doors	R 34,148	2.80	0	40	30	0	30	4.00	D	1.83	R 956	R 2,049	R 11,269	R 14,274
B005	KITCHEN / LAUNDRY/ DINNING	BUILDING FABRIC: Windows	R 73,670	3.85	0	95	0	0	5	4.00	D	2.83	R 2,873	R -	R 4,052	R 6,925
B005	KITCHEN / LAUNDRY/ DINNING	SPACE FABRIC: Ceilings and ceiling finishes: Internal ceilings and ceiling finishes	R 70,168	3.70	0	80	15	0	5	4.00	D	2.33	R 2,526	R 2,105	R 3,859	R 8,490
B005	KITCHEN / LAUNDRY/ DINNING	SPACE FABRIC: Floors and floor finishes: Internal floors and floor finishes	R 313,622	3.70	0	80	15	0	5	4.00	D	2.33	R 11,290	R 9,409	R 17,249	R 37,948
B005	KITCHEN / LAUNDRY/ DINNING	SPACE FABRIC: Plumbing	R 46,652	3.75	0	85	10	0	5	4.00	D	2.33	R 1,726	R 933	R 2,566	R 5,225
B005	KITCHEN / LAUNDRY/ DINNING	SPACE MECHANICAL: Airconditioning and ventilation: Air conditioning: High wall split units	R 29,406	5.00	100	0	0	0	0	4.00	N	2.83	R 588	R -	R -	R 588
B006	MORTUARY / STORE	BUILDING FABRIC: Windows	R 26,878	3.75	0	85	10	0	5	4.00	D	2.33	R 994	R 538	R 1,478	R 3,010
B006	MORTUARY / STORE	SPACE ELECTRICAL: Power generation: Automatic mains failure diesel generators	R 317,189	4.00	0	100	0	0	0	4.00	N	1.83	R 12,688	R -	R -	R 12,688

Table 4: Condition-based Maintenance Budget – Building Level

Building Number	Name of Building	Estimated Current Construction Cost (1st Qtr 2006)	Area (m^2)	Weighted Average Condition	CONDITION PROFILE: Condition 5 Preventive Maintenance	Condition 4 Condition-based Maintenance	Condition 3 Repair	Condition 2 Rehabilitation	Condition 1 Replacement	Suitability	Risk Rating	MAINTENANCE BUDGET REQUIREMENT	REHABILITATION BUDGET REQUIREMENT	REPLACEMENT BUDGET REQUIREMENT	TOTAL BUDGET REQUIREMENT
B002	ADMINISTRATION	R 418,538	114.6	4.02	8.18	89.64	0.12	0.00	2.06	4.06	2.26	R 14,743	R 258	R 9,472	R 24,474
B004	GENERAL WARDS	R 3,169,093	858.1	3.86	0.00	95.21	0.37	0.00	4.42	4.00	2.76	R 129,172	R 3,696	R 154,166	R 287,035
B008	CONSULTATION / LAB/ RECEPTION	R 3,943,772	775.9	3.97	0.62	97.80	0.44	0.05	1.09	3.99	2.30	R 141,543	R 6,368	R 47,263	R 195,175
B010	DOCTORS QUARTERS	R 3,670,076	1101.0	4.89	91.48	7.19	0.00	1.33	0.00	4.00	2.26	R 73,474	R 24,339	R -	R 97,813
B014	MATERNITY	R 4,910,565	1239.0	3.88	0.00	95.38	0.30	1.12	3.20	4.07	2.75	R 180,944	R 34,855	R 172,586	R 388,385
B021	CARPORT	R 3,194	25.1	1.00	0.00	0.00	0.00	0.00	100	3.63	1.50	R 86	R -	R 3,514	R 3,599
TOTAL FACILITY		R 33,395,122	8,102	4.11	17.25	79.80	1.04	0.45	1.46	4.04	2.66	R 1,050,000	R 147,356	R 536,605	R 1,733,961

In Table 4 above, the elements for each building are rolled-up to provide the budgets at building level, which is then rolled-up further to provide the required budgets and associated condition profile at facility level.

The cost of maintenance work increases as the condition deteriorates, and this is the primary reason for the decaying built environment. Because the demand for action is much higher in the case of backlog maintenance, available funds are first allocated to these activities and due to the high cost all the available funds disappear in backlog maintenance activities, with very little left for planned preventative maintenance. The consequences of this are increased backlog maintenance (portions in Condition 5 and 4 slipping towards 3, 2 and 1) and reduced service life of existing buildings. The solution to this problem is to allocate available funds (R1,027,421) in the same ratio as the required budget for maintenance (60.6%) : rehabilitation (8.5%) : replacement (30.9%) as illustrated in Table 5 below, thus ensuring that funding is available for planned preventative maintenance.

Table 5: Budget Allocation

	MAINTENANCE BUDGET REQUIREMENT	REHABILITATION BUDGET REQUIREMENT	REPLACEMENT BUDGET REQUIREMENT	TOTAL BUDGET REQUIREMENT
TOTAL FACILITY	**R 1,050,000**	**R 147,356**	**R 536,605**	**R 1,733,961**
Budget Required	**60.6%**	**8.5%**	**30.9%**	**100%**
Fund Allocation	**R 622,155**	**R 87,313**	**R 317,954**	**R 1,027,421**

2.2. Valuation of depreciated replacement cost for financial reporting

International Public Sector Accounting Standard (IPSAS) 17 prescribe the use of depreciated replacement cost for financial reporting purposes and this value is reflected in the asset register. The depreciated replacement cost is defined as "the current cost of reproduction or replacement of an asset less deductions for physical deterioration and all relevant forms of obsolescence and optimisation." (IVS GN No 8, 2005). In the calculation of the depreciated replacement cost, the Valuer shall "assess the current gross replacement cost of the asset … and deduct allowances for physical deterioration, functional or technical obsolescence, and economic or external obsolescence." The deduction of the condition-based maintenance, rehabilitation and replacement budgets from the current gross replacement cost provides for physical deterioration. In Table 4 above, the Estimated Current Construction Cost or current gross replacement cost of the total facility amounts to R33,395,122, while the total budget required to address the physical deterioration is R1,733,961, giving us a depreciated replacement cost of R31,661,161 minus allowances for functional or technical obsolescence, and economic or external obsolescence.

2.3. Performance evaluation and tracking

In Figure 3 below, condition profiles for two condition assessments of a rural hospital in South Africa are shown. The length of the bars represents the total floor area in square metres at the time of the assessment and the coloured areas represent the floor area in the five condition categories.

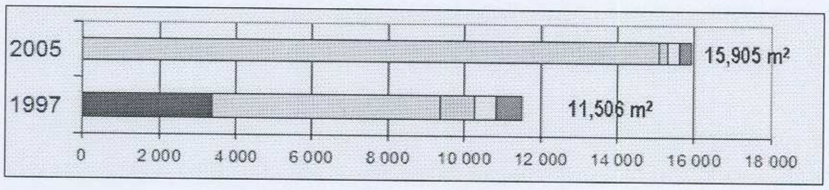

Figure 3: Changes in condition profiles between subsequent assessments

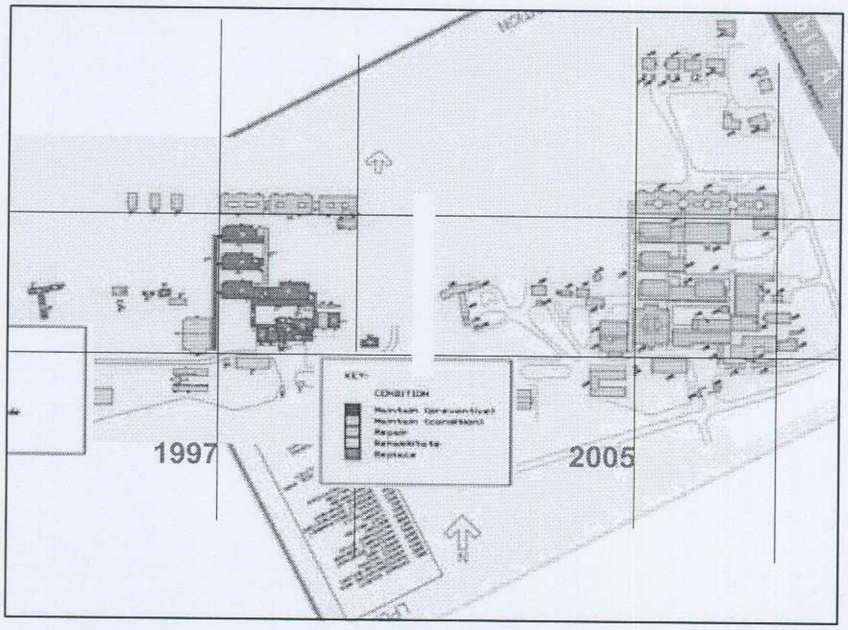

Figure 4: Colour-coded site plans showing average condition of buildings

Over the eight year period between 1997 and 2005 an additional 4,399 m^2 floor space was added (needs-backlog eradication), and most of maintenance backlog was eradicated, as can be seen by the decrease in the three areas on the right-hand end of the bar. The disappearance of the dark colour (dark blue) on the left-hand end is an indication that no preventative maintenance was done due to the focus on backlog (needs and maintenance) eradication. This is a clear illustration of the consequences of not doing preventative maintenance. With the addition of 4,399 m^2 floor space one would expect an increase in the percentage in Condition 5 (dark blue). The average condition has changed from 3.94 in 1997 to 3.89 in 2005. In Figure 4 above the effects of the backlog eradication, as well as the use of colour in graphical reports, are illustrated. Please note that the colour-coding was changed between the assessments.

During 1995 the South African National Department of Health commissioned the CSIR to conduct a National Health Facilities Audit (NHFA). The condition assessments of a large academic hospital conducted during the 1995 NHFA are shown on the left-hand side in Figure 5 below in the format of a Condition Matrix. The columns represent the floors and departments in each building, while the rows represent the services or elements on each floor. Each element on each floor is coloured according to the assessed condition rating. The four dark-coloured rows indicate Condition 2 that requires replacement or upgrading. These dark-coloured rows represent the fire services, steam reticulation, heating and air-conditioning in the particular hospital.

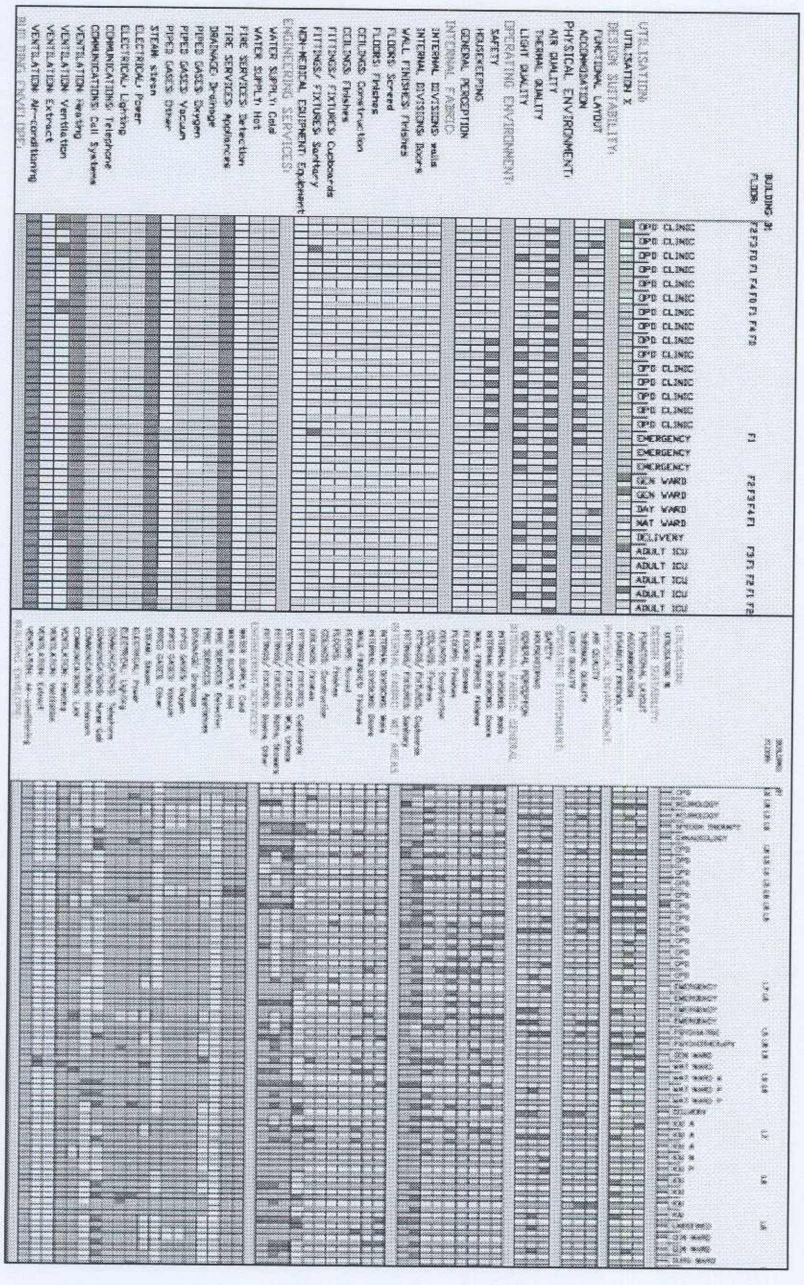

Figure 5: Condition Assessment Matrices (1995 NHF Audit left & 1999 Audit right)

A subsequent audit, which provided for additional components, was conducted during 1999 as shown on the right-hand side in Figure 5 above. The fire services, steam reticulation, heating and air-conditioning rows are no longer dark, which indicate that these services have been replaced or upgraded since the previous audit. The condition of the building fabric however deteriorated between the assessments, which indicate a lack of preventative maintenance during this period due to the focus on upgrade and replacement of the mechanical services.

The condition profiles for a set of rural hospitals in South Africa resulting from condition assessments in 1997 and 2005 are shown in Figure 6 below. The average profiles are shown at the bottom of set. From this illustration it can be seen that similar to the hospital in Figures 3 and 4 above, the focus was on backlog eradication between the assessments.

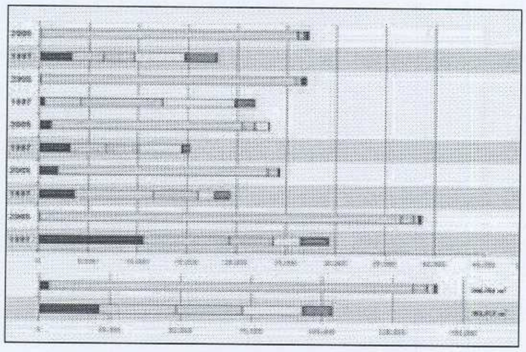

Figure 6: Performance Tracking of Hospitals

The responsible government department responded to the 1997 assessment by addressing the backlogs (needs, standards and condition/maintenance), with very little preventative maintenance, as illustrated by the 2005 assessment. The focus has now shifted to the implementation of a preventative maintenance programme to retain the hospitals in the current condition within funding constraints.

2.4. Service Life Prediction

The global importance of and need for sustainable socio-economic development demand an informed decision-making process from the built environment. Resources and non-renewable resources in particular, should be used as responsible and best possible to ensure optimum service life and life cycle costs, which depend on the ability to quantify and predict the changes in condition over time in any given physical and operational environment. This can only be achieved if the change in condition is monitored on a continuous basis to ensure appropriate and timely corrective actions, and develop a consistent and continuous condition assessment database on condition changes over time for the improvement of service life prediction models (e.g. “Factor Method”).

In Figure 7 below the condition assessments of a set of six academic hospitals in South Africa are shown on a graph illustrating changes in condition over time for different levels of maintenance based on a Markovian service life prediction model for academic hospitals (Mc Duling, 2006).

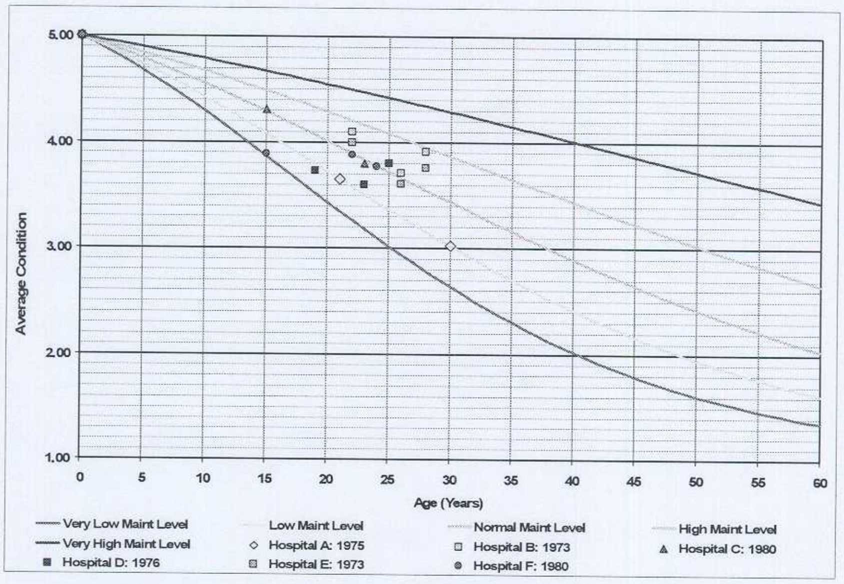

Figure 7: Condition Assessment Results vs. Maintenance Levels (Mc Duling, 2006)

Definition of maintenance levels:

<u>5 – ‘Very high’:</u> Planned preventative maintenance forms the basis of a regular maintenance programme

<u>4 – ‘High’:</u> Planned and unplanned condition-based maintenance

<u>3 – ‘Normal’:</u> Focus is on repairs and ‘so-called’ day-to-day maintenance, planning focussed on routine tasks

<u>2 – ‘Low’:</u> Ad hoc repairs or replacements; Reactive maintenance, no planning involved

<u>1 – ‘Very low’:</u> No or very little maintenance, only absolutely essential repairs or replacements (often with used parts)

From Figure 7 it can be seen that Hospital A has reached an average condition of 3, the minimum acceptable performance level for an academic hospital only thirty years after completion, which means its service life is 40% less than its design life of 50 years due to too low maintenance levels. Regular and consistent condition assessments could have resulted in appropriateness of maintenance levels and implementation of suitable corrective actions to prevent this loss of service life.

3. CONCLUSIONS

The performance of the built environment needs to be assessed on a continuous basis to ensure sustainability. Condition assessments can be a very powerful performance measurement tool provided that it is done on a regular and consistent basis. Due to the relative high costs involved in conducting condition assessments, the assessment system and process should be designed to optimise the application of the assessment data through value addition as illustrated above.

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