“QUANTIFYING THE CONSEQUENCES OF MAINTENANCE BUDGET CUTS”

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Abstract

Because it is difficult to quantify the cost of deferred maintenance and neglect, maintenance work has always been subjected to budget cuts, as reflected by the sad state of neglect of many of our assets. Reliable statistics are required to quantify the consequences of maintenance budget cuts or postponed maintenance. Such data, however, seldom exist and could take years to accumulate. This paper, based on work done by the presenter in preparation of a PhD (Engineering) thesis, under the guidance of Professors Horak and Cloete, will illustrate how management could be enabled to “forecast” the consequences of budget-cuts and budget allocations and improve the cost-effectiveness of maintenance. Although based on the maintenance of buildings, the principles could also be applied to maintenance of other assets, it is basically only the timeframe that differs.

1 Introduction

According to Lee [1] “The built environment expresses in physical form the complex social and economic factors which give structure and life to a community. The condition and quality of buildings reflect public pride or indifference, the level of prosperity in the area, social values and behaviour and all the many influences both past and present, which combine to give a community its unique character. There can be little doubt that dilapidated and unhealthy buildings in a decaying environment depress the quality of life and contribute in some measure to antisocial behaviour”.

Unfortunately, as Seeley [2] puts it, maintenance work “possesses little glamour, is unlikely to attract very much attention and is frequently regarded as unproductive”, and although “many of the managerial and technical problems are more demanding of ingenuity and skill than those of new works”, the development of new technology in the built environment remains focussed mainly on the construction of new buildings.

The sad state of neglect of many public facilities can mainly be attributed to insufficient funds for maintenance work and maintenance budget cuts during the financial year. There is a general belief that preventative maintenance can easily be postponed until financial constraints may be less tight, and because it is difficult to quantify the cost of neglect, maintenance work has always been subjected to under-funding and budget cuts. It is therefore not surprising that maintenance activities other than day-to-day, ad-hoc or emergency work are mostly of an aesthetic or cleaning nature aimed at hiding the damning signs of neglect.

The lack of accurate current information on building conditions and maintenance requirements are the main reasons why maintenance budget allocations are insufficient. If the condition of the building is unknown, the maintenance requirements, cost and timing of the work is also unknown. As a result, maintenance budgets are dominated by contingency provisions for day-to-day and emergency unplanned maintenance, replacements or repairs and are, therefore, normally based on the previous financial year’s maintenance expenditure with an allowance for inflation and some renovations. If there are any funds left, preventative maintenance may be considered.

Financial managers know that maintenance budgets are in general not very accurate and maintenance managers over-estimate funding requirements during the preparation of budgets in anticipation of budget cuts. Under these circumstances, it is very difficult to defend maintenance budgets effectively against budget cuts and they easily fall pray to cuts during times of financial hardship.

Assessing the current condition, defining the maintenance required and calculating the budget requirements are the easy part of the maintenance manager’s task. The difficult part is the allocation of the available funds, which is almost always much less than required. The success of maintenance management is determined by the extent to which the average condition of the assets has been improved through the application of the limited funds available. “The value of planning depends to a large extent upon the accuracy with which future performance can be estimated.” [1]. The consequences of budget allocation decisions therefore depend on the ability of the maintenance manager to predict the change in condition as a result of the subsequent maintenance work or the postponement thereof.

2 Problem Definition

Maintenance can be defined as “The combination of all technical and associated administrative actions intended to retain an item in, or restore it to, a state in which it can perform its required function.” [5]. The Maintenance Manager will seldom, if ever, have sufficient funds for maintenance. The biggest problem is how and where to apply the available funds to ensure the maximum benefit. To be able the decide on the application of available funds the Maintenance Manager must predict how the condition of the asset will change over time if maintenance is done or not.

To be able to predict the change in condition over time the Maintenance Manager requires access to reliable statistics on the performance of the asset under similar conditions. In the civil engineering industry the roads engineers are in an enviable position in the sense that they have accumulated statistics on pavement performance over many years and today have computer models that can simulate pavement performance with a great deal of accuracy. In the industrial environment Maintenance Managers are also fortunate to have access to reliable plant performance statistics and in most cases can predict with confidence how the condition of the asset will change over time.

In the built environment the consequences of neglect is unfortunately less visible and it is therefore easy for Decision Makers and Financial Managers to cut building maintenance budgets. The Building Maintenance Manager must therefore be able to forecast the consequences of budget cuts and this can only be done if change in condition can be predicted.

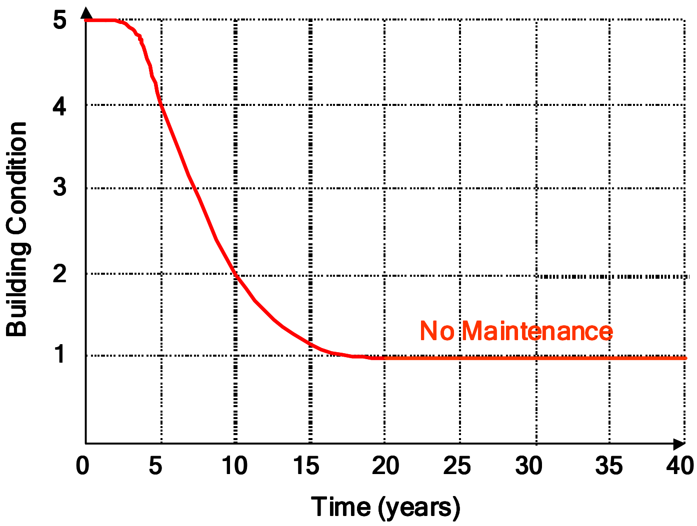


Figure 1: Change in Condition over Time

Figure 1 illustrates the change in building condition over time if no maintenance is done. It is based on a five-point rating system commonly used in building maintenance management with Condition 5 indicating the condition at Time 0 when the asset is new, and Condition 1 when the asset needs to be replaced. Although this is a typical graph for buildings, it is also applicable to other assets, only the timeframe may vary. The problem however is that this graph in Figure 1 was drawn by hand and not calculated because there is no formula or statistics to support a calculation. What is therefore required is a formula supported by reliable statistics, which do not exist, to be able to calculate the change in building condition over time.

3 Change in Condition over Time

A building is a complex three-dimensional composition of a diverse range of fabrics and materials, each with its own characteristics, which interacts differently to the environment, could be old or brand new, raw or processed, come in different forms, shapes, sizes and finishes, and its applications could vary considerably.

The rate of change in the condition of the building fabric is determined by the exposure of the building to the environment and the building's ability to resist the deterioration of the fabric as a result of the exposure to the environment.

3.1 Influence of the Environment on the Deterioration of Building Fabric

The environment in and around a building can be divided into a physical and operational environment.

Physical Environment: The physical environment is determined by the climate in and around a building, the level of pollution and the exposure to the climate and pollution. The climate could be favourable or aggressive and has a major impact on the deterioration rate. The level of exposure to moisture, humidity, heat, cold, wind, dust, hail, snow, ultra-violet rays and pollution influence the deterioration rate.

Operational Environment: The levels of maintenance and utilisation determine the operational environment of a building. If the level of maintenance is low or the level of utilisation is high, the rate of deterioration will be high. The operational environment could also be aggressive such as at public schools, where vandalism is a major problem, or industrial plants, where the use or production of aggressive chemicals could also have a major impact on the deterioration rate.

3.2 Factors Influencing Resistance

Resistance is defined as "the ability not to be affected by something, especially adversely"[3]. The resistance of a building to deterioration can therefore be defined as the ability of the building not to be affected adversely by its environment. The following factors are some of the factors that determine the resistance to the environmental impact on the building:

Building Fitness: The "fitness" of a building is determined by the age and current condition of the building. Just like the human body, a building needs to be fit to withstand the onslaught by the environment. An old building has less resistance to the impact of the environment than a new building. When a building is in a bad condition the surfaces are normally deteriorated and offer less resistance.

Quality: The quality of the fabric, material and workmanship in the initial construction and subsequent maintenance also has a major affect on the resistance of the building to the environment. It is interesting to note that according to Seeley [2] hospitals built in Britain during the 1960's and 1970's can cost up to three or four times as much to maintain as older hospitals because of the experimental methods by which many were constructed. He also points out that the appalling state of repair of many of Britain's school buildings is "rooted in the educational building boom of the 1960's when decades of common sense in materials and detailing were discarded in favour of non-durable and inadequately researched materials, poor and sometimes 'unbuildable' detailing, and lax supervision of construction."

3.3 Deterioration Rate

In order to quantify the rate at which the building fabric deteriorates it is necessary to measure the impact of the environment against the resistance offered by the building fabric. This is not as simple as it sounds, due to the building's complex three-dimensional composition of diverse fabrics and materials, and the environment's many facets. The lack of reliable statistics and research further complicates the analysis. The accumulation of the required statistics will take years.

There is however a solution to this problem. The use of artificial intelligence applications makes it possible to build models for the analysis of such complex problems where statistics are not available or could take years to accumulate. The Neuro-fuzzy system is such an application that was used to analyse the influence of the environment and resistance of the building fabric on the deterioration rate, and produced very exciting results.

Based on the results of this analysis it is possible to calculate the change in condition over time if no maintenance is done, as illustrated in Figure 2 below.

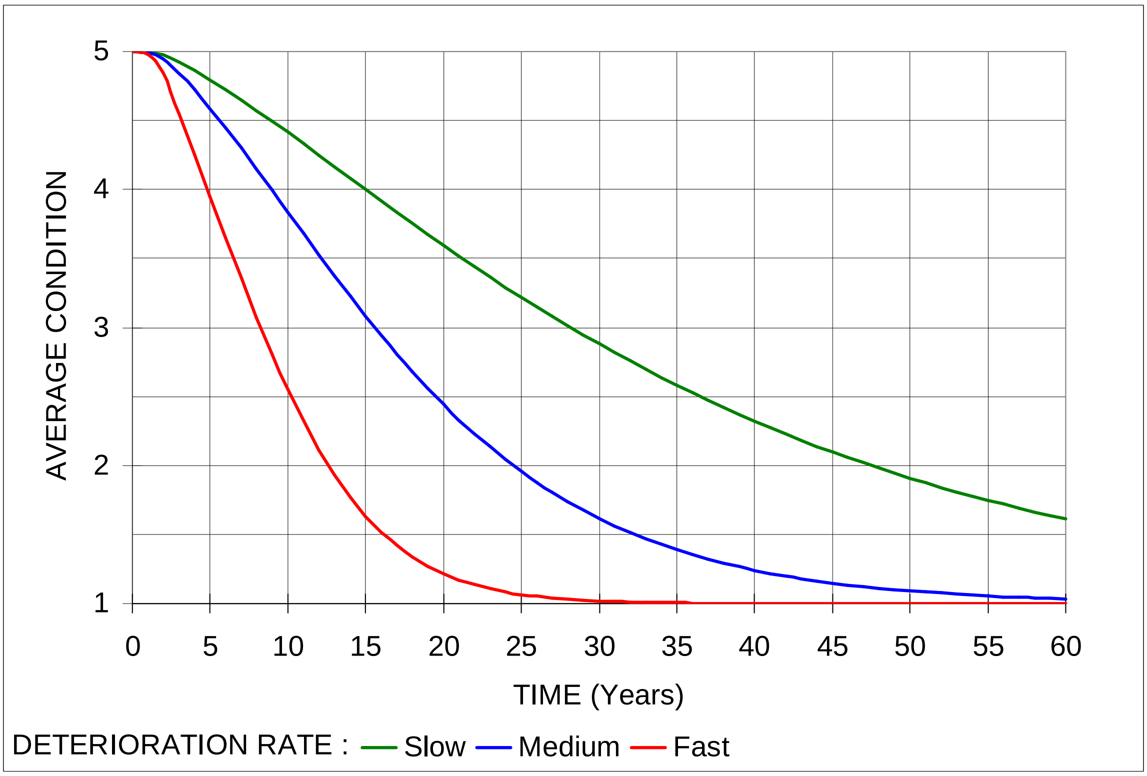


Figure 2: Change in Building Condition over Time (No maintenance)

The difference between Figure 1 and Figure 2 is that Figure 1 was drawn by hand, based on experience and common sense, while Figure 2 was calculated. Figure 2 also illustrates that the analysis tool can accommodate different rates of deterioration. With this technology it is possible to calculate how much the condition of the asset will deteriorate and the cost to reinstate the asset to the desirable condition if maintenance work is deferred.

It has become international standard practice in building maintenance management to use condition ratings, an example of which is shown in Table 1 below.

Condition Rating Colour Coding	 Technical Terms	 Layperson Terms	Description
5	**As New**	**Very Good**	The fabric, element or building is either new or has recently been maintained; does not exhibit any signs of deterioration.
4	**Maintenance Required**	**Good**	The fabric, element 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	**Repairs Required**	**Fair**	Significant sections or elements require repair, usually by a specialist. The fabric, element 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	**Renovations Required**	**Poor**	Substantial sections or elements have deteriorated badly, suffered structural damage and 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	**Replacement Required**	**Very Poor**	The fabric, element 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.

Table 1: Condition Ratings [4]

The combination of condition ratings with colour has made it an even more powerful and user-friendly reporting tool. Using the colour coding in Table 1, Figures 3 and 4 illustrate how the condition profile of a building changes over time if no maintenance is done.

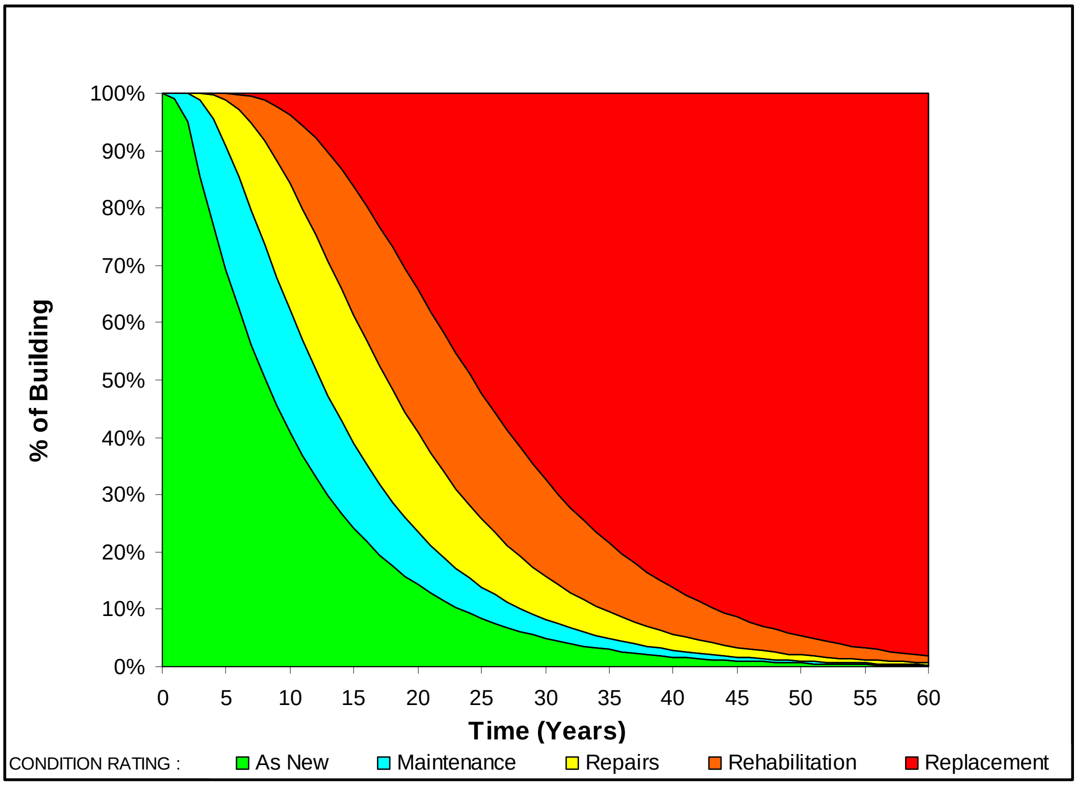


Figure 3: Change in Condition Profile over Time (No maintenance)

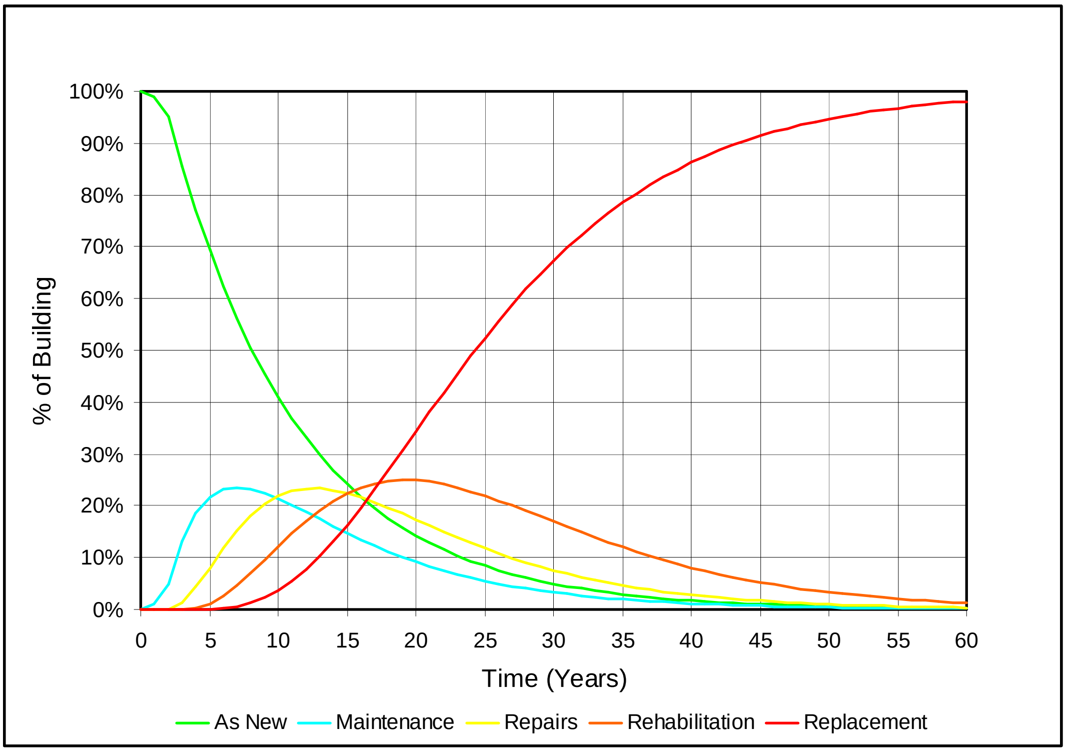


Figure 4: Change in Condition Categories over Time (No maintenance)

4 Scenario Planning

Following a maintenance budget cut, the Maintenance Manager needs to decide on how to allocate the available budget. The budget allocation should be based on the priority of the work and how the condition profile will change as a result of the allocation.

4.1 Budget Allocation Options

There are four options available for the allocation of maintenance budgets.

Option 1: First allocate funds to the assets in the worst condition. This approach is called the "Bottom Up" approach, because the allocation starts at the bottom of the condition scale. The focus is on the replacement and rehabilitation of buildings not in a desirable condition.

Option 2: Start allocating the available funds to the assets in the best condition. This approach is called the "Top Down" approach and starts with the allocation of funds to assets in condition 5. The focus is on the maintenance of buildings in desirable condition and the motivation for this approach is to keep the assets in that condition.

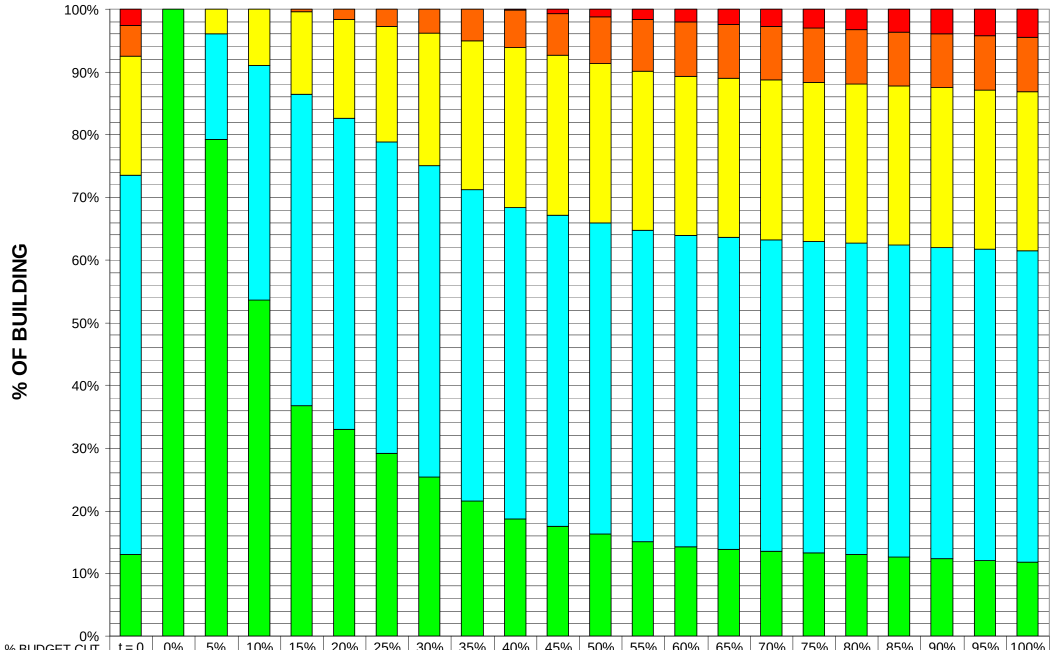
Option 3: Equal distribution of available funds to all condition categories. This option is called the "Balanced" approach. The budget allocation to each condition category is based on the same ratio as the available budget to the required budget.

Option 4: Allocate funds on ad hoc basis to occupant making biggest noise. This is the most likely option followed by most Maintenance Managers faced with a similar scenario. With this approach the Maintenance Manager normally ends up with not spending all the funds available.

The following case study, based on an actual case, will be used to illustrate how the calculation of the change in condition can be used in maintenance budget scenario planning.

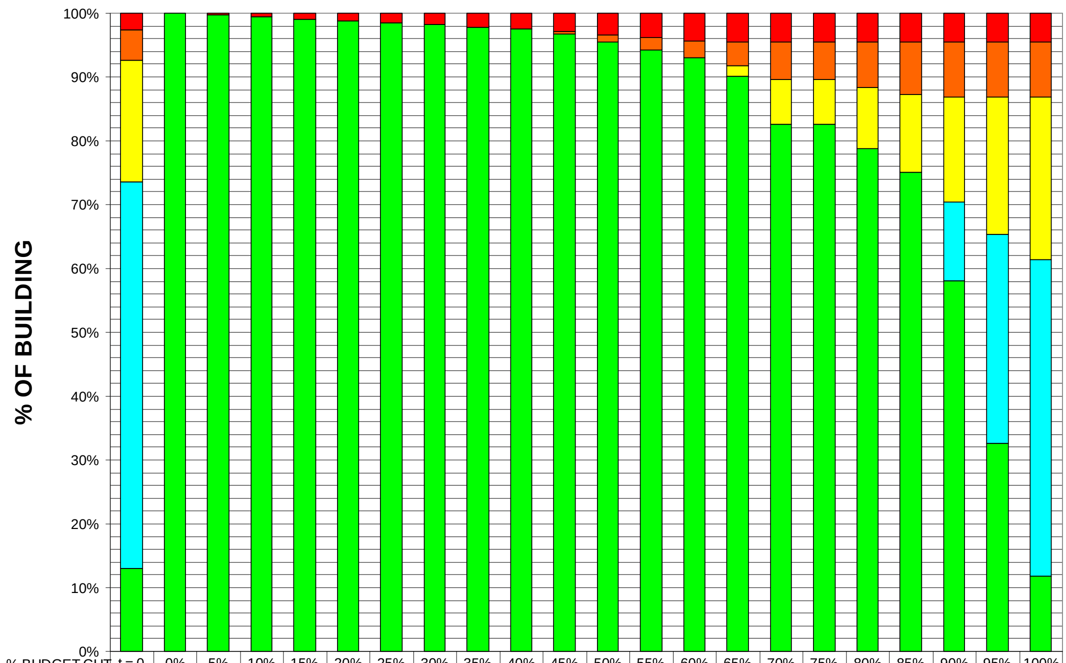
The Maintenance Manager of a large organisation has done an assessment of the current condition of all fixed assets owned by the organisation. The current average condition is 3.77. It is assumed that if an asset is attended to during the budget period and the asset is in any condition other than condition 5, the asset will be reinstated to condition 5. The question is how much will the condition profile of assets not attended to during the budget period deteriorate as a result of the budget cut.

Based on the methodology in Section 3, Figures 5 to 7 below illustrate how the overall condition profile of an asset portfolio will be affect due to budget cuts for the first three different approaches.



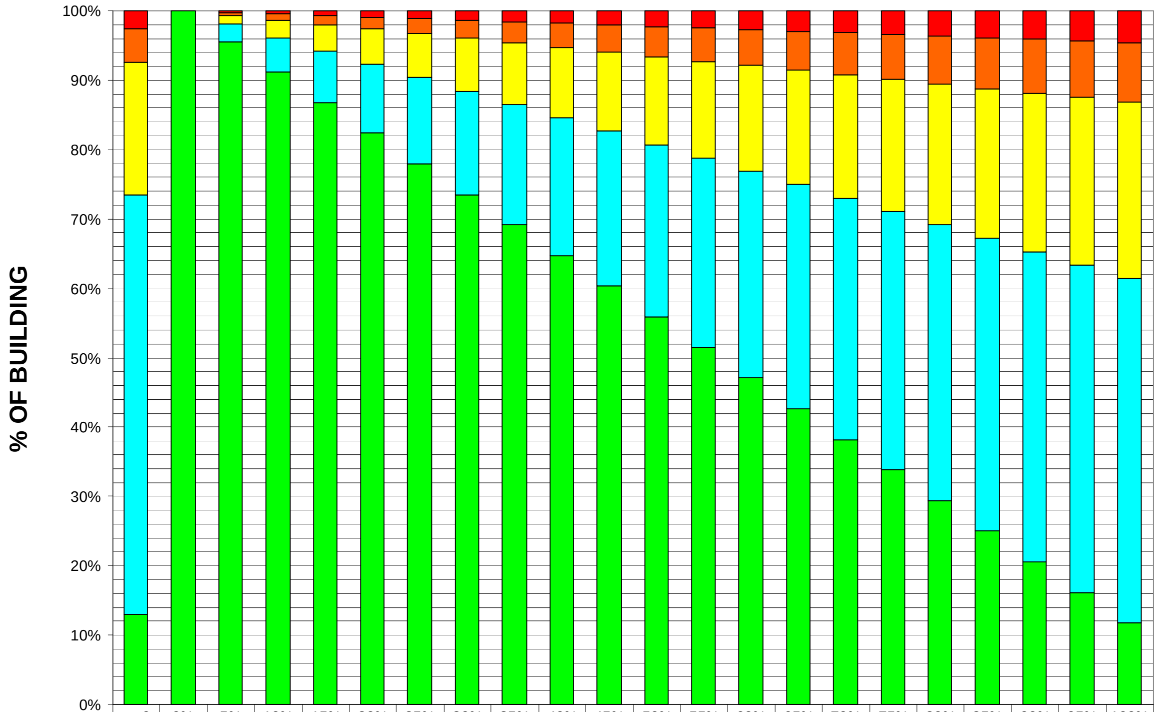
% BUDGET CUT	t = 0	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Replacement	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	2%	2%	2%	3%	3%	3%	4%	4%	4%	5%
Rehabilitation	5%	0%	0%	0%	0%	2%	3%	4%	5%	6%	7%	7%	8%	9%	9%	9%	9%	9%	9%	9%	9%	9%
Repairs	19%	0%	4%	9%	13%	16%	18%	21%	24%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Maintenance	60%	0%	17%	37%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
As New	13%	100%	79%	54%	37%	33%	29%	25%	22%	19%	18%	16%	15%	14%	14%	14%	13%	13%	13%	12%	12%	12%

Figure 5: Changes in Condition Profile due to Maintenance Budget Cuts: "Bottom Up Approach"



% BUDGET CUT	t = 0	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Replacement	3%	0%	0%	1%	1%	1%	2%	2%	2%	2%	3%	3%	4%	4%	5%	5%	5%	5%	5%	5%	5%	5%
Rehabilitation	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	2%	3%	4%	6%	6%	7%	8%	9%	9%	9%
Repairs	19%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	7%	7%	10%	12%	16%	22%	25%
Maintenance	60%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	12%	33%	50%
As New	13%	100%	100%	99%	99%	99%	98%	98%	98%	98%	97%	95%	94%	93%	90%	83%	83%	79%	75%	58%	33%	12%

Figure 6: Changes in Condition Profile due to Maintenance Budget Cuts: "Top Down Approach"



% BUDGET CUT	t = 0	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Replacement	3%	0%	0%	0%	1%	1%	1%	1%	2%	2%	2%	2%	2%	3%	3%	3%	3%	4%	4%	4%	4%	5%
Rehabilitation	5%	0%	0%	1%	1%	2%	2%	3%	3%	3%	4%	4%	5%	5%	6%	6%	6%	7%	7%	8%	8%	9%
Repairs	19%	0%	1%	3%	4%	5%	6%	8%	9%	10%	11%	13%	14%	15%	17%	18%	19%	20%	22%	23%	24%	25%
Maintenance	60%	0%	2%	5%	7%	10%	12%	15%	17%	20%	22%	25%	27%	30%	32%	35%	37%	40%	42%	45%	47%	50%
As New	13%	100%	96%	91%	87%	82%	78%	74%	69%	65%	60%	56%	51%	47%	43%	38%	34%	29%	25%	21%	16%	12%

Figure 7: Changes in Condition Profile due to Maintenance Budget Cuts: "Balanced Approach"

With graphs like this it is possible to quantify how much the condition profile of assets not attended to during the budget period will deteriorate as a result of budget cuts.

Based on the condition assessment the Maintenance Manager calculated a "zero-based" maintenance budget to the amount of ZAR500,000,000. To the frustration of the Maintenance Manager management cut the maintenance budget with 70% and only allocated ZAR150,000,000 to the maintenance budget, 30% of what is required. Management also assured the Maintenance Manager that future planning could be based on a constant allocation of ZAR150,000,000. The Maintenance Manager is now faced with the problem of how to allocate only 30% of what is required and still improve on the current situation. The first three options and the budget allocations are shown in Table 2 below. For the purpose of this paper Option 4, which is similar to Option 1, will not be considered.

CONDITION RATING	AS NEW	MAINTENANCE	REPAIRS	REHABILITATION	REPLACEMENT	AVERAGE CONDITION
	5	4	3	2	1	3.77
% of FACILITIES	13%	60%	19%	5%	3%	100%
BUDGET REQUIRED	R 5,000,000	R 60,000,000	R 125,000,000	R 100,000,000	R 210,000,000	R 500,000,000
% of BUDGET	1%	12%	25%	20%	42%	100%
BUDGET AVAILABLE						R 150,000,000
AVAILABLE/REQUIRED						30%
BUDGET ALLOCATION OPTIONS						
OPTION 1 : FOCUS ON REHABILITATION & REPLACEMENT BUILDINGS NOT IN A DESIRABLE CONDITION : "BOTTOM-UP APPROACH"						
BUDGET ALLOCATION	R 0	R 0	R 0	R 0	R 150,000,000	R 150,000,000
% of REQ'D BUDGET	0%	0%	0%	0%	71%	30%
% of FACILITIES	0%	0%	0%	0%	2%	2%
OPTION 2 : FOCUS ON MAINTENANCE OF BUILDINGS IN A DESIRABLE CONDITION : "TOP DOWN APPROACH"						
BUDGET ALLOCATION	R 5,000,000	R 60,000,000	R 85,000,000	R 0	R 0	R 150,000,000
% of REQ'D BUDGET	100%	100%	68%	0%	0%	30%
% of FACILITIES	13%	60%	13%	0%	0%	86%
OPTION 3 : EQUAL DISTRIBUTION OF AVAILABLE MAINTENANCE BUDGET : "BALANCED APPROACH"						
BUDGET ALLOCATION	R 1,500,000	R 18,000,000	R 37,500,000	R 30,000,000	R 63,000,000	R 150,000,000
% of REQ'D BUDGET	30%	30%	30%	30%	30%	30%
% of FACILITIES	4%	18%	6%	1%	1%	30%

Table 2: Maintenance Budget Allocation Options

4.2 Change in Condition Profile

The change in the condition profile due to the 70% budget cut for Options 1, 2 and 3 are shown in Figures 8, 9, 10 and 11 below. The left-hand column represents the current condition profile. The figures illustrate how the condition profiles change over time with the same constant budget allocation of only 30% of the required maintenance budget to all three options.

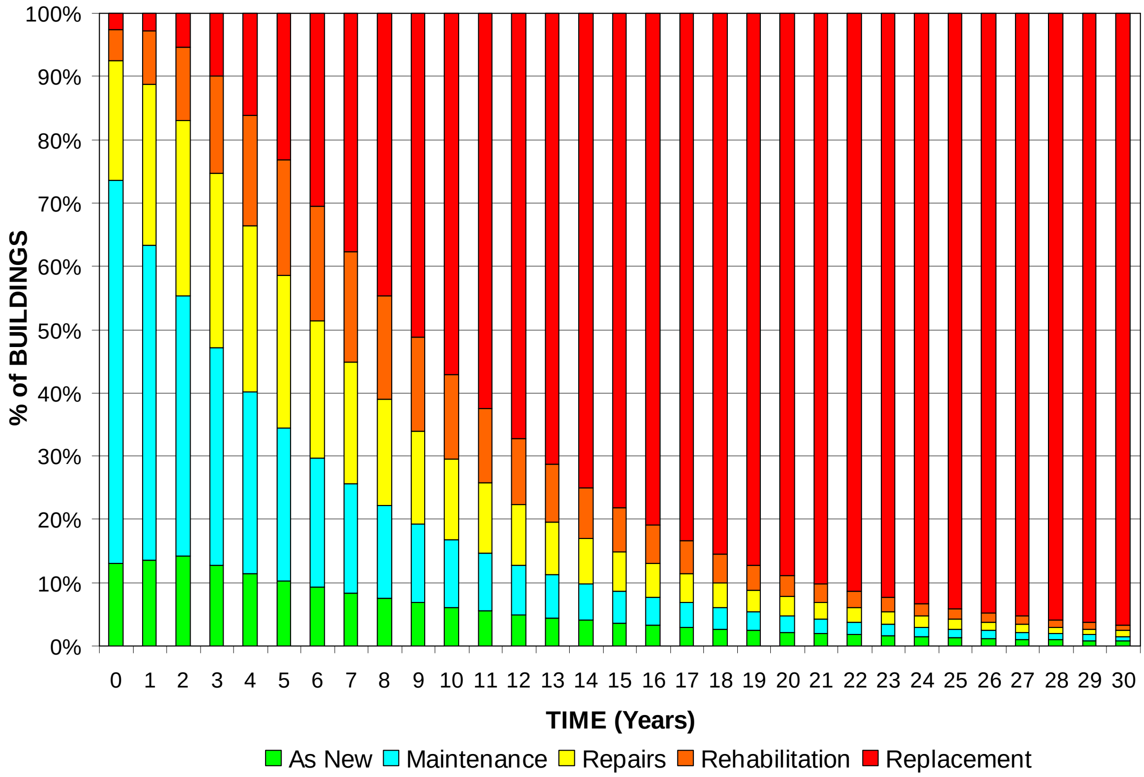


Figure 8: Option 1 – "Bottom-up Approach"

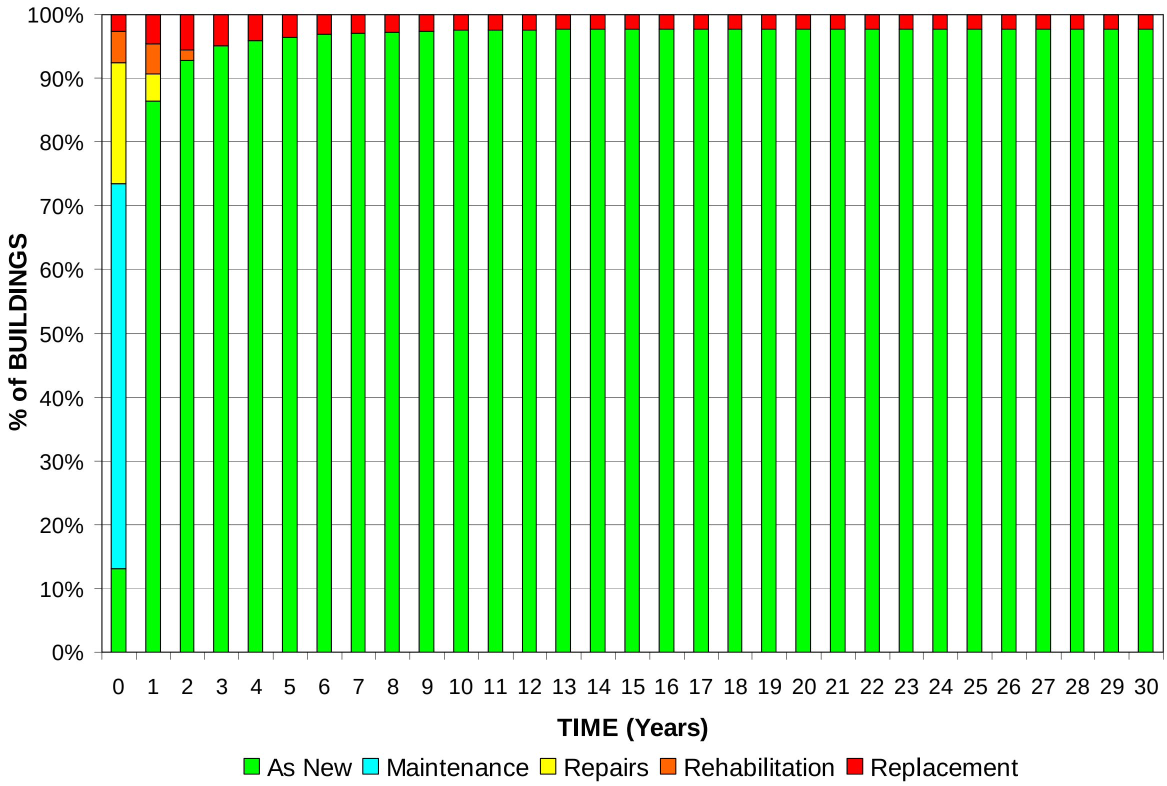


Figure 9: Option 2 – "Top-down Approach"

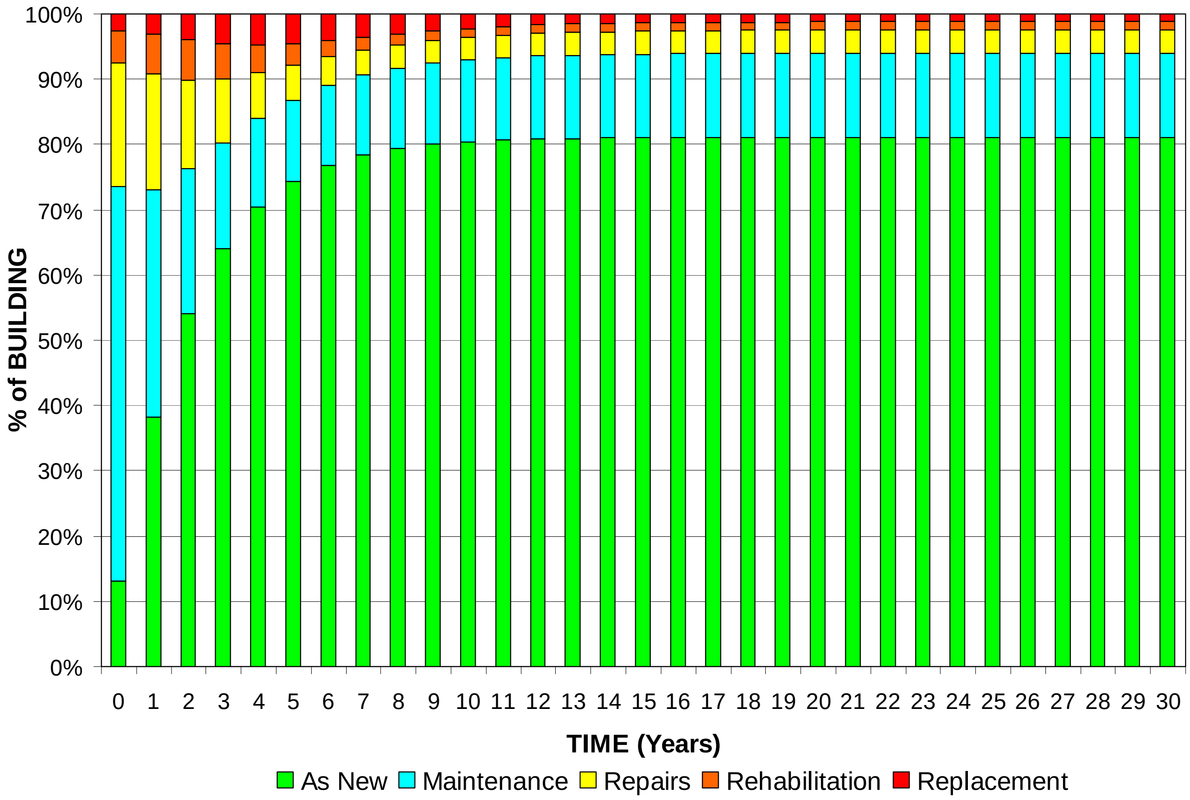


Figure 10: Option 3 – "Balanced Approach"

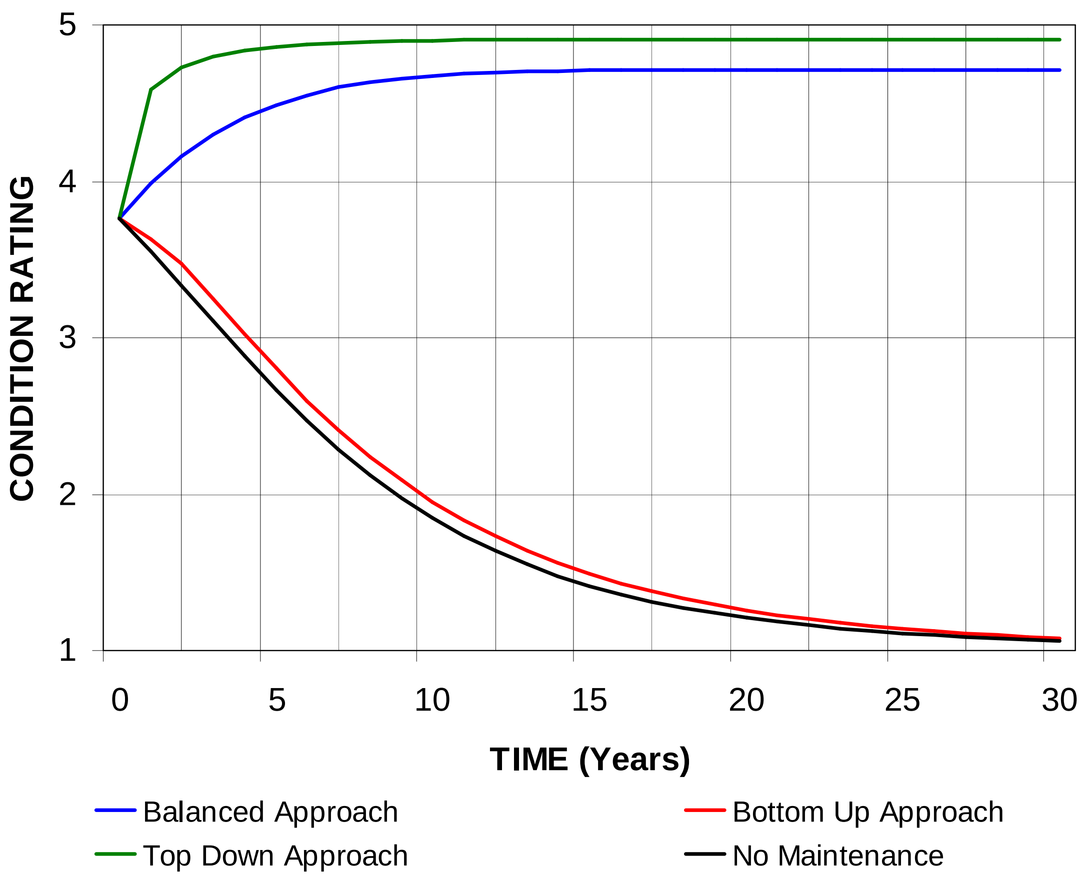


Figure 11: Change in Average Condition over Time for Options 1,2 and 3

From F… fference
betwee… Option 2
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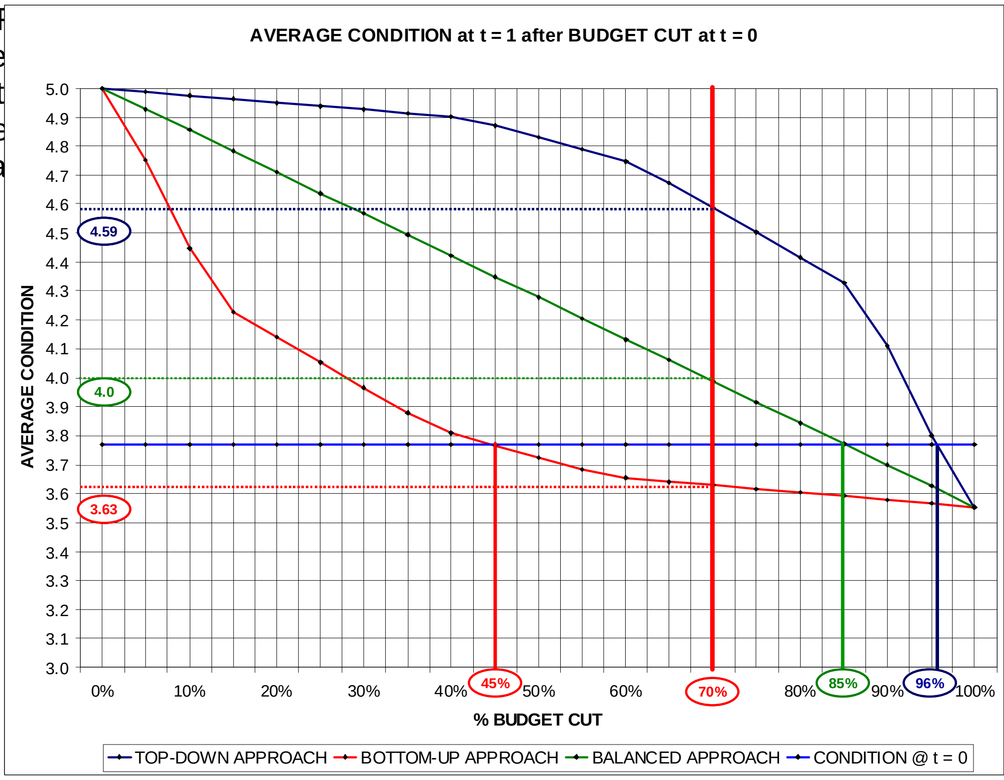

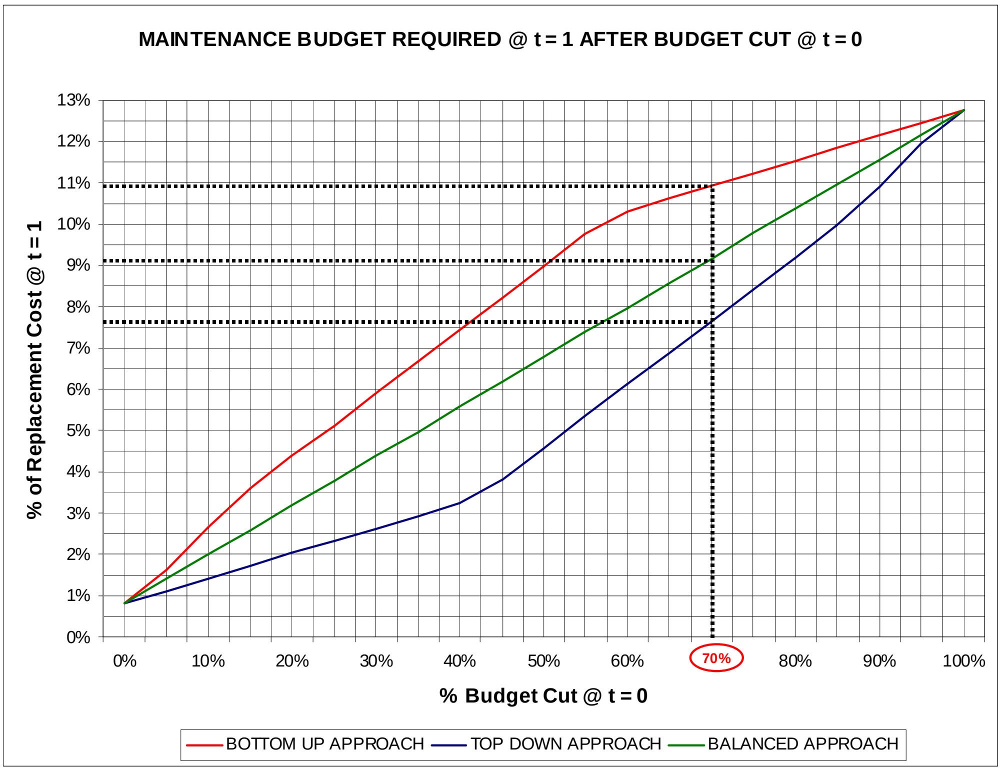

Figure 13: Maintenance Budget Required at t = 1 after Budget Cut at t = 0

Figures 12 and 13 above provide a graphic illustration of how the consequences of budget cuts and allocations can be quantified. Armed with these two graphs the maintenance manager can defend the maintenance budget against cuts by being able to quantify the change in condition and cost implications as shown in Table 3 below.

Approach	0% Budget Cut			70% Budget Cut			Cost of Budget Cut
	t = 0	t = 1	Total	t = 0	t = 1	Total	
Bottom up	R570m	R75m	R645m	R170m	R982m	R1,152bn	R507m
Balanced				R170m	R825m	R995m	R350m
Top down				R170m	R680.5m	R850.5m	R205.5m

Table 3: Cost of Budget Cuts

5 Conclusion

Form Figures 5 to 13 the following conclusions can be made:

Option 1: In Figure 8 the change in the average condition of the asset portfolio is shown. From this it is clear Option 1, the “Bottom Up” approach, is the wrong option because there is no improvement in the average condition. This is because assets in Condition 1 require all the available funds and nothing is left to prevent assets in other conditions to deteriorate. In Table 2 it can be seen that in Option 1 only 2% of the assets can be attended to with the available funds, which is less than the 3% of the assets falling in Condition 1. The problem is that there is not enough money in the budget to attend to all the assets in Condition 1, while assets in other conditions are left to deteriorate to Condition 1 at a rate faster than what can be returned to Condition 5 with the available budget. It is interesting to note the resemblance between the Bottom Up approach and no maintenance (Figure11).

Option 2: Option 2, as illustrated in Figure 9, shows a remarkable improvement of 22% in the average condition over the first year notwithstanding the 70% budget cut. The main problem with this approach is that initially nothing is done about the assets in Conditions 1 and 2 until such time when assets in Conditions 4 and 3 have been reinstated to Condition 5. This is not acceptable to decision makers, especially politicians, as it creates the impression that complaints about assets in a bad condition are not attended to. It is interesting to note that there will always be assets in Condition 1 because the average lifespan of buildings is about 50 years, which means 2% must be replaced every year.

Option 3: While Options 1 and 2 are the two extremes, the results shown by Option 3 not only is realistic, but also proof that even with a massive budget cut of 70% it is still possible to make a change provided that funds for maintenance is allocated to the maintenance of assets in all condition categories. Compared to Option 2 the initial results may be less impressive (6% improvement in the average condition over the first year), but the maximum assets in Condition 1 at any stage is less than in the case of Option 2. Option 3 also enables the Maintenance Manager to attend to the most urgent cases in Conditions 1 and 2, and at the same time create the impression that the maintenance actions are well planned and complaints are attended to.

It is possible to forecast the consequences of decisions in maintenance management if the change in condition can be quantified. The Maintenance Manager should base all maintenance budget allocation decisions on the change in condition that could be achieved through the allocation. The size of the budget cut is not important, but rather how the available Maintenance Budget is allocated. If the maintenance budget allocation is less than what is required it should not create panic, provided that the available funds are allocated to all condition categories in a balanced manner.

It should also be remembered that it costs less to maintain an asset in a good condition than to return the asset to a good condition once the condition has deteriorated. Condition deterioration should be prevented through preventative maintenance.

The solution to budget cuts is the implementation of a balanced Asset Preservation Programme that provides for a Maintenance Programme (assets in Conditions 5 and 4), a Rehabilitation Programme (assets in Conditions 3 and 2) and a Replacement Programme (assets in Condition 1). Funds should be allocated to all three programs to ensure that all condition categories are addressed in a balanced manner.

6 References

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