

## **Service life and sustainable design methods: A case study**

**Dr Johann Mc Duling Pr Eng<sup>1</sup>**  
**Geoff Abbott Arch**<sup>2</sup>

T 51

### **ABSTRACT**

The design life of hospitals normally varies between 50 to 60 years. This paper presents a case study of a major academic hospital that reached the end of its service life only 30 years after commissioning due to a combination of unsustainable design methods and inappropriate maintenance levels. Unsustainable design methods, such as long narrow multi-floor structures resulting in excessive walking distances and ineffective flow of patients and visitors, and insufficient structural depth and height, impaired the ability of the existing structure to accommodate changing demands of a modern health care environment, and the maintainability of services, such as sanitation, steam, ventilation and air-conditioning.

According to Ashworth [1996] building materials, components and technology may last for 100 years or more depending upon quality and standards, while engineering services have a life expectancy of about 15 years, and finishes and fittings frequently less than 10 years. Information technology hardware systems “are becoming outdated even after a period of only 3 years.” This raises the question of a realistic design life for health care facilities. Should we not rather use a shorter design life to accommodate changing needs in modern healthcare technology and differences in life expectancy?

Inappropriate maintenance levels in addition to impaired maintainability of services due to unsustainable design methods caused premature deterioration to the extent that the facility’s condition could no longer support a healing environment, resulting in a need to replace the hospital.

### **KEYWORDS**

Service life, design life, sustainable design methods, maintainability, maintenance levels.

<sup>1</sup> Senior Researcher: Asset Management, Architectural Sciences, Built Environment, Council for Scientific and Industrial Research, Pretoria, South Africa, Phone +27 83 700 4027, Fax +27 12 349 9700, [mcduling.johann@builtcare.co.za](mailto:mcduling.johann@builtcare.co.za)

<sup>2</sup> Specialist Research Architect: Health Facility and Asset Management, Architectural Sciences, Built Environment, Council for Scientific and Industrial Research, Pretoria, South Africa, Phone +27 12 841 2542, Fax +27 12 841 3504, [gabbott@csir.co.za](mailto:gabbott@csir.co.za)

## **1 INTRODUCTION**

This paper presents a case study of Tygerberg Hospital, a major academic hospital near Cape Town in South Africa, that reached the end of its service life only 30 years after commissioning due to a combination of unsustainable design methods and inappropriate maintenance levels. Tygerberg Hospital was conceptualised nearly 50 years ago and has been in operation for 32 years. During this time the community served and service required have changed as have health service delivery and medical training philosophy and practice, medical technology has developed substantially, and new technologies such as ICT have evolved. Unsustainable design methods, such as long narrow multi-floor structures resulting in excessive walking distances and ineffective flow of patients and visitors, and insufficient structural depth and height, impaired the ability of the existing structure to accommodate changing demands of a modern health care environment, and the maintainability of services, such as sanitation, steam, ventilation and air-conditioning. At the same time maintenance has been wholly inadequate and the condition of the buildings has deteriorated significantly. Many of the technical and engineering systems have also reached the end of their design life.

Tygerberg currently operates as an academic institution with 1 290 commissioned beds, some 600 fewer than the original design provided for when built in the early 1970's. The facility has some 74 buildings totalling some 312 000 m<sup>2</sup>. Not all the buildings are currently used as hospital buildings. The main block is some 218 000m<sup>2</sup> and is 15 storeys high.

## **2 FACILITY ASSESSMENT**

During 2005 the Council for Scientific and Industrial Research [CSIR] was commissioned to undertake a high level options review of Tygerberg Hospital aimed at identifying and quantifying the implications of redeveloping the facility from its current service to its planned use in terms of the 2010 Health Service Plan for the Western Cape. The study was confined to the administration block, the main hospital block, mortuary, oncology unit, boiler house, pump house and main electricity substation as well as the interlinking site engineering services reticulation.

The provision of health services at Tygerberg Hospital is influenced by the physical design of the facility, the current condition of the buildings and services infrastructure and the way in which the facility is currently being operated and maintained. The review covered, therefore, both an assessment of the existing structure in terms of its current use, condition, functionality and suitability as well as of the potential of the existing shell for redevelopment. As such the study provided the platform for the development of options for redevelopment.

A wide range of issues were identified in the study pertinent both to the development of options for the redevelopment of Tygerberg as well as important for the ongoing operation of the facility in the interim period while the selected strategy is being implemented. Should the existing facility be retained, the location of some departments will need to change as existing relationships between departments are not always ideal and many departments would need to be remodelled to a greater or lesser extent to accommodate more efficient planning, new service requirements and general upgrading.

A range of condition and non-compliance issues were highlighted by the assessment team as needing either critical or urgent attention. Critical issues included soil water discharge pipes and stacks and fire systems, while urgent issues included theatre air-conditioning, vacuum, potable water, lifts, cleaning and various hospital maintenance issues. Measures have been introduced by the Department to address these issues in the short to medium term during the redevelopment process. Some of these will impact on the redevelopment strategy and investment required.

## **2.1 Physical Assessment**

The overall condition of the facility was found to have deteriorated further from the average 3,65 condition established in the 1995/96 National Health Facilities Audit to 3,02 on a 5 point condition assessment scale [5 being very good and 1 very bad] representing an increase in the maintenance backlog over the 10 year period of some ZAR335m [ZAR7 = US\$1±]. This average figure hides a range of elements where the condition was found to be substantially worse while in a few areas the condition had improved due to limited recent repairs and upgrading [as in some wards]. While the overall shell of the building, with the exception of the roof, appeared to be in relatively good condition, of primary concern are a number of core systems and elements identified such as the soil water [sewage] system in the building, various mechanical systems including air-conditioning, medical gases and steam systems and some electrical systems such as lifts. The level of maintenance was found to be very low with a lack of planned or preventive maintenance.

The poor condition of key systems and components in the facility coupled to physical design constraints and ad-hoc changes made to the building in use, have led to the situation where the facility, in many respects, no longer meets required service delivery standards or legislated performance safety standards and has reached the end of its service life 20 years prematurely.

## **2.2 Functional Assessment**

The current utilisation of Tygerberg Hospital, at 1 290 beds, is more than 35% below the original design capacity. With the planned utilisation expected to remain at about 1 300 beds, the existing facility measures nearly twice the area per bed than currently accepted as the norm, with significant negative functional and operational implications. There is no clear entrance or point of arrival, and the dual corridor legacy of the original functionally separated design and current scattered location of departments [such as the poor relationship between theatres and ICU's] lead to poor functioning, operating inefficiencies and pressure on staff and risk to patients. The functional layout of wards and ICU's are particularly poor, being constrained by the physical shape of the building and circulation. The design and current use does not allow good operational practice to be adhered to, resulting in high infection risk to patients and staff alike. Of particular concern is the use of the ICU's as thoroughfares from one side of the hospital to the other and various compromises in good theatre practice.

A number of issues were also identified in the assessment where there was concern regarding patient and staff safety through non-compliance with provisions of the Occupational Health and Safety Act [OHS] and the National Building Regulations [NBR]. Areas highlighted in the operational risk and regulatory compliance assessments include fire risk, materials handling, air-conditioning and ventilation systems, finishes, water supply and sanitising equipment and medical gases. Action, identified during the assessment, has been initiated to bring aspects of the facility into line with most requirements of the OHS Act and NBR. Some are being addressed at a management level but many more are fundamental in nature, such as fire compartmentation and shallow buildings unsuitable for modern hospital layouts, and will require major remodelling of the shell to resolve.

## **2.3 Financial Performance**

It is estimated that the current equivalent cost to rebuild the hospital as it now stands is some ZAR1,92bn [including Value Added Tax and professional fees], more than 50% above the current benchmark cost of R1,24bn for a new facility. The estimated budget to reinstate the facility to an acceptable condition is ZAR788m or over 60% of the cost of a new facility. The actual annual current maintenance expenditure of ZAR35m is only 4,6% of the estimated current requirement.

The total hospital [including salaries, administration and medicine] and facility operating costs

[including utilities, steam, security, cleaning, building and equipment maintenance] are 32,5% and 4,8% respectively of the current equivalent construction cost. Facility operating costs are well below benchmark levels as building maintenance, cleaning and security are all well below estimated funding requirements. The balance between facility and service operating costs will change for those options where the total building area is reduced to actual requirements.

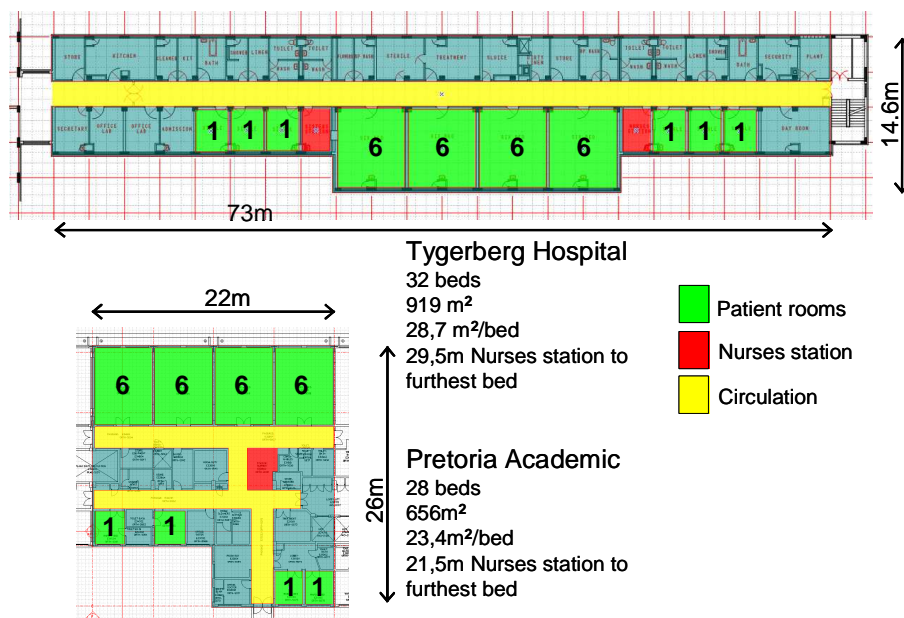
## 2.4 Transient, Alterable and Fundamental Issues

Issues identified during the assessment can be classed into one of three broad categories: transient, alterable or fundamental issues. Transient issues can generally be addressed through management intervention alone and include housekeeping, and some legislative compliance and safety issues, such as blocking of escape routes by stored equipment. Alterable issues generally require minor or major capital work and include issues that can be undertaken without significant, long term disruption to services and include issues such as redecorating or repair of finishes, and repair or replacement of engineering plant or equipment [e.g. air-conditioning, lifts and standby generators].

Fundamental issues affect the basic structure and systems and require major intervention and disruption to normal operation, usually involving major building work at high cost. These include issues such as layout, structure, and replacement of major engineering systems and networks. All three levels are evident at Tygerberg. Many of the problems, such as the shallow buildings and the physical spread of the overall structure [24 km of passages] are fundamental and intractable and can only be addressed through extensive demolition and remodelling of the shell at very high cost.

### 2.4.1 Design and Layout

Most new wards in modern hospitals have a far more compact layout than those at Tygerberg, see Figure 1 below. There are significant advantages to a compact design including shorter walking distances between patient beds and key work areas [nurses station, clean and dirty utility, etc], better observation of patients by staff, less overall area, better external wall to area ratios and therefore lower cost. A compact ward with a central nurses' station also allows more effective air-conditioning air flow with supply flow from the nurses' station outwards through patient and service rooms.

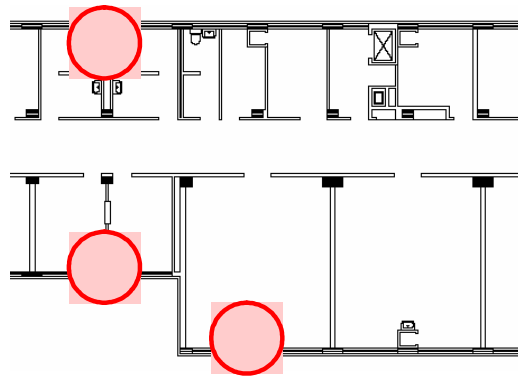


**Figure 1:** Ward shape comparison

The current elongated layout was designed originally for natural ventilation. Air-conditioning was added but is not working. The location of the plant rooms [at the furthest point from the entrance near the escape stair] is problematic as all maintenance and moving of soiled filters have to go along the length of the ward. The elongated ward required the separation and duplication of some support spaces including two nursing stations [ward secretary at entrance, sister's station and nurse's station along the length of the ward], two sluice rooms [including duplication of equipment], two linen rooms, and main kitchen and sub-kitchen. Control of the ward and observation of patients is problematic and security is a concern. Patients in single rooms towards the end of the wards can easily be forgotten. Many of the wards have their escape doors leading to the fire escape stairs locked for security reasons or open but not alarmed.

#### **2.4.2 Replacement of Major Engineering Systems and Networks**

The access to service ducts is from inside the building as shown in Figure 2 below. This makes maintenance and repairs extremely difficult. Removing blockages from sewer pipes is difficult resulting in spillages of waste, sometimes into wards, as shown in Figure 3 below. Replacing sewer pipes can only be addressed through extensive demolition and remodelling of the shell at very high cost. The same applied to the steam and airconditioning installations.



**Figure 2:** Location of Service Ducts

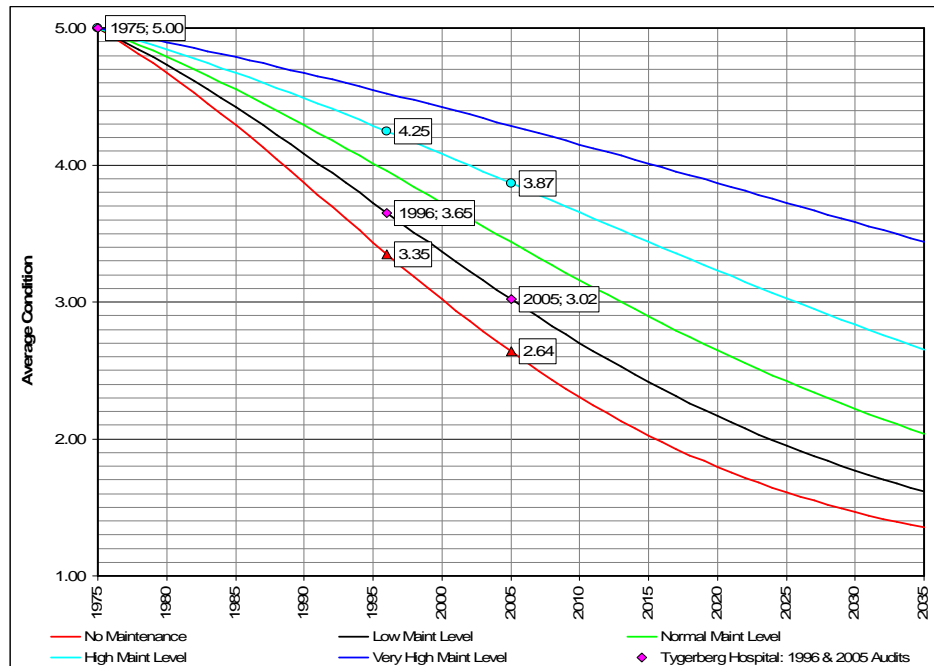


**Figure 3:** Duct to Service Duct, Inside Service Duct and External Wall outside Service Duct

#### **2.4.3 Maintenance Levels**

In Figure 4 below, the actual average condition of Tygerberg Hospital as assessed during the NHFA and 2005 CSIR assessment is compared to the anticipated change in average condition over time for various levels of maintenance, ranging from no maintenance to a very high level of maintenance. For a health care facility, such as Tygerberg Hospital, a high level of maintenance [the curve second from

the top] would be appropriate. From the graph it can be seen that the 1996 NHFA and 2005 CSIR Assessment average condition of Tygerberg Hospital falls on the low maintenance curve.



**Figure 4:** Anticipated Average Condition over Time vs Level of Maintenance [Mc Duling, 2006]

The anticipated average condition of Tygerberg Hospital should have been around 3.87 for a high level of maintenance and 2.64 for no maintenance. The consequences of the inappropriate level of maintenance amount to R428 million more required now than what should have been the case if the facility was properly maintained [high level of maintenance].

### 3 OPTIONS DEVELOPMENT AND APPRAISAL

In order to address the primary concerns identified in the assessment study, three broad redevelopment options, outlined below, were identified for further development, costing and evaluation. The results of the assessment and the options development study were presented at a workshop of key role players from the Hospital, the Medical Faculty and the Departments of Health and Public Works. The advantages and disadvantages of each option were reviewed and a high level of consensus reached that Option C, for a new facility, would provide the best solution.

#### 3.1 Option A – Rehabilitation

This option involved the reuse of the existing hospital buildings with minimal alterations and upgrading, sufficient only to address areas of critical interventions identified in the assessment and to create separate level 2 and 3 management units. This option was not supported as, while the capital costs and relative speed of delivery are lower than other options, most of the inherent constraints, costs and inefficiencies of the existing shell would remain and, as the area will still be far more than required, operational costs would be far higher than other options, leading to substantially higher operational costs in total.

#### 3.2 Option B – Remodelling

Option B involved the reuse of the existing shell with extensive remodelling to address key

functional, condition and compliance constraints identified in the assessment. Entrances, circulation and layouts would be rationalised and many features of a modern hospital could be built into the design. While the solution would have offered a workable hospital within the existing shell and the net present value [consolidating capital and operating costs over a 10 year period] would be slightly less than for a new facility, the solution was not supported, as there was still a significant legacy cost to the remainder of the shell and the severe disruption to hospital operation, patients and academia during remodelling.

### **3.3 Option C - New Facility**

Option C involves building an entirely new facility on the same site and either the demolition or reuse of the existing facility for a new function. While this solution has higher capital costs, operational costs will be the lowest of the three options and over a short period the solution will become far more economic than working with the existing facility. This solution was supported for further development as it offers the most effective financial and functional solution and has the major advantage in that all construction work will be separated from the running of the existing facility.

## **4 CONCLUSION**

Tygerberg Hospital reached the end of its service life only 30 years after commissioning. The design life of hospitals normally varies between 50 to 60 years, which means between 40% and 50% of its design life has been lost.

Building materials, components and technology may last for 100 years or more depending upon quality and standards, while engineering services have a life expectancy of about 15 years, and finishes and fittings frequently less than 10 years.

This raises a number of questions around a realistic design life for health care facilities. Should a shorter design life not rather be used to accommodate changing needs in modern healthcare technology and differences in life expectancy? Can we really plan for 50 to 60 years when technology develops at a mind-boggling rate? Why plan and design for 50 to 60 years if after 30 years new healthcare needs render the facility unsuitable? Should we not rather use a shorter design life to accommodate changing needs in healthcare technology?

## **REFERENCES**

Ashworth, A., 1996. Assessing the Life Expectancies of buildings and their Components in Life Cycle Costing. Cobra '96, Royal Institution for Chartered Surveyors.

Capital Investment Manual: Business Case Guide, 1995. London: HMSO

Design Brief Working Group, Richard Burton [Chairman], 2002. "Advice to trusts on the main components of the design brief for healthcare buildings." NHS Estates, Department of Health, July 2002.

Mc Duling, J.J., 2006. Towards the Development of Transition Probability Matrices in the Markovian Model for the Predicted Service Life of Buildings, PhD Thesis, Department of Civil and Biosystems Engineering, University of Pretoria, South Africa.