DESIGNING FOR MAINTENANCE

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DECLARATION

I, the undersigned, hereby declare that this document represents my own work in all respects and that no part thereof has been copied from another source without properly referencing thereto and that this document has not been previously submitted for any degree or diploma at another tertiary institution.

Signed on this …… day of January 2006

……..
Melvin Syce

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ABSTRACT

This treatise is a study of the methodology and the thought processes followed when buildings are designed, in order to determine to what extent, if any, designers consider the need for buildings to be maintained long after they walk off site and part with the project. The concept of taking future maintenance requirements into account as part of the design process is referred to as “designing for maintenance” (DFM).

It can be assumed that, from a professional perspective, designers must keep the client’s needs in mind when designing. Facilities managers face the challenge of balancing a budget with maintaining a functional building – a dream building would be a maintenance-free building.

Armed with the knowledge of DFM it is hoped that future buildings will be designed in a manner that will facilitate maintenance, thereby achieving significant savings on the life cycle costing of buildings.

Buys (2004) suggests that designers should adopt a more open-minded approach toward maintenance during the design stages of buildings. Maintenance, with reference to access, methods, material and funding, could benefit from this approach, with a positive effect on the life cycle costing of a building. In order of priority when starting a building project, the design process is at the top of the list. Because this process happens right at the outset of a project, it is important to address the level of maintenance awareness that goes into designing, at this stage.

The research concludes that one of the methods which could have a permanent effect on designers’ awareness of DFM would be to include it in the subjects taught at schools where designers are trained. This idea was discussed with a number of lecturers in this field and they were all in favour of this approach.

There is a perception that built environment practitioners and professionals such as architects and contractors in the various fields related to the built environment, often engage in their particular task as if they exist in isolation from the project as a whole and from the rest of the project team.

However, it is becoming increasingly evident that all built environment aspects are interwoven and interlinked, and that all are part of a larger context. With reference to the built environment as a whole, no action or element exists in isolation from a larger web of activity.

The challenge, to nurture within students an awareness of the range and interconnectedness of elements and processes that contribute to the holistic idea, rests with the educators in the design fields, because it is clear that the final impact of any project relies to a large extent on what was specified by the designers in terms of materials and construction methods. The impact of the world's six billion inhabitants on the environment is clearly a critical issue but does little to influence the actions of most design professionals.

Documented experiences should serve as valuable tools to guide designers towards making more educated decisions on building design. Built environment professionals should educate themselves about the range of issues involved in the analysis, design and production of the built environment and the interaction between these factors.

Keywords: Maintenance, Design, Costs, Buildings, Obsolescence.

ABBREVIATIONS USED IN THIS STUDY

BM	-	Benchmarking
BSI	-	British Standards Institute
DFM	-	Designing for Maintenance
FET	-	Further Education and Training
FM	-	Facilities Management
IT	-	Information Technology
LCC	-	Life Cycle Costing
NMMU	-	Nelson Mandela Metropolitan University
PET	-	Port Elizabeth Technikon
POE	-	Post Occupancy Evaluation
SACAP	-	South African Council for Architectural Practitioners
SAIAT	-	South African Institute for Architectural Technologists
Vista	-	Vista University Port Elizabeth

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CHAPTER 1 – THE PROBLEM AND ITS SETTINGS

The design and production processes in the built environment can be viewed as a play on a stage where the ‘actors’, or decision makers, each have their own goals and motivations. As they interact with one another over specific development issues, they constitute an organisational framework for the evolution of the built environment.

1.1 INTRODUCTION

The construction phase begins with the development of the project design, which is based on the approved schematic design determining building materials and methods. Once the construction is completed, the developer has to search for and manage tenants, collect rents, and generally maintain and administer the project or sell to new owners. This is the facilities management stage of the process. A building’s life span can be 100 years, and beyond. The tendency is for maintenance costs to escalate over this period and it is therefore important to bear this in mind during the design stage. If this is not done, an investment can become a financial burden.

1.2 THE RESEARCH PROBLEM QUESTION

Can designing a building more effectively contribute to more effective maintenance of that building, thereby adding value to the life cycle costing of such a building?
Does this mean that the aesthetic contribution of the design profession should be seen as less important, in order to achieve DFM?

1.2.1 Problem statement

Buildings need to be maintained long after they have been commissioned.

Bearing in mind that maintenance could account for up to 30% of a company’s budget, the question that should be asked is: Should maintenance be an important consideration during the design stages of a building?

"The efficiency, convenience, life span, economic viability and appearance of any building can be affected by decisions taken and actions performed at any time in the history of a building project, from its initial conception to its final demolition. Designers should be involved in all these decisions, and their relationships with the other participants are of vital importance," (Mills 1996).

1.2.2 Sub-problems

- How does DFM affect suppliers of material?
  It is common knowledge that certain materials have an industry life span – which refers to the length of time a certain product is likely to be in demand for various reasons, such as:
  - Resources available to manufacture the product,
  - Trends supporting like or fashionable products, and
  - Economic influences on the market, etc.

- Is ignorance of DFM driving the industry to come up with more innovative methods of achieving maintenance on buildings?
  Assuming that some designers are ignorant of the fact that they can positively influence the life cycle costing (LCC) of such buildings by taking DFM into account, therefore:
  - Methods are developed to fulfill the role of supporting longevity of materials by maintaining them effectively.
  - Hard-to-reach areas have forced industry to come up with specialised equipment such as lifting equipment, in order to address such problems.
  - Materials are designed and manufactured to withstand specific wear.

1.3 HYPOTHESES

The following hypotheses have been formulated against a background of discussions (with maintenance personnel, contractors, suppliers and colleagues) and the review of related literature and general perceptions:

The first hypothesis

The architect's attitude is a hindrance to designing for maintenance and it is suspected that designers are concerned only with the aesthetics of their buildings.

This study investigates the possibility that architects are more concerned with the visual impact of their buildings than with the practical implications of carrying out maintenance on the building. The saying goes: "He is only as good as his last project". Therefore, when the opportunity arises, the architect would attempt to design an impressive structure, leaving the problem of cleaning and maintaining it to the facilities managers.

The second hypothesis

No methods and procedures exist that can assist with the successful implementation of DFM.

The third hypothesis

Architects are not well informed on the topic of DFM and therefore do not rate it as important.

1.4 DELIMITATIONS

This study has been conducted from the perspective of public institutions, and tertiary education institutions specifically, which rely largely on government subsidies for their funding. Such institutions tend to have limited maintenance budgets as well as specific maintenance needs and challenges. The conclusions of this study may not be relevant to the private sector where owners may have more capital to spend on the maintenance and upgrading of their buildings.

DFM may be a more significant consideration in public buildings such as hospitals, schools and tertiary education facilities. Some buildings need to be more robust due to their function and the activities which take place in and around them. Hospitals, for example, are home to large numbers of movable items, such as stretchers and wheelchairs that can damage floors, walls, doors etc. It therefore makes sense that places like these should be designed to facilitate maintenance.

A further delimitation relates to the questionnaires used in the research. It is not possible to exercise control over who completes the questionnaire.

1.5 AIM AND MOTIVATION FOR STUDY

The aim of this study is to establish whether increased awareness of maintenance during the design stages of a building would have an effect on the life cycle costing of a building, specifically the maintenance costs. Is there a gap between the designing and the maintenance of a building?

Extensive studies have been done on the two subjects of design and maintenance as independent functions. However, only a few authors have briefly touched on the link between these two subjects – how design affects maintenance.

Another major motivator for DFM is building preservation. Land on which to build is becoming increasingly scarce. Demolishing buildings in order to rebuild is costly. A solution would be to design buildings to last longer. That can only happen if maintenance is considered in the design of buildings.

1.6 IMPORTANCE OF THE STUDY

The intention of this study is to determine whether sufficient evidence exists to suggest that the maintenance of buildings costs more due to poor design at the inception stages.

It is argued that it is important to create awareness in the minds of designers that buildings need to be maintained after completion and that maintenance should be as affordable as possible in order to enhance the life cycle costing of such a building.

Clients and designers alike should become more aware of the possibilities which exist to have buildings designed in a manner that can reduce maintenance. This holds numerous benefits, the resulting reduction in maintenance costs being the most important.

The involvement of experienced maintenance managers during the design process should become more important because clients who understand the importance of DFM would require that all possible DFM aspects be assessed and effectively dealt with during the design phase.

The most likely person to suffer financial loss as a result of ignorance of DFM would be the owner of the building. Therefore it is important to determine if DFM is an applicable phenomenon that can assist with the preservation of buildings in a manner that proves to be cost effective.

The South African Government's "Macro-economic Strategy on Growth, Employment and Redistribution" (1996: 17) states, *inter alia*, that "this strategy envisages a substantial acceleration in government investment spending, together with improved maintenance and operation of public assets". Owners such as government are investing more in infrastructure. These types of buildings should be built in line with DFM principles.

It is no secret that tertiary institutions are receiving reduced subsidies from the government. This suggests a need for a more pro-active approach to the maintenance of their infrastructure. Executive management of institutions should adopt "a stitch in time saves nine" approach. This pro-active approach should start right at the beginning of projects – that is, at the design stage of the building.

The academic enterprise does not exist without facilities, and their condition is paramount to the institution's ability to sustain programmes (Kaiser 1990). Van der Have and Armstrong (1996: 343) state that "decisions negatively impacting the physical appearance of the campus can turn away potential students, researchers and special events – all of which have an impact on budget".

Management of tertiary institutions is spending a very low proportion of their total budget on maintenance. A maintenance budget based on the previous year's spending plus adjustments for inflation could become a recipe for disaster (Buys 2004).

Building projects have three main “life cycle phases”:

- planning and development
- procurement, and
- operation and management.

Brandon (1997: 154) states that “there is always the nagging doubt that if we don’t take life cycle costing into account then we are not really providing the best solution for our clients”. This research will endeavour to highlight the important role that design, as part at the inception phase of the project, plays in the final phase of a building – its operation and management.

1.7 ASSUMPTIONS

The following assumptions are made:

- The need for maintaining buildings will carry on for as long as we build them.
- Owners will always try to cut down on maintenance budgets.
- The respondents to the questionnaires are well informed and well qualified to give quality feedback on the information requested.
- The responses are thoughtful and sincere.
- Suppliers do not continue to keep stock of products for long periods in order to meet their clients’ needs for maintenance. Rather, they renew products often to keep up with trends. Doing otherwise would not make good business sense.
- Should designers become more aware of DFM, the cost of maintaining buildings could be reduced, thereby making the life cycle costing of a building more viable.

1.8 DEFINITION OF TERMS USED IN THIS STUDY

Buildings: Any structure erected that would require some form of maintenance afterwards.

Designers: Any person involved in some form of design work relative to the construction of a building, i.e. architectural or engineering.

Maintenance: Refer to definition of maintenance in literature

Maintenance management: The organisation of maintenance with an agreed strategy (Vanier & Lacasse, 1999).

Brainstorming: A widely used creative technique for generating a large quantity and broad variety of ideas for alternative ways of solving a problem or making a decision. All judgement and evaluation are suspended during the freewheeling generating of ideas.

Depreciation: An accounting device that distributes the monetary value (less salvaged value) of a tangible asset over the estimated years of productive or useful life. It is a process of allocation, not valuation.

Life cycle costing (LCC): An economic assessment of an item, system, or facility and competing design alternatives considering all significant costs of ownership over the economic life, expressed in terms of equivalent rand, or, the present value of the total cost of an asset over its operating life, including initial capital cost, occupation costs, operating costs and the cost or benefit deriving from disposal of the asset at the end of its life (Chanter & Swallow. 1996).

Maintenance costs: The costs of regular custodial care and repair, annual maintenance contracts, and salaries of facility staff performing maintenance tasks.

Obsolescence: The condition of being antiquated, old fashioned, out of date, resulting from a change in the requirements or expectations regarding the shelter, comfort, profitability, or other dimension of performance that a building or building

subsystem is expected to provide. Obsolescence may occur because of functional, economic, technical, or social and cultural change.

Post Occupancy Evaluation (POE): Collection and analysis of information, particularly from users, to assess how well a facility's performance matches user needs and design intent.

Replacement costs: Building component replacement and related costs that is included in the capital budget and are expected to be incurred during the study period.

1.9 ORGANIZATION OF THE REMAINDER OF THE STUDY

Chapter 2 documents the review of related literature around different aspects that influence DFM. Maintenance, Design and Life Cycle costing are considered to be the most important. Literature around each of these topics are discussed in this chapter in an attempt to give an insight into the dynamics of how these influence DFM

Chapter 3 cover the design of the research and the methods embarked upon to achieve the end result of this study. It also discusses the data collection methods and procedures. In order to establish a clear picture of the phenomena that influence my research topic directly or indirectly I am discussing these to give more insight on how it affects DFM.

Chapter 4 discusses the results from the various methods of sampling and present them in a manner as described in Leedy. This chapter also deals with the testing of the hypotheses.

Chapter 5 summarises the findings, concludes the document and attempt to recommend possible direction forward to try and deal with the perceived problem.

CHAPTER 2 – LITERATURE REVIEW

2.1 INTRODUCTION

Saunders, Lewis and Thornhill (1997: 79) suggest that "it is necessary to have a clear picture of the phenomena on which you wish to collect data prior to the collection of the data". The aim of this chapter is therefore to explore and gain insight into the concepts of maintenance, design and life cycle costing in order to place the research in context.

2.2 MAINTENANCE

There can be no better explanation of why maintenance is required on buildings than this statement from Ellis, Hutchinson & Barton (1975:3):

> "That which is taken from the ground tends to return to the ground".

This was their thinking some 30 years ago on the subject of maintenance. Despite the dynamically changing environment that has affected existing buildings and the professions over the 30 years; the need for maintenance on buildings has not lessened. Resources for maintenance, on the other hand, are constantly on the decrease.

A number of recent studies have addressed issues of maintaining buildings. Professions, strategies, procedures and methods have all been investigated, and some fields have been altered and/or added at some stage over the last 30 years. All of these studies have one common denominator: reducing the proportion of budgets allocated to maintaining buildings. Awareness of the importance of building maintenance stems from the fact that buildings are getting older and the amount of money spent on maintenance is increasing annually despite some of these efforts.

One can safely assume that maintenance starts when the building is handed over to the client at the end of the construction period. The amount of maintenance required will depend on the type and quality of material used, construction techniques, quality

of workmanship, use of the buildings, and the maintenance policies of the organisation.

2.2.1 Definition

O'Sullivan (1987: 269) defines maintenance as "an activity carried out on and around buildings from handover to demolition, to sustain them to an acceptable standard". Lee (1988) and Wordsworth (2001) describe these actions as "preventative maintenance" and "corrective maintenance" (the distinction between these two terms is discussed later in this chapter).

Maintenance management, like facilities management, is taking on a completely new meaning in today's competitive world. The most significant obstacle confronting building maintenance managers today is, having to do more with fewer resources. As a result, organisations are forced to take a hard look at ways to reduce building maintenance costs.

Shohet, Puterman and Gilboa (2002) state that there is a growing awareness worldwide of the importance of the maintenance of constructed facilities due to the growing complexity of buildings, and the higher proportion of maintenance costs in the life cycle costs of buildings.

Various definitions of maintenance exist among maintenance managers, as defined by various authors and institutions. They include:

a. Maintenance includes the costs of regular custodial care and repair, annual maintenance contracts, and salaries of facility staff performing maintenance tasks. Replacement items of minor value or having a life of less than five years are included as a part of maintenance i.e. replacing light bulbs and repainting are normally included under the maintenance category (Kirk and Dell'Isola, 1995). It may be more descriptive to describe the latter work as "running maintenance", together with other work such as cleaning floors and windows, replacing broken tiles, etc.;

b. Work undertaken in order to keep, restore or improve every facility, i.e. every part of the building, its services and surrounds, to a currently acceptable standard and to sustain the utility and value of the facility (Chanter and Swallow, 1996); and

c. The function of keeping assets in, or restoring it to, good operating condition, keeping its original productivity capacity. It includes all the following actions: servicing, testing, inspection, adjustment/alignment, replacement, troubleshooting, calibration, modification and overhaul (Pauw, 1993). This definition relates more to the maintenance of machinery and equipment.

Certain key aspects can be drawn from the above list, namely:

- Maintenance involves actions that must be performed.
- Maintenance work must be carried out regularly.
- All of these actions have financial implications for the owner or organisation.
- An understanding of the performance of the components that need to be maintained is essential in order to keep them up to an acceptable standard.

However the task of maintenance is defined, it needs to be executed in an organised fashion.

2.2.2 Classification of maintenance

Maintenance can be classified into two main categories – planned and unplanned. Planned maintenance systems tend to have higher overhead costs than unplanned systems, but should, if properly devised, lead to fewer breakdowns.

2.2.2.1 Planned maintenance

Hutchinson, *et al* (1975: 347) defines planned maintenance work as “the necessary work organized and carried out with forethought, control and the use of records to a predetermined plan”.

Planned maintenance can be sub-divided into corrective and preventative maintenance.

- **Corrective** – Seeley (1987: 3) defines planned corrective maintenance as “work carried out after a failure has occurred and intended to restore an item

to a state in which it can perform its required function". This involves maintenance work carried out after a failure for which advance provision has been made in the form of materials, labour and equipment. Chudley (1991) defines corrective maintenance as work carried out after a failure has occurred. It can range from a simple fuse replacement to the complete replacement of a major component.

- **Preventative** – Seeley (1987: 2) defines this as "work carried out at predetermined intervals or corresponding to prescribed criteria and intended to reduce the probability of failure or the performance degradation of an item". Magee (1988: 239) describes preventative maintenance as "those maintenance activities which are executed to ensure the continuous operation of a facility, system, or piece of equipment". The frequency of the maintenance actions on a specific part will be determined by the manufacturer's specifications, maintenance inspections, or the failure-frequency of similar parts or elements.

Preventative maintenance policies should be put in place. These policies could contribute immensely to the prevention of major breakdowns in equipment or the failure of materials or components, which normally result in costly maintenance work.

It is therefore essential for all organisations to implement a preventative maintenance management policy so that maintenance expenditure can be kept to a minimum (Buys 2004). Management may argue that it is costly to implement a policy of preventative maintenance management as equipment, parts or materials may be replaced prematurely. The maintenance programme must thus be continually updated and evaluated to ensure that the cost of frequent maintenance does not exceed the cost of downtime and fixing of the equipment or replacing of the part or material. A good balance between the cost of preventative maintenance and the cost of corrective maintenance should be managed in order to achieve optimum use of resources.

Preventative maintenance work can be categorised according to the scope of the required work, i.e. major repair or restoration, periodic maintenance, or routine day-to-day maintenance (Mills 1994). The first category includes work that frequently incorporates major improvement to bring a building up to current standards, e.g. re-

roofing, rebuilding defective walls, or replacing a mechanical hoist in a factory. This can also be referred to as shut-down maintenance. Periodic maintenance is work of slightly less magnitude and is usually done by in-house maintenance staff or outside contractors. This could be work such as internal or external painting.

Routine day-to-day maintenance consists of regular work such as checking whether gutters are clean, servicing mechanical and electrical installations or equipment, and replacing faulty light bulbs. Mills also emphasizes the important interrelationship between these three categories in that they operate with the relentless force of a law, i.e. neglect of routine maintenance and preventative measures leads to more extensive periodic maintenance and, in the long run, major repair or restoration which could have been avoided or postponed.

2.2.2.2 Unplanned maintenance

This type of maintenance refers to work that may result from unforeseen breakdowns. Damage caused by external forces such as storms, floods, earthquakes, or power surges, is also classified as unplanned maintenance due to the fact that this type of work is mainly of a corrective nature. Seeley (1987) argues that maintenance work can also be categorised as predictable or avoidable. The former is regular periodic work that may be necessary to retain the performance characteristics of a product as well as that required replacing or repairing the product after it has achieved a useful life span; the latter is work required to rectify failures caused by incorrect design, incorrect installation or the use of faulty materials.

2.2.3 Impact of Design on Maintenance Work

It is said that when working on difficult to maintain areas, some maintenance personnel may feel like the person who has just bought a new vehicle that, when it comes time to change the oil, leaves him scratching his head, wondering why the designers of the vehicle didn’t make it a little easier to maintain. This problem is quite apparent on some buildings.

For example, some buildings do not have the catwalks that usually ease the maintenance on high bay light fittings. All too often, maintenance-friendly designs are sacrificed in the name of competitiveness or cost. The plain and simple truth about

this is that this drives up the cost of maintaining simple items. So what is the maintenance manager to do, especially when maintenance crews have been reduced to the bare minimum?

The achievement of good design in the planning of buildings as worthy objects is understood and recognised, but less understood and appreciated is the need for constant maintenance (Reekie 1972: 131). Means of eliminating or minimising the effects of time, weather, destructive organisms and wear should be considered at the design stage of any building.

Completely maintenance-free buildings are still only a dream. There is ample evidence from observation and research as to how constructional failures, staining, soiling, deterioration and damage are caused. In the arrangement of elements, methods of assembly, and choices of materials, surface treatments, etc., attention should be paid to the prevention and/or reduction of known causes of failure.

On the maintenance front, constant vigilance and repetitive attention are necessary to stay abreast. At tertiary institutions, not all buildings can be closed down completely, or even partially, to allow the maintenance crew to do essential work. This is one of the key considerations to be kept in mind by designers when designing buildings for specific purposes. The usage of some university buildings has as much as doubled as student numbers have increased over the last few years. In addition, most of the university buildings are used almost all of the time – not only during the day, but also in the evenings (lecture halls, library, offices, study areas, hostels, etc are all in use both during the day and at night). New courses catering for adult learning also contribute to the usage of these venues after hours. The types of buildings affected would be both administration buildings and lecture venues, of which the latter are used over weekends and even during recess periods.

At a university, the maintenance staff will always face the challenge of gaining access to buildings to undertake any form of corrective maintenance work.

Excessive maintenance costs that occur during the occupancy stage of a building's life, that is, after the construction stage, can be minimised to a large extent if the life cycle cost approach is used during the design stages of a building. Clients should be

aware of, and consider, the potential cost of maintenance when initial decisions are made around the capital costs of investing in property.

Careful consideration should be given to the following:

- Choice of materials. This always impacts on maintenance costs.
- Access for maintenance work to be carried out easily, quickly, safely and economically with minimum disruption to occupants or users – adequate working space, accessibility, sufficient lighting and ventilation.
- Availability of replacement materials (Mills, 1994).

To what extent is maintenance considered when materials are specified during design? For the architect to specify the very best obtainable material and appliances for a project is a fairly sure but expensive way of reducing future maintenance, but there are many materials that are almost as good as the best and are considerably less expensive. This can range from structural timber and cabinetwork to toilet accessories and mechanical and electrical devices. A study of structural, electrical and plumbing codes will be rewarding, as will be a request for suggestions from contractors. The author in his experience has found many materials and devices which are able to perform efficiently, which are trouble-free over long periods of time, and which can be considerably less expensive than some of their highly touted competitors.

Reiner (1979) reports that "…. the architect should specify the very best obtainable material and appliances for a project …", Buys (2004) states that it is not uncommon to find that buildings are inherently expensive to maintain because of inappropriate priorities applied during the design stage.

The idea of DFM has been contemplated from as far as 30 years back. Lee (1988) lists the following risks which can be regarded as a starting point for a checklist to be used during design:

1. Failure to follow well established design criteria in the choice of structural systems and selection of materials;
2. Ignorance of the basic physical properties of materials (for example, allowance for the differing thermal and moisture movements of materials used in combination);
3. Use of new materials or forms of construction which have not been properly tested in use;
4. Misjudgement of user and climatic conditions;
5. Poor communication between different members of the design and construction teams; and
6. Incorrect construction methods.

All maintenance issues and problems are not always design-related, but design is unquestionably a major part of their solution. If it is believed that design makes the difference, then we have to accept its “complicity” in social problems and its responsibility to collaborate and address them. The act of building is an act of creative destruction, and it is the designer’s responsibility to make sure his or her ideas and ideals are worth the trouble.

2.2.4 Strategies in Maintenance

In order for the maintenance function to run effectively, certain strategies need to be in place to ensure maximisation of resources against the need for maintenance.

Preventative maintenance is planned work. Maintenance personnel should anticipate the completion of all preventative maintenance work, as in all cases it can be predicted. Major failures, special events, and other unplanned work will occasionally interrupt the schedule for preventative maintenance work. This often results in the postponement of scheduled work or sometimes the cancelling of some jobs. In cases like these the tasks at the lower end of the priority scale are deferred. Thus the ranking of maintenance on a priority scale becomes crucial when a decision needs to be taken as to which job to defer and which jobs must continue.

2.2.4.1 Best Practice Strategies

Buys (2004) ranked the criteria for best practice in maintenance management systems. The top five, in order of importance, were:

- The establishment of regular inspection cycles to identify maintenance work;
- Adopting a life cycle costing approach during the design stage of a building project;
- Having a sound maintenance management policy to set minimum standards;
- Setting priorities to determine the sequence of maintenance work; and
- Good communication at all levels of the institution.

It is significant that the consideration of maintenance during the design stages of any building is ranked as the second most important requirement. As indicated in the LCC section of this study, this aspect can drastically reduce the annual budget on maintenance to buildings.

Lee (1988) confirms that building maintenance should be planned and managed as efficiently as any other corporate activity and should not be done purely as a reactive measure.

2.2.4.2 Recording

As maintenance tasks are signed-off as completed, they should be documented for future reference. This will give maintenance managers, *inter alia*, a tool to make predictions regarding future maintenance work based on a fairly accurate platform.

This recording should focus on the performance of materials and/or parts. Items that require constant maintenance or repair work can be highlighted and the problem eliminated. Unexpected failures can be diagnosed early and more easily. This can often be traced back to a recent repair task and, as Magee (1988) states, the best-suited maintenance staff can then be assigned to do the work.

Keeping a record of the personnel member or subcontracted company who performed the task previously would be extremely helpful. Buys (2004) opined that the recorded data should, however, be “usable” data and not just “stored” data; i.e. it should be in a form which, once analysed, can be used to provide useful feedback to assist in future maintenance management decisions.

2.2.4.3 Maintenance reports

It should be possible to draw a report on work done in order to obtain information on all completed, current and future maintenance work, when required. Maintenance managers have to make important decisions regarding maintenance work to be carried out, such as whether the work must be carried out immediately or whether it can be deferred, to redirect or re-allocate resources for maintenance work to be done, and to determine whether an item should be repaired or replaced. To make these decisions, they must have all the relevant information available, such as cost implications of the various alternatives and minimum acceptable standards. Apart from being kept informed of the costs of all maintenance work continuously, maintenance managers should also ensure that all maintenance work is completed timeously. Postponed maintenance work may eventually lead to major cost implications for the organisation as it may become impossible to reinstate the item, it may cause damage to other items, or it may have to be replaced, resulting in a shutdown of operations. An effective maintenance work report-back system should be in place, in order to enable maintenance managers to:

- Ensure that all maintenance work is carried out;
- Monitor the progress of work;
- Re-schedule resources if necessary; and
- Order additional material or parts if necessary.

2.2.4.4 Research

Operations research techniques could assist decision-making within the maintenance department. DFM is a typical area to be researched for effectiveness as it has been shown to have serious shortcomings. A prime aim should be to improve the efficiency and productivity of maintenance methods (Seeley, 1987).

2.2.4.5 Setting priorities

Funds for carrying out maintenance tasks are becoming scarcer; therefore it is becoming more essential to strive for “value for money” in maintenance programmes. Buys (2004) reasons that a maintenance plan based on a balanced assessment of priorities, and up-to-date knowledge of the condition of the buildings, will help to ensure that difficult long-term decisions are not outweighed by short-term considerations.

Lee (1988: 254) and Magee (1988: 161) list the following categories for setting out priorities:

a. Emergency – work which truly stops the use of the facility; work should commence immediately and continue until the facility is restored to sufficient use e.g. water flow from a broken water pipe must be stopped immediately;
b. Urgent – work which, while not completely prohibiting use of the facility, represents a threat to full facility use, and includes threats to the safety of the occupants of the building e.g. malfunctioning fire alarm or sprinkler system or a broken light bulb in a workshop where insufficient lighting could lead to errors in some critical task; work is normally started on the day the problem is reported;
c. Routine – status assigned to the majority of work requests received and which does not limit or threaten facility use or occupants. It is normally remedied within five to seven days e.g. a single defective light bulb; and
d. Deferred – work that is not necessarily required but is desirable, e.g. painting of an office, replacing ceiling tiles or carpets.

From these descriptions of maintenance, it is understandable that Government-funded organisations, such as universities, will feel increasing pressure to erect buildings that will be easier and cheaper to maintain, with the aim at keeping costs to a minimum. From a top management perspective it is always easier to cut back on the maintenance budget, even though this can have a negative impact on the life of the building in years to come.

2.2.5 The Evolution of Facilities Management

Having permanent maintenance management in place is a new trend that is starting to emerge as building owners more and more realise the importance of the cost of maintenance in relation to the overall running costs of property, hence the introduction of facilities management (FM) as a profession.

With the constant evolution of the FM profession one can almost accept that the professional solution to DFM would stop here. Facilities managers should take the responsibility for initiating and driving DFM along with the designers.

Cutting down on maintenance costs, purely as a means of saving money, is not good management practice. This leads to decay in buildings that further leads to substantially high costs to correct at later stages. Buys (2004) stated that in this way a vicious circle of constant decline builds up at a faster rate than the original cutback in maintenance might suggest.

This could be regarded as one of the most important reasons for the rapidly increasing importance of facilities managers. It has evolved into a boardroom level of profession, highlighting the effectiveness of talking to the top decision-makers in organisations regarding maintenance matters.

2.2.6 Summary

This section documents the maintenance of buildings as assets. A review of the applicable literature has been conducted in order to define and categorise maintenance. The impact of design on maintenance, effective maintenance strategies, and the evolution of facilities management has also been reviewed. The intention is to give an insight into the action and the impact of maintenance, and the benefits of effective maintenance strategies.

Performing maintenance on buildings can be simple or challenging, depending on the application and the location of the components to be maintained. Often cranes, high-lift equipment, etc, are required to perform the most basic maintenance procedures such as changing of bulbs, glazing, or even painting. These simple, basic maintenance procedures frequently become dangerous and even difficult to perform, and the downtime required to complete them is increased, all because of the location of the item to be maintained or the nature of the application. Even basic maintenance may be dangerous to perform simply because of the location of the item.

The objectives of maintenance are to prevent deterioration of materials or parts; to prevent the failure of components, equipment and installations (heating, lighting, lifts, escalators, fire and burglar alarm systems); to maintain decorative surfaces; to ensure the safety and health of occupants, visitors and the general public; and to maintain the value of the property – “neglected maintenance can cause the greatest loss an owner can suffer on a real estate investment” (Downs 1991: 154).

Westerkamp (1997) states that, the mission of the maintenance function are to keep assets in an “A” condition. Furthermore, the cost of maintenance itself must be minimised. This includes the cost of planned and unplanned maintenance, downtime and loss of production costs.

This is easily one of the biggest problems maintenance managers face as maintenance budgets seem to be the easiest to cut in times of financial stringency.

2.3 DESIGN

Design professions, especially architecture, have at their base a visionary charge and a utopian agenda, yet they are simultaneously driven by financial profit and political conservatism (Knox & Ozolins 1992). While much thinking is going into the design of buildings we should also start to think about designing buildings that are cheaper and easier to maintain.

This study endeavours to show that the design process can predict maintenance difficulties on buildings and that, by acting on these predictions, it is possible to minimise the cost of building maintenance.

2.3.1 Definition

Design is a word of many meanings, some of which can be imprecise and/or misleading. Design can be seen as the conscious or intentional putting together or shaping of materials to meet certain needs (Reekie 1972). The profession has evolved from a creative focus, to socially responsible and, more recently, a business orientation. It can be said that the design and planning professions have become institutions that embody a large number of contradictory identities.

This definition implies two considerations:

- The establishing and clarifying of the requirements of needs, and
- Decisions as to the best means of physical realisation within prevailing circumstances.

Design is a significant and challenging job. It requires designers to be equally interested in the built environment and the people who will own, occupy, experience and face the effects of the buildings they design.

Ultimately the object of all planning and building design is the production of an environment for efficient and happy living.

2.3.2 Education in design

Education and training are the most fertile ground for sparking a paradigm shift in design education for the construction industry's development and enhancement. A review of the outcomes of tertiary institutions' programmes and a realignment of these outcomes to place education explicitly in the context of a changing construction industry is required.

More emphasis should be placed at universities, universities of technology and further education and training (FET) colleges on teaching built environment students about the maintenance of buildings.
Students need to be trained how to:

- Identify items or components that need maintenance;
- Identify the origin of the defective work or the reason why maintenance is required; and
- Formulate the best method and procedure to execute the desired maintenance work.

Maintenance staff should also be trained to keep up with the latest technology.

Beyond the content of curricula, a much larger debate is taking place about graduates' level of preparedness for entering the design profession. Some practitioners believe that the accreditation requirements have not yet caught up with the realities of increasingly complex practice. As the list of professional services increases, the ability to introduce students to all the tasks diminishes. Most tertiary institutions therefore take the view that it is more important to teach the student to learn, and expect that the practicalities of practice be learnt on the job. However, for this to occur, the professions must have the resources to facilitate that learning, an ingredient that is absent when finances are restricted (Horwitz 2000:136).

Some practitioners indicate that when they hire recent graduates they look for applicants with strong problem-solving and computer skills and the ability to express ideas visually. They are of the opinion that whilst in-house training can overcome an individual's lack of knowledge in some facets of practice, it cannot be used to acquire the skills if the essential academic training has not been achieved. Practitioners increasingly require graduates to be able to work in teams, especially as practice is heading towards a more collaborative, and interdisciplinary mode. Yet, many graduates enter the workforce unprepared to integrate their project knowledge across disciplines and, of greater concern, show no desire to understand why this would be of any importance. Often graduates are predisposed to suspect the motivations of their colleagues in related disciplines – a practice that is usually further exacerbated in the workplace (Horwitz 2000:139).

Vigorous debate is taking place within the international professional community regarding the "generalist" and "specialist" approaches to professional training and practice. Surveys conducted within the United States indicate that architects are undertaking more and more work upstream of the actual design process with some practices focusing exclusively on this work phase. The perception is that the balance between "generalists" and "specialists" is not right (English 2002:114).

Until quite recently designers relied almost exclusively on intuitive methods, and design ability was widely held to be innate and largely unteachable. As Lawson (1994) puts it, "Society had a right to expect its designers to be responsible and accountable and have more control over their processes". After years of neglect when design methods had no place in the curriculum at all, they were finally taught and described in textbooks but, as Lawson (1994) argues, perhaps design must be learnt rather than taught.

2.3.3 Attitudes in design

Some architects convey a perception that they adopt a “don’t care” attitude towards their design with respect to maintenance; with the focus of their efforts on the building aesthetics only.

This study of DFM questions whether architects should design their buildings in a manner that would facilitate maintenance, or whether the maintenance aspect should evolve with new innovative methods to support the design of the building.

Bad design costs more. Inconsiderate attitudes towards DFM are costing building owners more money in the long run.

2.3.3.1 Journey into an architect’s mind

MacKinnon (1962) writes: “It is in architects, of all our samples, that we can expect to find what is most generally characteristic of creative persons … In architecture, creative products are both an expression of the architect, and thus a very personal product, and at the same time an impersonal meeting of the demands of an external problem.”

Architecture has evolved and changed over the last decade to an extent that would have been inconceivable a decade ago. These changes have been paralleled, in recent years, in both rapidity and scope. The alienation created by old style modernism, as represented by the post-war building boom, has finally culminated in a pluralist ideology that now runs the gamut from the machine aesthetics of high-tech at one end, through to traditional design, covering a number of gradations in between. The pluralist climate has encouraged a variety of architectural attitudes and ideologies to co-exist in a way that has re-invigorated the entire profession right across the spectrum and has allowed it to appeal to many different beliefs and tastes (Knox & Ozolins 2000).

Quinlan Terry asks: Why is it that old materials last for hundreds of years, whereas modern materials don’t,’ or why ‘old buildings are easy on the eye and new buildings not’.” In his opinion, the answers are obvious and the choice is between what he categorised as “short lived lusts of a throwaway society with their glossy, space aged structures, which suck out the earth’s resources and leave behind a scrap heap of

unrecyclable rubbish" on the one hand, and the traditional techniques of building on the other. In order to clarify the issue further, he frequently points out that traditional building techniques are not only more environmentally friendly, because they involve natural, rather than man-made materials, but also that such materials are more compatible to human sensibilities.

Norman Foster shows that "enlightened attention to detail, as well as due consideration to the needs of all parties concerned with the design, can result in highly creative architecture that also works." Thus, designing with maintenance in mind could be done with excellent results.

Tadao Ando feels that the way materials go together is the beginning of architecture.

2.3.3.2 Design methods

The majority of books on design offer criticism and analysis on the end products of the design process instead of the process of designing itself. Designers rarely reveal the methods that they use when designing.

Design methods of some talented contemporary architects were studied by Lawson in his book *Design in mind.* It can be said that all of the architects studied have extraordinarily inquisitive minds which lead them into endless searches for knowledge and understanding, which they enjoy pursuing through a process of solving other people's problems.

This further seems to lead them to be prepared to spend a great deal of time and expend considerable effort in working with their clients. Evidence suggests that design is a painful and frustrating, but extremely satisfying, process involving huge intellectual commitment on the part of the designer. It also flourishes best when there is an equal commitment from the client and clearly benefits from a close and trusting relationship between client and designer.

Design is prescriptive in that the designer's job is to tell us how things ought to be. It is expected that designs should have artistic value, yet design is more than art, for designs must not only express appropriate ideas and values but must also be usable and work; furthermore, design should support maintenance especially where maintenance budgets are expected to be low.

The observation of designers at work has never been a popular technique, since their external behaviour does not reveal much about their mental processes. Of course, designers must sell their services in the market place and so may not always describe their processes honestly. Lawson's experience, having taught design students for many years, suggests that, when they like a solution, they are amazingly creative at imagining the "logical" processes that led to that solution! They are also at times quite capable of denying both to themselves and others the obvious importance of issues which they have chosen either to ignore completely or to relegate to minor consideration. A view of design as a sequence of "assimilation", "analysis", "synthesis", "evaluation", and "communication" was reinforced by the Royal Institute of British Architects in its stage model of design practice, around which the standard practice fee was constructed.

2.3.3.3 Keeping design in mind

How is architecture, which is at the core of the design professions, responding to the call of DFM? It should adapt its preoccupations and processes to develop new paradigms to sustain this new call, ie it should design for maintenance. Without confining the architectural intuition and creativity, these professionals must strike the balance between the two extremes. An attitude that accords the poorer client the same respect as the more wealthy clients is needed. Engaging in dialogue should be at the same intense level irrespective of the wealth of the client.

Design should never be seen as purely problem-solving; this attitude would be doing the profession a disservice. A large part of the business involves identifying problems, understanding and clarifying objectives, and attempting to balance criteria for success. The layman often imagines that design starts off with a brief presented by a client. We now recognise that designers often come to understand their problems through their attempts to solve them. Sometimes testing leads to refinement of a solution or rejection thereof. In either case the designer learns more about the problem. It can safely be assumed that clients choose architects to some extent because they liked earlier designs they saw.

Well-known architect Richard Burton clearly feels that the interaction between members of the design team can be a very important influence on the design process. An argument for group work put forward by Burton and his team of three is

that the group has the advantage over the individual because ideas can become personal property or one's own intellectual territory. The strength of that territory is considerable, and the difficulty of working alone is often in the breaking of the bonds caused by it. With groups like these bonds are broken easily, because the critical faculty is depersonalised. Designers should have open and well-educated minds to be interested in a wide variety of issues.

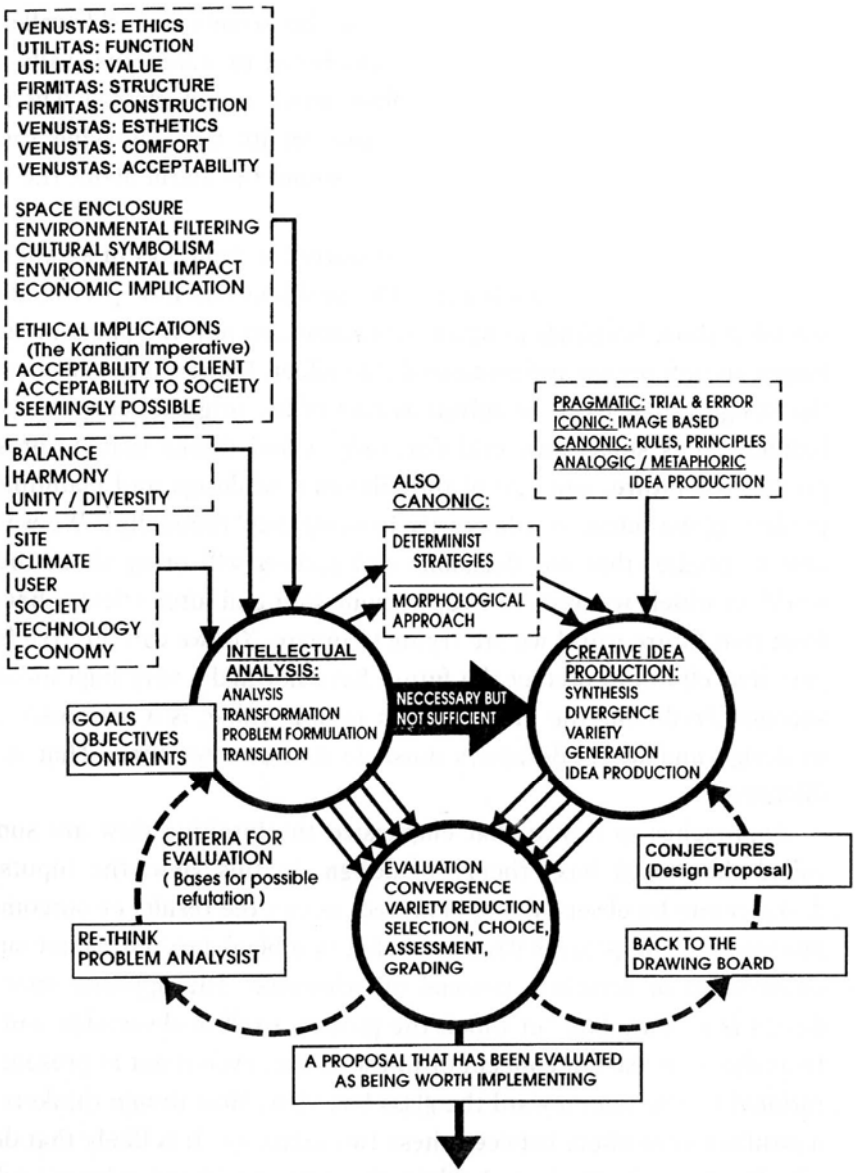


Figure 1 ***Third Model of Designing*** *based on Karl Popper's Model of Conjecture and Refutation – adapted from Geoffrey Broadbent.*

Figure 2.1 above describes the cyclical design process, listing parameters that inform design, integration of those parameters into design solutions, and criteria for analysis of design solutions (Donald P. Grant 1984).

2.3.4 Design Management

Design liability is a sensitive topic, particularly among design professionals. Designers argue that with the introduction of value management for design solutions, they will have to accept long-term liability and responsibility for their designs. They remain responsible for their designs and so it can be reasoned that they must also take responsibility for changes and recommendations made by other stakeholders. Clients also appreciate the notion of single-point responsibility, therefore it seems almost impossible to separate design liability from value management responsibility.

2.3.4.1 Designing with others

Brainstorming could be one of the best techniques to assist on a DFM project. As described earlier, brainstorming is a widely used creative technique for generating a large quantity and broad variety of ideas for alternative ways of solving a problem or making a decision. All judgement and evaluation are suspended during the freewheeling generating of ideas.

Large projects often involve client committees which can create continuity problems when staff leave or are promoted. Richard Burton feels that the higher the level of client contact in the organisation, the better the process works. Burton works hard at getting feedback from the users of the building and, in particular, he has pioneered the use of psychologists in the design process.

Many top designers emphasise the involvement of the client in the design process. Unfortunately clients are rarely trained for this role. It is, however, a different experience when the client is represented by a large committee as opposed to an individual. In scenarios like these, the representative would be the facilities manager.

Peer review, as an objective evaluation of a design by an outsider, can bring experience to a project. This will also lessen the extent to which design is a cause of building defects, that later become burdensome maintenance issues.

2.3.4.2 Using Technology

In the architecture, engineering and construction industries, computer-aided visualisation technology can cover the whole lifecycle of a product from presentation

of initial concepts to the final stages of production, and can also extend to maintenance issues. Three-dimensional walkthroughs can be created from hand-drawn sketches at the very early stages of the design process. Design teams can use three-dimensional models to communicate design intent to clients and users, and to compare and evaluate design options.

During the more advanced stages of design, three-dimensional representations can be used to check the integrity of services coordination, accessibility and maintainability. During construction, visualisation can facilitate the interpretation of design details by site operatives. The concept of visualisation is not limited to modelling physical objects but can be extended to many other fields where prediction of behaviour is required. For the purposes of this study, the application of visualisation in the process of design and construction was researched. The types of projects that made use of some of these techniques at various stages of the process are:

- Collaborative working during concept design stage,
- Design development and marketing in the house building sector, and
- Modelling of design details during the construction stage.

Education, especially through the introduction of the more technical qualifications in architecture in the early 1980s, has done much to introduce a more technical approach to thinking while designing and to encourage innovation when both students and educators began to explore the role of all participants in the profession of architecture and how other ideas and techniques could be applied, such as information technology and the use of computerised visualisation techniques. All of these developments are beginning to have a significant impact on the processes of designing. Most graduates are now equipped with a much broader understanding of the context of their work, together with an awareness of the economic implications that design decisions could have on the maintenance of buildings.

Information Technology (IT) assists in manipulating similar aspects of construction to those traditionally handled by architects and engineers through the ages. Distance is minimised by electronic communications so that members of a project team do not have to be in the same location, and designs can be presented and explained using advanced visualisation technology. Through simulation of processes before they

happen, dynamic forms of presentation and by sharing work worldwide (Rob Howard 1998), brainstorming over distance has become possible.

The production of working drawings was not envisaged until the mid 1970s. Then the benefit was expected to come from the re-use of tried and tested details. This benefit has been limited by changing styles of building and architect's belief that every project is different (Rob Howard 1998).

The effects of IT on building design are only just starting to be felt as technology provides opportunities for new forms and can simulate some of their characteristics. In future there will be more radical effects on the process of commissioning buildings, pre-assembling them as models in computers, and handing them over to their users as electronic systems to be managed like a factory.

There is a tendency to see a few spectacular developments as solving a range of problems in construction. Virtual reality is one of these and, while it's present manifestation is just another stage in the development of visualisation, its potential is for simulating buildings in many ways; not just their appearance, but their performance and the process of constructing them as well.

Nigel Cross (1977) argued that computers are intrinsically harmful to the design process. This statement is not entirely accurate when looking at DFM. The fact that computers can easily convey the message of what is inside the designer's mind makes it easier for other stakeholders to scrutinise the design in order to support maintenance. Many architects still feel that designing should be done with pen and paper through free-hand sketching. Conceptualising ideas happens more easily if a free flow action is applied. Therefore the total design process should not happen on computer solely but computers should be applied as an enhancement of the process. This is the part of the process that attempts to convey the designers' inner thoughts into reality for the layman to understand.

2.3.4.3 Being Responsible

"Design firms have a significant role to play in adding value to the final product because it is during the design process that the greatest savings in time and cost can be made in a project" (Love *et al* 2000: 200).

Cornick (1991) in his foreword cites the contention of Jefferson (1989) that some 50% of defects in buildings arise through decisions or actions taken in the design stages and ”with the costs of rectifying building failures running at 12 – 15% of total construction expenditure, the rewards for improving quality in design are very great”. The same can be said about maintenance.

2.3.5 Post Occupancy Evaluation

In the 1970’s, psychologists and architects pioneered the post occupancy evaluation of buildings in an effort to build an objective, reliable database on the impact of designed environments on occupants’ health, well-being and performance. The architectural profession resisted this effort at objective evaluation as an infringement on professional prerogatives, and institutional clients discouraged outside evaluation as a potential source of criticism of their decisions.

Post Occupancy Evaluation (POE) is a means of evaluating a building after it has been designed, constructed, and occupied for a period of time. It usually entails surveys, observations, and interviews with users and operators of the building. The aim is to assess how well the building performs and “fits” users’ needs. The hope is that improved tools and instruments can be devised to perform these evaluations, and that learning from the evaluation can lead to better buildings in the future.

Studying POE reports on buildings could give a good indication of what could be done differently to achieve a high level of DFM.

Inadequate design can result in difficulties arising during the occupation/maintenance phase of the project cycle. This can be viewed as a building defect due to deficient design. McGeorge and Palmer (1997:67) conclude that, historically, attention to maintenance and renewal performance has been limited because designers responsible for new facilities have been unaware of the post-construction problems and inefficiencies experienced by those who have to maintain and operate them. They also contend that maintenance and renewal considerations in the early stages have been impeded for reasons such as time pressures, unaware decision-makers and ill-informed designers.

The British Standards Institute (BSI) estimates that 90% of building design errors arise because of failure to apply existing knowledge that can mainly be drawn from maintenance personnel and possibly an up-to-date database that can be accessed by a wide spread of built environment professionals. This database can be created but the problem of encouraging designers to access the information will most likely persist.
Furthermore the “isolation of designers from the construction process” (Hyde1995:47) hinders their education in buildability, constructability or design for maintenance.

Hyde (1995:47), in his research findings on “buildability as a design concept”, suggested that the construction process should be less prescriptive and more performance-based, and that this would allow greater competition between structural systems.

The root of designers’ ignorance of DFM could be the lack of shared knowledge. Similar to arguments that the contractor should be involved in the design process in order to create more buildable structures, it can be argued that maintenance personnel be involved during the design stages in order to spot the “regular” maintenance pitfalls and assist in eliminating these.

2.3.6 Aesthetics

The term “aesthetic” derives from the Greek *aisthanesthai* which means “to perceive” and *aistheta*, “things perceivable” (Porteous 1996). The Greek philosopher Aristotle’s *Poetica* may be called the earliest work on aesthetics.

Aesthetics is defined as “the knowledge which derives through the senses; scientifically it is about beauty in art theory” Stierlin H (1977). The Penguin Encyclopaedia (2004) describes aesthetics as, “a branch of the philosophy with the nature of the beautiful, with judgements concerning beauty and taste, and with theories of criticism in the arts”.
The physical environment and its mental and emotional effects result in the main from perception through sight. Therefore the appearance of buildings is of great importance practically and psychologically (Reekie 1972).

Overall there are three main areas of knowledge in the history of aesthetics:

- Knowledge which is derived through the senses of things perceivable,
- Knowledge of the nature of beauty, and
- Knowledge of theories of criticism in the arts.

Attractive and aesthetically pleasing buildings are significant and even crucial to our well-being and health. We need a sensibility in design, a spirituality and sweetness, which may be attained with a deeper understanding of people's emotional and spiritual needs (Stokols 1991).

In everyday speech, aesthetics mainly means that something has a visually pleasant, well proportioned, well ordered, and clean appearance. All the parts fit together and there is a sense of completeness, whether it is a well-dressed person, a neatly laid table, an interior or a building façade. We perceive aesthetics to be about pleasant visual experiences of the state or properties of an object or an environment.

2.3.7 Summary

Investigations on the subject of design are still in their infancy. It can be said that design requires of us to have considerable amounts of knowledge beyond that which is stated in the problem description.

A possible conclusion that can be drawn from the "design" study is that more should be done about the education processes of design in architecture. If corrective designing can happen as a result of POE then it may be a case of ignorance of potential problems, not a question of a solution not being found during the initial design.

What cannot be denied is that a designer is unlikely to be successful unless he is able to generate ideas. There will be times when analytical thought is appropriate, and a critical and evaluative faculty essential. We need a shift in the design professionals' way of thinking, a paradigm shift if we want to achieve the DFM initiative.

People who are committing large amounts of capital to investment in buildings expect value for money. One fundamental question to be asked in this research is how lower maintenance costs can be achieved by designers ensuring the efficient and effective use of resources in the production and use of buildings and materials.

There are many examples of failures and successes in building design and construction; the differences lie not only in the nature of design but also in the relationship between the design, construction and the control of costs.

The two basic functions in building production remain design and construction; both can be done well or badly and both can negatively affect the costs of a building. Ultimately, the design process dictates the what's and how's to the construction phase through specification and therefore does hold a crucial portion of the responsibility.

2.4 LIFE CYCLE COSTING

Life cycle costing (LCC) balances construction costs and costs-in-use. Design team members and management must realise that the decisions they take during the design stage need to take into account the long-term financial consequences. Seeley (1997: 257) emphasises this aspect by stating that "most design decisions affect running costs as well as first costs, and what appears to be a cheaper building may in the long term be far more expensive than one with much higher initial costs".

It is thus evident that the lowest initial cost is not necessarily the most economical in the end, for cheaper materials and bad workmanship often require more frequent maintenance and may have a shorter working life than the more expensive alternatives. One of the decisions often taken to reduce initial construction costs is to

use plastered external walls rather than face-brick walls, resulting in increased maintenance costs during the occupancy of the building. Holroyd (2003: 82), however, warns that “the provision of unnecessary quality can prove expensive; it may be damaged by cheaper items or even look out of place”.

Life cycle costs can be divided broadly into three categories, namely “capital costs, costs-in-use, and the costs (income and/or expenditure) involved in final clearance of the site or disposal of the asset, against which can be offset the residual value of the asset, i.e. financial inflows accruing from disposal” (Chanter and Swallow 1996: 97).

Building is usually undertaken for a financial or social return. It is often then necessary to measure the benefit which the building or facility will give.

2.4.1 Definition

Life cycle costing, or “whole-life costing” (Ferry, Brandon and Ferry 1999), can be defined as an economic assessment of competing design alternatives, considering all significant costs of ownership over the economic life of each alternative, expressed in equivalent monetary value (Kirk and Dell’Isola 1995).

Lee (1988) and Wordsworth (2001: 17) state that life cycle costs are “the total costs of owning and using an asset over its predicted life span“.

Clift and Bourke (1998: 319) define whole-life costing or life cycle costing as “the systematic consideration of all relevant costs and revenues associated with the acquisition and ownership of an asset”.

Flanagan (1989: 176) elaborates on the previous definitions by stating that “life cycle cost is the total cost of ownership of an item, taking into account all the costs of acquisition, operation, maintenance, modification and disposal, for the purpose of making decisions”.

The life of a building can be divided into several phases, namely design, construction, occupancy and demolition. Of these phases, the “occupancy” phase stretches over a much longer time period than the other phases. Unfortunately, as

the initial construction cost is very high, management places much more emphasis on this phase than on the other phases. Magee (1988) states, that, the initial construction, as the most costly stage, receives a “lion’s share” of attention from the organisation. Operation and maintenance costs are often accepted as a given, but cursed for their nagging presence. There is no glamour in maintenance but, as a major long term cost, maintenance must be controlled as it can easily become a nagging expense.

2.4.2 Effect of LCC on DFM

As the cost of ownership of buildings continues to rise, property owners find it difficult to acquire initial capital for constructing new buildings as well as obtaining sufficient funds for annual maintenance and running costs to keep the building in good shape. Reduced government funding has forced organisations to ensure that they get good value for their money, whether it be during the design and construction of the buildings, during the use of the facilities, or at the disposal/demolition of the buildings.

Kirk and Dell’Isola (1995) are of the opinion that recent trends to minimise facility obsolescence, achieve environmental sustainability, and improve operational effectiveness have also forced decision-makers to examine in greater detail the resulting impact of various alternative design courses of action. The task facing designers today is to deal with limited economic resources in such a way that optimum design alternatives are selected and implemented.

Furthermore Kirk and Dell’Isola (1995) maintain that LCC helps design professionals to become more customer-focused so that owner problems of international competition, rising operation and maintenance costs, and overall business profitability are addressed. Although there has been an increase in the awareness of LCC by property owners, it is often found that the property owner and design professionals become so involved and pre-occupied during the design and construction stages of a contract that they tend to ignore the importance of LCC.

This is further aggravated when the building owner intends selling the property immediately after completion without consideration of future maintenance costs. The existing pattern of taxation encourages this approach to building finance (building

owners placing more emphasis on initial savings than on high maintenance costs) as tax allowances are given on building maintenance, but not on capital expenditure.

Of all the categories of life cycle costs, energy has received the most attention over the past years (Kirk and Dell'Isola 1995). From the standpoint of owner cost impact, however, maintenance is usually the more significant cost item of a LCC study. Ironically, this is the cost that has received the least research and documentation for designers' use.

It is therefore necessary for the management of the properties of tertiary institutions to emphasise the importance of maintenance and the impact that maintenance costs have on the profitability of a building project. It should be pointed out to learners in property and construction-related courses that maintenance costs are significant in any LCC analysis and should be included in all design alternatives.

To assist LCC decision-makers Kishk and Al-Hajj (1999: 99) propose a framework where the techniques of artificial neural networks and fuzzy set theory are incorporated. They maintain that "these techniques can model nonlinear characteristics, generalise and deal with situations including incomplete information, human judgement and uncertainty".

2.4.3 Importance of LCC techniques

Lee (1988) also states that for LCC to be effective it is essential that decisions on initial capital costs should be tempered by knowledge of the consequential maintenance and running costs. One way to ensure that this is done is to require that design proposals be accompanied by a LCC Plan as part of the maintenance manual provided to property owners. This will enable a better assessment to be made of the desirable level of maintenance expenditure.

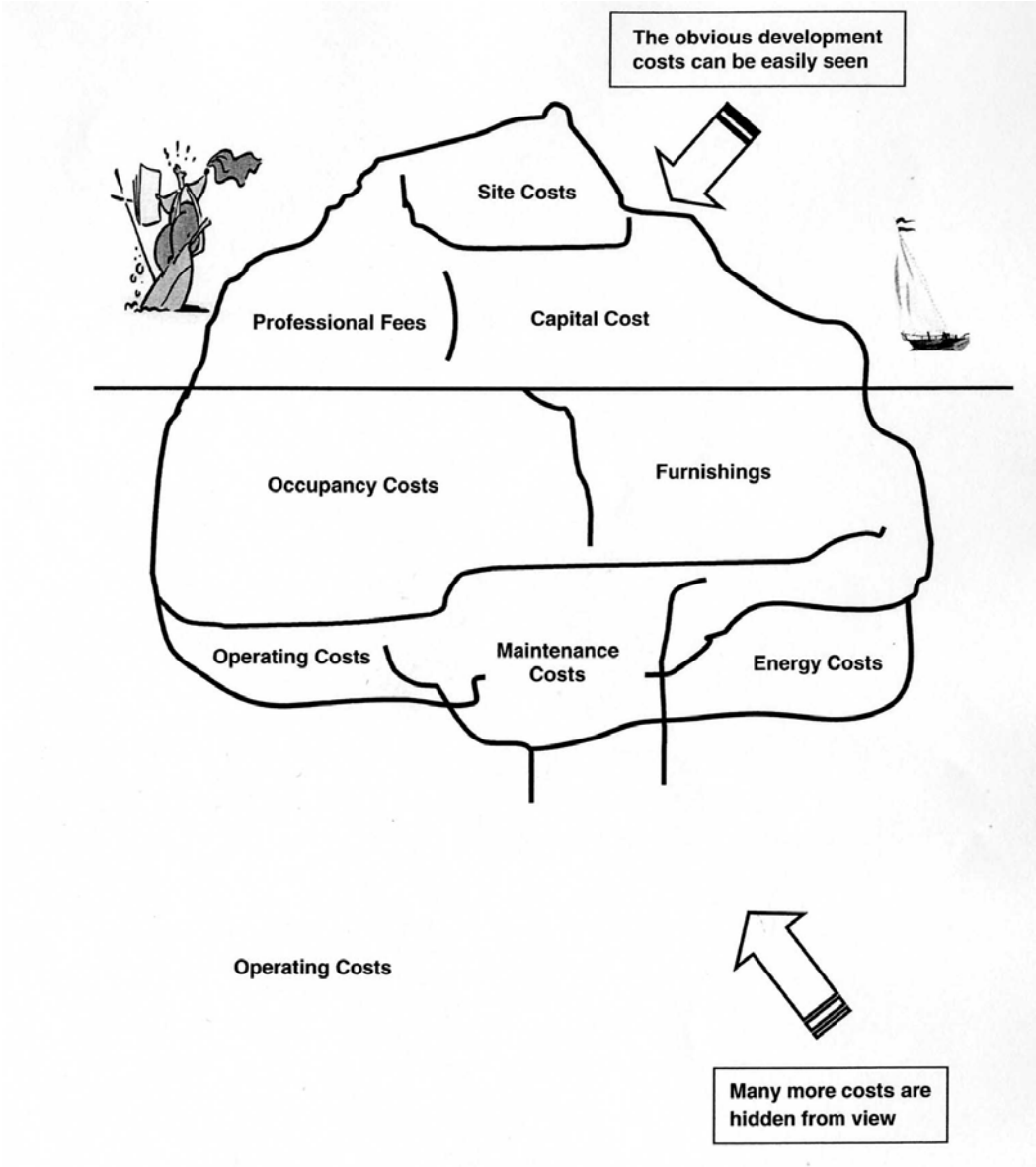


Figure 2 ***Components of life cycle cost****: Source: Adapted from Flanagan and Norman (1983).*

Figure 2.1 illustrates dramatically why LCC studies are so important in the establishment of the budget and cost plan for a future building. Accurate recording of the life cycle cost of buildings depends on regular collection of information on the building. Due to the years of life of buildings and the diligence, or lack thereof, of recording the data by the FM professional, the reliability of the data can at times be questioned.

Too often funds are allocated purely on the basis of short-term expediency and the long-term penalties of deferring maintenance are ignored. The result is that building deterioration is unchecked and a point is soon reached when disproportionately large sums have to be spent on expensive remedial work.

This view is supported by Flanagan *et al* (1989) who maintain that LCC also serves as a basis for budgeting for future expenditure; and that clients will therefore have a short- and a long-term strategy.

Flanagan, *et al* (1989) also reason that intangible benefits as well as the benefit of lower maintenance costs may flow from increased initial expenditure. Intangible benefits include:

a. Improved aesthetic quality – this has an effect on the number of customers, buyers and/or occupants who will visit or use the building, and enhanced rentability and justification for higher rates, thus increasing the "value" of the building;

b. Reduced disruption during maintenance; and

c. Increased income generating power of the building.

Design professionals and the property owner should take these benefits into account, not only during the inception phase of a contract, but also during all the phases of a project:

a. Inception phase - to find the most effective way of meeting a need for additional building space (either rearrangement of existing internal spaces, building an extension, development of a new site or the purchase/lease of another building);

b. Early design phase of a new building - to determine the most economical plan shape, structural form and internal layout;

c. Detail design phase - to identify the elements, components and finishes with the most economical total costs;

d. Construction phase – to eliminate (through regular inspections) poor construction and faulty materials which may lead to premature maintenance; and

e. Occupation phase - to assist in setting up planned maintenance and renewal policies.

The cost of ownership for facilities continues to rise. Owners are having difficulty both in obtaining initial capital to construct facilities and receiving adequate annual funding for maintenance, energy, replacements, and other costs to properly operate facilities.

Smaller government budgets and worldwide competition in the market place have created a situation in which owners are seeking design professionals who will give them the most effective LCC design solutions. In addition, recent trends to minimise facility obsolescence, achieve environmental sustainability, and improve operational effectiveness have forced decision-makers to examine in greater detail the resulting impact of various alternative design courses of action.

Changing facility users and their new demands; new materials, technology, procedures of construction, and operational new air pollutants; and new laws and regulations are all factors that bring about facility obsolescence, some even prematurely. Each factor requires the design professional to consider innovative alternatives that accommodate change in order to minimise premature obsolescence.

Donald Iselin rightfully points out: “We cannot afford to build in ways that become obsolete quickly in a changing world”.

Kirk argues that before they begin to design, architects and engineers should screen published literature in order to spot emerging issues. Professional forums that endeavour to enlighten professionals about emerging environmental problems and issues should become a bigger role-player in the education of practicing professionals. Pre-design and post-occupancy evaluation can be very helpful in gathering information regarding the best and worst building features, potential cost saving modifications and improved effectiveness of the facility which may be used as ideas for improved life cycle cost-effectiveness and minimised obsolescence.

2.4.4 Summary

The LCC approach should be followed when designing buildings in an attempt to achieve a “value for money” status and avoid the “cheap-to-build-expensive-to-maintain” phenomenon.

Design team members, top management and maintenance managers must look at a balance between construction costs and costs-in-use, and realise that the decisions they take during the design stage must take into account the long-term financial consequences. The lowest initial cost is not necessarily the most economical in the

end, for cheaper materials and bad workmanship often require more frequent maintenance and may have a shorter working life than more expensive alternatives. Maintenance managers must ensure that all new design proposals are accompanied by a LCC Plan as part of the maintenance manual provided.

The cost of ownership for facilities continues to rise. Owners are having difficulties both in obtaining initial capital to construct facilities and receiving adequate annual funding for maintenance, energy, replacements, and other costs to properly operate the facilities. A situation has arisen that has seen smaller government budgets seeking design professionals who will give them the most effective life cycle cost design solutions.

The use of a building during its life has enormous financial implications, which are generated and committed in its design, and these should therefore be considered by the design team at the earliest possible moment in the design process. Typical examples are ensuring that the specification of the materials and the components match the anticipated life of the building. There is little point in specifying a long lasting floor finish if the building is designed to have a short life. Clearly, the opposite is also true. Of particular significance are energy and running costs, which need considerable thought and consideration at the design stage.

Trends that have begun to emerge recently as issues of concern for the design professional are the following:

- Facility obsolescence,
- Environmental sustainability,
- Operational effectiveness,
- Total Quality Management,
- Value Engineering,
- Owners' rising expectations, and
- LCC assistance for recent trends.

Architectural design can be placed right in the centre of the economics of buildings as the key issue to determine the viability of construction work relative to LCC. It can be said that good, well-directed design multiplies the value of every cent invested in it. It is no longer enough to consider the costs and value of construction independent

of the way clients look at buildings. Clients are interested not just in the productivity of the building process but in occupancy costs in relation to their own economic objectives. Clients are now becoming interested in a new and most important concept: measuring the productivity of building use through time.

2.5 CHAPTER SUMMARY

Designers must take the maintenance of buildings into account during the design stages of a contract so that maintenance costs can be kept to a minimum during the life cycle of the building. It is advisable that facilities or maintenance managers should also be involved during the design stages of a contract so that they can provide information on maintenance aspects. Many designers often do not re-visit the buildings after completion to see what maintenance work has to be done or have a system in place whereby proper feedback regarding DFM could be achieved.

Seeley (1987) maintains that many of the design faults which result in high maintenance expenditure could conceivably be avoided if a maintenance manager, or someone with similar technical knowledge, joined the design team. Kooren (1987) is of the opinion that maintenance management should be initiated at the same time as the project definition is being established.

Miles and Syagga (1987) list three reasons why buildings are often found to be in desperate need of repair:

- Inadequate finance,
- Poor maintenance management, and
- Poor building design.

The following factors have forced decision-makers to examine in greater detail the impact of various alternative design courses of action. These are trends to:

- Minimise facility obsolescence,
- Achieve environmental stability, and
- Improve operational effectiveness.

A problem facing design professionals is how to deal with limited economic resources in such a way that optimum design proposals are selected and implemented. Literature on proven life cycle costing (LCC) guidelines exists, and this can assist designers in evaluating design alternatives that best meet the economic as well as non-monetary considerations of owners.

One of the factors that can bring about premature obsolescence of a building can be the need for materials for maintenance. Innovative alternative designs that can accommodate changes in material specifications, for example, should be expected from design professionals. This could also help deal with the issue of discontinued materials. Donald Iselin says in his book *The Fourth dimension in building: Strategies for minimising obsolescence*: “We cannot afford to build in ways that become obsolete quickly in a changing world”.

Environmental sustainability requires the design professional to seek materials and methods of construction that will not harm the environment.

Ransom (1981:166), states that despite calls for closer integration of design and construction, the roles remain essentially separate.

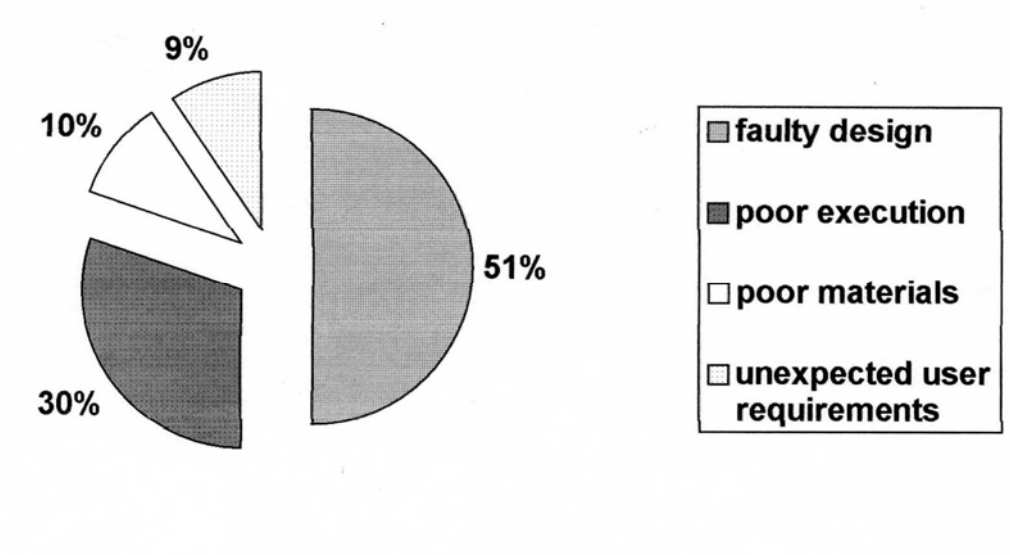


Figure 3 ***Causes of defects*** *(Ransom, 1981:165)*

CHAPTER 3 – RESEARCH DESIGN AND METHODOLOGY

This chapter explains the research methods used to acquire data for analysis. It also describes the population targeted, the reason therefore and the fieldwork done.

Two sources of information were employed during this research. The first source of information was the primary data accumulated from the responses to survey questionnaires sent to selected built environment professionals, with a particular focus on the architectural profession.

The second source of information was a review of the available literature in order to identify the factors that affect DFM and are to be examined in this study.

3.1 INTRODUCTION

The procedures and techniques employed during this study are discussed in this chapter. The main focus is on the steps taken in the construction of a theoretical basis for the study, the method of data collection and the sampling methodology. Regarding the techniques used in data collection, the choice of the measurement technique and its limitations are examined. The procedure used in the analysis and interpretation of the data is also discussed.

Two kinds of data were examined during this project, namely primary data and secondary data. The nature of these two types of data is outlined briefly below.

- **Primary data:** The responses to the questionnaires that were sent out to the professionals surveyed during this study.
- **Secondary data:** Literature, published studies and texts, as well as unpublished dissertations and theses, dealing with topics that closely relate to the main topic surveyed in this study.

Criteria governing the admissibility of data

Only professional architectural practitioners registered with their respective institutes and the South African Council for the Architectural Profession (SACAP) were surveyed in the study.

In terms of experience, practitioners with from one to more than 30 years of experience were tested in the study. It was anticipated that the difference in attitudes between the most experienced and the novice practitioners would make for an interesting result.

3.2 DATA COLLECTION METHODS AND PROCEDURES

Literature relating to the principal concepts that would be foundational to this study was reviewed. Such a review serves as a basis upon which theoretical assumptions are made about the phenomenon studied. Furthermore it enables the establishment of a link between theory and empirical research, and makes possible the explanation of the findings of the present study in terms of the theoretical propositions made.

For the purpose of this research, professional practising architects and architectural technologists formed the population used for the survey. A questionnaire was sent to SACAP in an endeavour to ensure that the maximum number of persons practising architecture could be tested.

In employing this method, the researcher quantifies the data and inspects them in their quantified form so that, having converted them to the language of mathematics, they may reply to the researcher in terms of quantitative values and by so doing give some indication of the characteristics and the dynamics which affect them (Leedy 1997: 142).

A survey method described by Leedy (1997) as the “two-stage descriptive survey method” was used for data generation and analysis. The qualitative data production stage comprised a preliminary research approach intended to generate important constructs or themes.

3.3 QUALITATIVE VS QUANTITATIVE METHOD

3.3.1 Methodology

Past records should not be seen as the only means of collecting knowledge on a specific subject. Events as they unfold around us every day should be observed and studied along with documented knowledge. By drawing conclusions from one set of data, conclusions may be drawn as to what might happen again under the same circumstances. Leedy (1997: 79) states that the method of research that looks with intense accuracy at the phenomena of the moment and then describes precisely what the researcher sees is called the descriptive survey, or the normative survey.
The term descriptive survey describes the essential character of the method. In employing this method, the researcher does two things:

- Observes with close scrutiny the population bounded by the research parameters; and
- Makes a careful record of what is observed, so that having made the observations, the researcher can then return to the record to study and discover the meaning of the observations described therein.

This method deals with a situation that demands the technique of observation as the principal means of collecting data (Leedy 1997: 79 - 80).

Qualitative: Large amounts of data are collected, assimilated and then analysed in order to arrive at well-informed conclusions. This method can also be described as authoritative.

Quantitative: According to Blaxter, Hughes and Tight (2002:79) “the way questions are asked influences what needs to be done to answer them” yet often the “methods cart” is placed before the “contents horse”. Quantitative research is empirical research where the data are in the form of numbers. It is indirect and abstract, and treats experiences as similar, adding or multiplying them together, or ”quantifying” them. An obvious weakness of quantitative research is that it omits “too much of what is human” (Blaxter *et al* 2002: 59). However, Howe (1994: 161) notes that “quantification does not eliminate qualitative judgements and therefore is not an

alternative to them" since quantitative data on its own does not provide "any real understanding of the lives behind the numbers".

3.3.2 Target Population

The population targeted by this survey was all architectural and building professionals throughout South Africa. The intention was to target all professionals in order to get a good spread of age, experience and attitude. Architectural professionals in South Africa are registered in four categories:

- Professional Draughtsperson
- Professional Architectural Technologist
- Professional Senior Architectural Technologist
- Professional Architect

All were allowed to participate in the survey in order to elicit a comparison between the more design-oriented and the more technical-oriented individuals.

3.3.3 Questionnaire Design

The questionnaire was derived from an extensive literature survey and scanning of the data thus generated. The questionnaire was administered via electronic mail (e-mail) because the respondents are nationally spread. The questionnaire used in this survey had random questions. The intention was to test the attitude of professionals to the topic.

3.3.3.1 Type of questions used

Closed-ended questions were used. Respondents were asked to select an answer ranging from "Completely Disagree" to "Completely Agree". The fact that questions could be answered by simply clicking a box on the screen was expected to positively influence the response rate.

For Blaxter *et al* (2002: 77,179) the questionnaire is one of the techniques "at the heart of survey research" and it is "one of the most widely used social research techniques". The questionnaire is regarded as a descriptive survey method and a commonplace instrument for observing data beyond the physical reach of the

observer. Leedy (1997:190) states that the researcher obtains data from a remote targeted source in an impersonal way.

Herbert (1990: 55) found that some of the advantages of using questionnaires are:

- Standardised wording and question order allow for responses to be compared;
- It is a fast way to collect data and the respondent has the freedom to answer from his/her perspective;
- It is often less expensive; and
- The respondent's confidence may be greater because anonymity is guaranteed and it is less exacting on the respondent than asking for an immediate response.

Blaxter *et al* (2002: 179) believe that the questionnaire has some unique advantages. When properly constructed and administered, it could serve as the most appropriate and useful data-gathering device in a research project. The use of a questionnaire to gather attitudinal perceptions on the issue at hand proved to be the most suitable data-gathering instrument to attain the objectives of this research.

3.3.3.2 Testing of the questionnaire

A draft questionnaire was pre-tested (Churchill 1995; Babbie 1998) by sending it to a few of the researcher's associates and co-workers to test its functionality.

The aim of the pre-test was to test the procedure to be used when sending out the questionnaire. It was important to ensure that participants would not be discouraged by a long questionnaire. It further helped to ensure that the instructions were clear and the questions concise.

The pre-test yielded very useful feedback. The questionnaire was finalised with the inclusion of a few open-ended questions to allow respondents to add their own comments.

3.3.3.3 Response rate

The response to the questionnaire was expected to be very slow as this time of the year most Architectural Professionals are rounding of their projects for the year. The results are mainly based on percentage comparisons and are structured around the main themes of the identified problem and sub-problems.

3.3.4 Sampling

Since it is not always practical and feasible to survey an entire population, the practical approach is to depend upon sample surveys.

Wisniewski (1997) found that typical sample sizes exceeding 30 could be deemed as statistically large.

According to Cooper and Schindler (2003: 178), “the basic idea of sampling is that by selecting some of the elements in a population, we may draw conclusions about the entire population”.

Kidder and Judd (1986: 154) believe that “sampling is the selection of a fraction of the total amount of units of interest to decision-makers for the ultimate purpose of being able to draw general conclusions about the entire body of units”.

Sampling is categorised as probability and non-probability sampling.

3.3.4.1 Probability Sampling

Probability sampling, which was used in this study, is based on random selection, which is “a controlled procedure that assures that each population element is given a known non-zero chance of selection” (Cooper and Schindler 2003: 183). This is the most common type of sampling and it will help to meet the objectives of this research. The sampling frame is drawn up and all within the list are included. The difficulties experienced in the use of random sampling are “a lack of a satisfactory complete list of a universe population” (Leedy 1997: 205).

3.3.4.2 Non-probability Sampling

When selecting this method of sampling the researcher has no way of forecasting, estimating or guaranteeing that each element in the population will be represented in the sample. The sample is selected either on a convenience or accidental basis or as a quota. Since this process is subjective and without safeguards such as control by criteria, it may render the research untrustworthy.

3.3.5 Questionnaire Administration

The questionnaire was sent to the head offices of South African Council for the Architectural Profession (SACAP) and South African Institute for Architectural Technologists SAIAT, with a request to distribute it via e-mail to all their emails. Both organisations agreed to do this.

The timing of the questionnaire distribution, being close to the annual Christmas shutdown, was expected to generate a good response as companies would start to slow down and respondents would have more leisure time to complete surveys.

Formats of questionnaire administration are the choice of the researcher. Current methods that are still deemed as very effective are faxes, e-mail, postal, personal or telephone interviews; with e-mail currently the fastest and most cost-efficient. The e-mail method of administering the questionnaire was found to be the most conducive for this study. Leedy's guidelines (1997: 198) were taken into account in preparing the questionnaire.

Reasons for using the e-mail method only are:

- Respondents have more time to complete to the survey.
- With interviews, bias on the part of the interviewer is a risk. With the e-mail method, the respondent is likely to have privacy while completing the survey. This aids in removing any possible bias. The use of this method increases the chances of sensitive questions being answered, as confirmed by both Barker (1996: 101) and Kress (1990: 100).

One of the main disadvantages of an e-mail survey is its low response rate. According to Barker (1996: 110),"responses to e-mail surveys are poor and returns of less than 60% are common".

As a counter-argument to this disadvantage, Welman and Kruger (1999: 160) state that participation may be motivated by an ego appeal, where respondents participate because they like the topic of the research and want to be noticed; a value appeal, where respondents wish to assist the researcher; or a combination of the two.

3.3.6 Results and Analysis

The results of the survey questionnaire are discussed in detail in Chapter 4.
The data analysis consists of examining, categorising, recombining and tabulating the results in order to addressing the initial question (Jankowicz 1995).

3.3.7 Bias

In an attempt to avoid bias, the names of the respondents were not asked. The responses were coded and tabulated in a Microsoft Excel spreadsheet from which averages were drawn.
Bias in the research design (Leedy 1997: 80) and in responses to the closed-ended questions might be present due to the fact that there is no evidence that the respondents have thoroughly applied their minds in responding to the questions.
The possibility of bias was mitigated as follows:

- The questions were not categorised, thus respondents could not draw conclusions as to the intentions of the researcher from the grouping of the questions;
- The questions tested a wide area of the field of expertise of designers; and
- The data were carefully documented and systematically presented so as to allow the researcher to draw fair and accurate conclusions.

3.4 CHAPTER SUMMARY

The research methodology used in the study and the method of data collection were discussed in this chapter. The types of questionnaires that could be used were examined and explained. The selection of the survey method was discussed and the use of the e-mail survey was explained. Sampling techniques, a description of the sample, and the types of sampling were examined. The reliability, validity and interpretation of the questionnaire were discussed, as well as the administration of the questionnaire.

The measurement instrument and the treatment of the data were also addressed. The results will be presented and their meaning in relation to the objectives of the research discussed in the following chapter.

CHAPTER 4 - RESULTS: PRESENTATION AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the analysis of the data collected. This involves a process of identification of patterns in order to effectively evaluate and relate the data to the framework created for this report. Findings are reported, based on the data collected through literature surveys and questionnaires. The procedures and the methods used for measuring the effectiveness of DFM are presented, and this methodology is then used to measure the levels of DFM awareness within the sample. The results obtained are presented in tables and comments are made based upon the findings.

4.2 RESPONSE TO QUESTIONNAIRE

The questionnaire was sent to the South African Council for the Architectural Profession (SACAP), with a request for them to distribute it to all their members. The target was to reach a minimum of 100 randomly selected individuals from this group.

Responses began arriving approximately a week after sending the questionnaire to the SACAP head office in Pretoria. The percentage response was approximately 20% (refer to Table 1 below). Compared with response rates in other research in the built environment (Nkado (1999) 25%, Crafford (2002) 19,3%, Smallwood (2000) 7.3%, Mbachu (2003) 40%, Jones et al. (1999) 19,6%; and Brümmer (1998) 16,3%), the overall response rate of 20% seems to be acceptable.

Table 1 – Summary of population surveyed

Sent	Late	Scrapped	Processed
100	0	3	20

Although efforts were made to achieve a higher response rate, the following could have had a negative effect on the response rate:

- The length of the questionnaire (5 pages);
- Many architecture firms log onto the internet via modems at intervals to upload and download mail etc. This method of connecting to the internet is not conducive to the transmission of large files as it is slow, and thus expensive.
- Respondents were possibly too busy wrapping up projects toward year-end which is in contrast with what was expected.
- Some blank responses received via e-mail could indicate the following:
    - Respondents did not understand that they needed to save the file first, then complete the questionnaire, and return it as an attachment to their reply e-mail.
    - Respondents did not have the time to go through the questions but returned the uncompleted document to indicate that they would not participate. This is also a method of acknowledging receipt of the survey. These were all scrapped as per Table 1.

Some respondents indicated by return e-mail that they would like to receive a copy of the survey report. This could indicate that there is some interest in the topic amongst the architectural profession.

4.2.1 Age profile

Table 2 below depicts the age profile of the respondents. The majority (87%) were from the age group 31 – 40. The remainder (13%) were over the age of 50. The 20 – 30 age group would either have recently completed their studies or have been still studying, and would therefore be too inexperienced to take part in this survey. The professional who would have been exposed to DFM issues would have a fair amount of site experience. The fact that only 13% were from the over-50 group indicates that they had probably never had maintenance feedback from maintenance personnel and had never had to deal much with DFM issues. The 31 - 40 age group would have completed their formal education and have had a minimum of 10 years experience, and would thus have had some type of exposure to DFM. It is likely that this group had some exposure to this topic during their studies and would thus have some degree of awareness.

Table 2 – Age Profile and experience

Range	Percentage	10 Yrs Experience
20 - 30	2%	0%
31 - 40	87%	89%
41 - 50	0%	0%
51 - 60	11%	11%
TOTAL	**100%**	**98%**

4.2.2 Professional Status

Table 3 below depicts the response from each of the four professional categories of the architectural profession. The majority of respondents fall in the category of Senior Architectural Technologist. This could indicate that the task of completing the survey was delegated to a lower-ranked individual, which could mean that the principal did not rate the study as important. Historically, architects are the principals of architectural practices. This attitudinal behaviour supports Hypothesis 1.

Table 3 – Response per professional status

Professional status	Percentage
Draughtsman	0%
Technologist	7%
Senior Technologist	80%
Architect	13%
TOTAL	**100%**

4.2.3 Strongest attribute in Architecture

Table 4 below shows the respondents' rating of their strongest professional attribute and the area in which they most desire to improve their abilities. Some 86% of the respondents claim to be strongest in the design field. The same percentage aspires to further improve their design abilities. This proves that design is the most sought-after attribute in the architectural profession. DFM requires design professionals to

develop additional skills, such as detailing and presentation. Detailing would assist in drawing exactly how structures should assemble and presentation skills would assist in highlighting and identifying possible DFM problem areas.

Table 4 – Architectural attribute

Direction	Strongest	Aspire
Design	86%	86%
Project Management	7%	7%
Detailing	0%	0%
Presentation	0%	7%
Working Drawings	7%	0%
TOTAL	**100%**	**100%**

4.3 BUILT ENVIRONMENT

Designers, architects and planners do not work in a vacuum, although at times they may be less than candid about the sources of their inspiration and the constraints within which they must function. Throughout history designers have responded to the changing conditions in which their given task was embedded. These conditions have political dimensions, such as who wields power in a given situation? They have economic dimensions – what financial means are at the disposal of the designer for a given task? They also have technological dimensions – what materials and techniques will the designers use to realise their solutions?

4.4 FACILITIES MANAGEMENT

Facilities management is the provision of a specialist management capability to plan, organise, control and supply the full range of technical and non-core support services which are essential to running any building or activity. It can also be seen as the co-ordination of buildings, work and people into a single interactive system dealing with issues usually outside the main core business areas.

Becker (1990: 1) states: “In the mind of top management, especially, facilities management resided in the basement, not the boardroom. This is odd, really, when one considers that facilities account for a huge portion of most large organisations’ total assets. They are a hidden resource.”

The involvement of the facilities manager from the design stages of a building will become more and more crucial. This involvement would ensure that the needs of the client are heard at the beginning of the project in order to achieve DFM.

The survey found that the majority (47% agree, 33% strongly agree) of professionals believe that post-occupancy evaluation should be encouraged in order to broaden their experience on DFM issues. Similarly, the majority (60%) request feedback on maintenance issues, but only 47% request input from maintenance personnel when designing buildings. This suggests that the importance of involving maintenance and/or facilities management personnel at the initial design stage, rather than requesting feedback only after the building has been completed, has not yet been fully realised.

4.5 ARCHITECTS

The concept of the individual artist-as-hero seems particularly nostalgic today in the face of increasingly complicated negotiations that design professionals wage over the smallest-scale design projects (Knox & Ozolins 2000).

For the designer, managing the many interested parties – consultants, regulators, review agencies, interested citizen groups, clients, owners, builders, and fellow designers – is a principal task. Design philosopher Donald Schon (1983) identified this as the distinction between theory-in-use and espoused theory.

Architects are likely to judge the success of their work in terms of its “artist/aesthetic quality as defined both by their personal vision and by prevailing architectural sentiment” rather than by the long-term relationship with and satisfaction of their client (Pressman 1995:226). The first part of this statement by Pressman is supported by the survey. In the finding that design is such a dominant attribute in an

architect's life, it can be concluded that they care more about the building aesthetic than the other aspects of building.

At the urban design scale, "design professionals have been found consistently to differ from the public in their appraisals of the built environment" (Nasar, 1989:33). Are designers born seeing buildings differently? Or are they educated to experience environments differently? Research studies by a variety of investigators lend support to the latter view. For example, first-year design students tend to evaluate furniture styles in ways similar to non-design students, but final-year students' evaluations are quite different from those of the non-design student and similar to the judgments of their instructors (Whitfield and Wiltshire 1995). Similarly, first-year architecture students' assessments of buildings are rather similar to those of non-architects, but are substantially different by the time they are ready to graduate (Hershberger 1969). One study suggests that, as architecture students progress in their education, they not only find "high" architecture more appealing, they are also less likely to view "popular" or vernacular buildings the way non-architecture students do (Purcell and Nasar 1995).

The vast majority of first-year architecture students seem to be at least partially motivated by the desire to help people. In a survey of nearly 650 students, Alrentzen and Groat (1994) found that approximately 90 percent of students listed "helping people" as a key motivating factor in their selection of architecture as an educational choice, just 7 and 6 percent below "opportunity to be creative" and "intellectual challenge" respectively. And yet, by the time these students become established practitioners, the architectural profession's value system that so strongly emphasises "design quality" (often defined in inaccessible, expert terminology) seems to have become effectively dominant (Pressman 1995).

This is supported by the current survey, where the majority (86%) of respondents indicated design to be their strongest attribute. Even though they claim to be strongest in design, they still aspire to be even better in this field. This is in contrast to the requirements of DFM.

Broadbent (1973) attempts to develop a design method for architects and, in so doing, discusses what can really be perceived as four tactics for generating design,

which he calls pragmatic, iconic, analogic and caconic. He identifies these approaches from a study of the history of architecture, throughout which they can be shown to have been used at various times. Whilst none of these seem now to provide a universally appropriate design method, taken together they are a useful addition to the designer's toolkit of tactics to be employed as and when appropriate.

Pragmatic design is simply the use of available materials and methods, generally without innovation, as if selecting from a catalogue. For pragmatic design to be useful the designer must be well versed in established techniques. Structural systems may be seen as essentially conservative and unlikely to lead to any dramatic failure. It could, for example, lead designers to select almost from a pattern book. While this alone might not be able to generate great design, it may prove a valuable tactic in identifying a range of possible forms for part or all of the design.

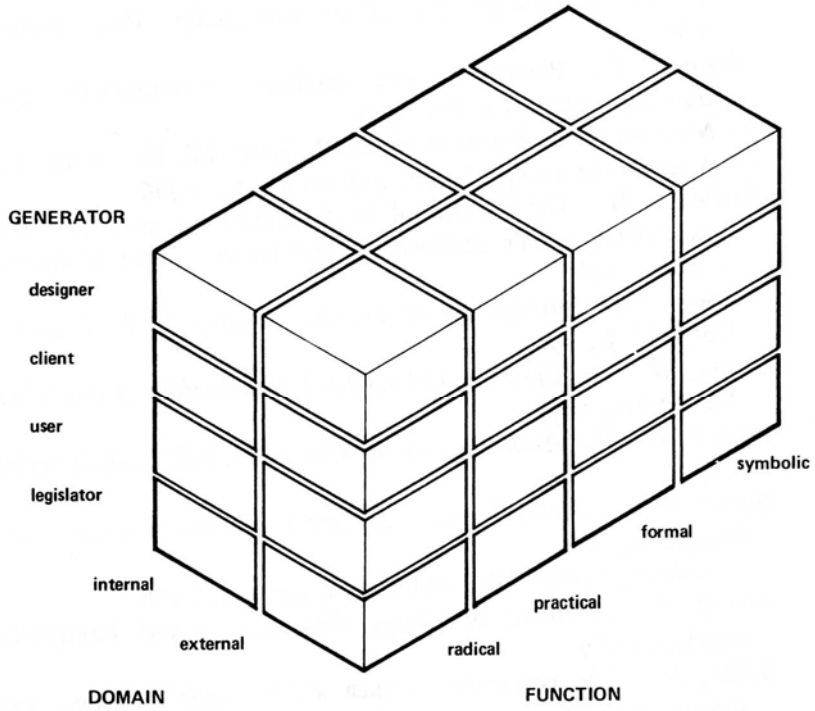
Pragmatic design is recommended as the method that should be applied when the need for DFM arises in a project.

Lawson's (1994) experience after teaching design students for many years suggests that, when they like a solution, they are amazingly creative in imagining the "logical" processes that led to that solution! They are also at times quite capable of denying, both to themselves and others, the obvious importance of issues that they have chosen either to ignore completely or to relegate to minor consideration. The Royal Institute of British Architects in its stage model of design practice, around which the standard practice fee was constructed, reinforced a view of design as a sequence of "assimilation", "analysis", "synthesis", "evaluation", and "communication".

4.6 PRINCIPLES OF DESIGN

4.6.1 Architectural challenge and response

With the industrial revolution, designers, like other artists, found themselves having to come to terms intellectually not only with industrialisation but also with modernisation. Meanwhile, the tremendous increase in the scale and pace of change in cities required their new buildings to fulfil all kinds of new economic, social, and cultural imperatives.



The completed model of design constraints.

Figure 4

Regarding designers' thought processes, Broadbent (1988) argues: "For it is exactly because the designer does not know what he will think next which makes design such a challenging and satisfying occupation".

Lawson (1994) stated that until quite recently designers relied almost exclusively on intuitive methods, and design ability was widely held to be innate and largely unteachable. "Society had a right to expect its designers to be responsible and accountable and have more control over their processes." After years of neglect, when design methods had no place in the curriculum at all, they were finally taught

and described in textbooks but, as Lawson argues, perhaps design must be learnt rather than taught.

It has become more evident that humankind has a huge responsibility toward nature and its preservation. As the two major contemporary causes of pollution, the impact of habitat and transport on the natural environment should be addressed as a priority. The design of motor vehicles has shown tremendous responsibility with attempts to steer design in a direction that can only benefit our planet, for example with regard to control of with gas emissions. Legislation played a major part in this turnaround of attitude. However, in the survey at hand, the majority of respondents felt that more legislative control in the built environment would stifle creativity in architecture (27% agree, 40% strongly agree).

4.6.2 Information technology

Design and construction documents have generally become increasingly more comprehensive and detailed, and can now sometimes run to many thousands of sheets (Kostof 1986; Cuff 1992; Robbins 1994). It is now also possible for designers to analyse typical maintenance problems and to document proper solutions.

Through digital networking, inexpensive computing, and increasingly diverse and sophisticated software, the world is shrinking and becoming more and more densely interconnected. Design professionals will be no less affected by the digital revolution than everyone else (Mitchell 1995, 1999).

Regarding the evolution of computers around the subject of design, as set out in section 2.3.4.2 Using Technology, the value input from the client does not have to be at the same level as that of the design professional. By presenting the idea visually in real terms, one can rely on the maxim ”a picture paints a thousand words”.

4.6.3 Design Practices today

There are four areas of rapid transformation defining design practices today. These are: digital technology, globalisation, local politics, and sustainability. These trends are intrinsically linked, such that advances in digital technology profoundly implicate

globalisation, which is at the same time bound to local politics. Indeed, each of these forces of change is systematic, and its effects are felt throughout design practice.

4.6.4 Digital Technology

Computerisation carries immense yet different implications for architecture and planning. Among planners perhaps the most significant impact of digital technology concerns the realm of information management. In the first wave of computerisation in architecture, applications were limited to management tasks such as accounting and word processing. By the late 1970s, it became evident that computer-aided design would significantly change the way work got done in architecture firms. Still, it took over 20 years for that evidence to be visible in mainstream architectural practice. Today it is common practice to send drawings via the internet to consultants, and for project teams within an office to collaborate through a networked set of computers.

In order to make an objective assessment of a design, or to set about the process of designing, consideration has to be given to three aspects:

- Function: the satisfying of requirements of use or purpose;
- Structure: the physical implementation of function by the best available materials, construction, manufacture and skills as conditions permit; and
- Appearance: the obtaining of satisfactory visual effects (sometimes referred to as ”aesthetic values”).

These three points appear to be the fundamental issues to deal with in designing. They are closely interrelated, and each to a greater or lesser extent, according to the nature of the subject, influences the other.

Integration may well be the key-word in good design. Not only does it mean the correct combining of parts into a whole, but it also implies integrity, soundness and honesty.

4.6.5 Brainstorming

There are many published techniques for identifying, analysing and restructuring problems, and for comparing and evaluating solutions, but, with the exception of the open-ended thinking methods such as brainstorming, synectics and lateral thinking, there is little help with the actual creation of the physical form from a set of abstract

relationships. Even such tools as the so-called “creative techniques”, such as brainstorming, cannot themselves directly assist with form generation but really only provide a mental atmosphere conducive to the free flow of ideas.

Well-known architect Richard Burton clearly feels that the interaction between members of the design team can be a very important influence on the design process. Brainstorming is a strategy used by Burton and his team of three, because the group has the advantage over the individual and thereby avoiding the trap of ideas becoming personal property or one person’s own intellectual territory.
The strength of that personal territory is considerable, and the difficulty of working alone is often in the breaking of the bonds caused by it. With groups like these, bonds are broken easily, because the critical faculty is depersonalised. Designers should have open and well-educated minds to be interested in a wide variety of issues.

Some 53% of respondents to this survey do not use the technique of brainstorming when designing. This practice could be a major factor hindering the successful implementation of DFM, because it excludes the opinions or expertise of others (be they other architects or other professionals such as facilities managers) in the design process.

4.7 TESTING OF THE HYPOTHESES

4.7.1 Hypothesis 1

The designer seeks to impose his own order and express his own feelings through his design. This is not just pure wilfulness, as some would have it, but a necessary process of self-development through each project and, in many cases, a need to maintain an identifiable image to prospective clients. “The more famous and celebrated the designer, the greater the client’s risk, for such designers live in the glare of publicity and are unlikely to wish to compromise their stance. This can create client-designer tension” (Rowe 1987).

Quinlan Terry asks: “Why is it that ‘old materials last for hundreds of years, whereas modern materials don’t,’ or why ‘old buildings are easy on the eye and new buildings not’.” In his opinion the answers are obvious and the choice is between what he categorised as ”short lived lusts of a throwaway society with their glossy, space aged structures, which suck out the earth’s resources and leave behind a scrap heap of unrecyclable rubbish” on the one hand, and the traditional techniques of building on the other.

In this survey, the majority indicated (47% agree, 7% strongly agree) that they “always” keep maintenance in mind when designing. On average, the respondents agree that they do consider maintenance requirements when they design, and that:

- DFM is worth the design cost implication.
- DFM should be part and parcel of the process when designing buildings.
- Maintenance considerations are very important when designing.

The majority of the surveyed population also feel that it can be assumed that architects do consider maintenance when designing.

The first hypothesis, that architects are concerned only with the aesthetics of their buildings, is thus not supported by the results of the survey. However, the fact that architects did not form the majority of respondents to the survey (see 4.2.2), suggesting that they did not consider the topic to be of importance, does lend some weight to the hypothesis.

4.7.2 Hypothesis 2

This hypothesis states that no methods and procedures exist, that can assist with the successful implementation of DFM.

Brainstorming techniques: This could be one of the best techniques to assist on a DFM project. As described earlier, this is a creative technique used for generating a large quantity and broad variety of ideas for alternative ways of solving a problem or making a decision. The survey found that only 40% of architectural professionals use this technique for generating design results, however 53% say they do use teamwork to get the job done.

Computer visualisation: The emergence of the use of computers to convey visually the architect's ideas, proves to be a significant factor that can assist DFM. Visualisation techniques such as 3D modeling can assist maintenance managers in predicting potential maintenance hazards. This is supported by 60% of the surveyed population who agree that computer technology today can greatly assist with the visualisation of maintenance aspects while designing.

Maintenance records: As a maintenance strategy, records need to be kept to assist in planning maintenance programmes. These records can also be invaluable as feedback to designers in order for them to predict future maintenance needs. The survey indicates that 60% of designers request feedback from maintenance personnel on buildings they have designed.

This hypothesis is not supported. Methods and procedures do exist that can be employed to achieve success with DFM.

4.7.3 Hypothesis 3

This hypothesis argues that architects are not well informed on the topic of DFM and therefore do not rate it as important.

On the question of whether the topic of DFM is part of the curriculum in architectural schools, the results were: 27% strongly disagree, 13% disagree and 33% neutral. A minority of 27% agreed that it is part of the curriculum. This shows some confusion and uncertainty, and possibly differences in curricula at different architecture schools.

The weighting suggests that the topic is not dealt with effectively in the curriculum. The fact that 60% of designers request feedback from maintenance personnel suggests that there is some awareness. The starting point for awareness of DFM should be at the schools of architecture. Furthermore, architectural professionals should be encouraged to apply self-study on this subject in order to stay informed on the latest developments that can assist them in their decision-making.

The first part of this hypothesis is supported, in that architects are not well informed about DFM. However, the second part, that they do not rate DFM as important, is not supported. Some 53% disagree and 7% totally disagree in response to the statement that DFM is unimportant at the design stages of a building.

4.8 CHAPTER SUMMARY

It would appear that one of the major contributors to DFM would be the involvement of experienced maintenance personnel and the compilation of well-documented maintenance guidelines, especially in instances where DFM would be specifically required.

Design brings about evolution. All objects are designed and, over the previous millennia, things have become what they are today because of design. As design has such a profound impact on our lives, it should be undertaken responsibly.

At the rate that information is shared today, changes can be made easily and readily, and be exchanged much more efficiently than before, thus enabling designers to easily accommodate input from facilities managers.

The prime responsibility of architectural design should be to house humans. The second responsibility would be to achieve this in an economically and environmentally sustainable manner.

Those aiming to become designers or planners are often given the impression that once they have mastered the skills of manipulating urban and architectural forms, they are equipped to tackle almost any problem associated with cities and the built

environment in general. This is in part due to the way in which design is often taught: as a synthetic activity, often excluding rigorous analysis of the problems that are intended to be solved, designed, or planned. Becoming aware of one's limitations in understanding complex phenomena is an important precondition for successful design solutions.

"Visualisation" is the key concept, with the assistance of computing technology to facilitate the presentation and understanding of the designer's thinking.

CHAPTER 5 – RECOMMENDATIONS AND CONCLUSION

5.1 INTRODUCTION

The intention of this report is not to prescribe to designers how to go about designing but rather to raise awareness of the need for DFM (Design for Maintenance). It would not do justice to the profession of architecture, much less the philosophy of design, to attempt to prescribe methods of design; rather their creativity should be allowed to come forth with solutions.

5.2 MAIN FINDINGS OF THE STUDY

The main aim of this study was to test levels of awareness of Design for Maintenance (DFM) amongst the South African architectural profession. An extensive literature review, summarised in Chapter 2, was undertaken on the topics of maintenance, design, and life cycle costing. This review formed the background to the study and informed the construction of the research. The research results are presented in Chapter 4.

Key findings of the research were:

- Members of the architecture profession consider design to be their strongest attribute, and also the area in which they would like to further their skills. They rated attributes such as detailing and presentation skills, both of which could assist them in a DFM approach, much lower than design skills.

- While the majority of architecture professionals surveyed agreed that post-occupancy evaluation of their buildings should be encouraged, and stated that they did request maintenance feedback on their buildings, fewer reported actually obtaining input from maintenance personnel at the design stage.

- The majority of respondents claimed to “always” keep maintenance in mind when designing and agreed that maintenance considerations are “very important” in design.

- The majority also agreed that DFM is worth the cost implication, and that it should be an integral part of the design process.

- Rapidly dwindling natural resources and growing awareness of the impact of humankind on the natural environment have led to legislation which has impacted, for example, on the design of motor vehicles to produce lower levels of harmful gas emissions. Respondents to this survey, however, believed that more legislative control over the built environment would stifle creativity in architecture.

- Creative thinking techniques such as brainstorming facilitate a team approach to design problems, where the expertise of various professionals could be shared to produce an optimum result. However, the majority of respondents to the survey did not use brainstorming techniques when designing.

5.3 RECOMMENDATIONS

The need for maintenance is not decreasing. Buildings are becoming increasingly complex and their life spans longer, but maintenance budgets and resources are not increasing at the same pace. This study has documented how taking maintenance issues into account at the design stage can impact positively on the long-term maintenance costs. The key to achieving this is to raise awareness amongst the architectural profession of the concept of Design for Maintenance (DFM) and, more importantly, for them to adopt strategies and tactics to implement it. However, levels of awareness of – and more importantly, commitment to – DFM amongst the architectural profession could be improved.

Based on the research conducted, a number of recommendations can be made to facilitate the implementation of DFM.

Maintenance and related issues should form part of the curriculum for the education of architectural professionals. In terms of continuing education for practicing designers, professional forums that endeavor to enlighten professionals about emerging environmental problems and issues should play a bigger role.

Also on the continuing education theme, it is suggested that professional workshops be held for practitioners, focusing on the challenge of identifying common development processes and practices that support and enable building maintenance. The main goal of the workshop would be to challenge individuals who are involved in the built environment to design for maintenance, and to challenge assumptions about building design methodologies. In order to achieve this goal, maintenance managers could develop and present anecdotal models to demonstrate the factors that have enabled teams to successfully design buildings that require less maintenance.

Proven life cycle costing (LCC) guidelines exist and should be followed in the evaluation design alternatives that would best meet the economic and non-monetary considerations of building owners. The consequences of various courses of action for an owner should be assessed in such a way that all involved in the design process are able to make better decisions.

Maintenance managers must ensure that an LCC Plan accompanies all new design proposals as part of the maintenance manual.

It is further advisable that facilities or maintenance managers are involved during the design stages of a contract so that they can provide information and criticism on maintenance issues that have been previously experienced and documented. They can also assist in highlighting common maintenance pitfalls to be avoided in the design. Because the design process takes top priority when starting a building project, it is important to address the awareness of maintenance issues at this early stage.

Technology has made it possible for the non-designer, in this case the client or experienced maintenance manager, to see exactly what goes on in the designer's mind before a cent is spent on construction. This allows the client or maintenance manager to advise on design aspects that might affect maintenance costs, before the costs are incurred.

Where DFM is required on a building project, the maintenance or facilities manager should drive this process, alongside the designer.

Bearing in mind that the architectural profession still values aesthetics over maintenance-friendliness, it will be up to maintenance and facilities managers to devise strategies to ensure that the designers they hire give priority to DFM considerations on their projects.

Designers would be strongly advised to start making an effort to visit buildings after completion, and have discussions with the owners, occupants, and/or maintenance staff. In this way they could gather information on maintenance work that could have been avoided through more appropriate designing.

Taking this idea a step further, maintenance and facilities managers should make post-occupancy evaluations (POE) a formal part of their maintenance plans, and ensure that the designers are involved in such evaluations. These POE reports would provide good indications of what could be done differently to achieve a higher level of DFM on the next building project.

Instances where design issues have hampered maintenance efforts should be documented to a central database accessible to all, with the aim of enabling professionals to make more informed decisions regarding DFM. Documented experiences should serve as valuable tools to guide designers towards making more educated decisions on building design.

5.4 CONCLUSION

The awareness of DFM within the architectural fraternity has been tested and presented in this research. This research study has endeavoured to equip design practitioners with guidelines and assistance in the area of DFM and its practical implementation. Its further aim was to evaluate factors, concepts and techniques and scrutinise the effective applicability into our construction industry.

Raising awareness of DFM amongst designers is an important objective that could have a positive effect on maintenance costs, thus impacting on the life cycle costing of buildings. The research suggests that designers' perceptions of DFM need some adjustment.

Design professionals play the central role in the built environment, which is a social, political and cultural construction. A call to design for maintenance also implies a commitment to more sustainable design, with the potential for a positive future impact on the environment as a whole.

All design professionals should understand that architecture is never alone in this world. Maintenance issues and problems are not always design-related, but design is unquestionably a major part of their solution. If it is believed that design makes the difference then we have to accept its ”complicity” in social problems and its responsibility to collaborate and address them. The act of building is an act of creative destruction, and it is the architect’s responsibility to make sure its ideas and ideals are worth the trouble.

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B

Survey Questionnaire

APPENDIX B

Dear Colleagues

As part of my studies towards a MSc Built Env. Specializing in Facilities Management, I am researching the effects that design input has on the maintenance cost of buildings.

I herewith would like to invite you to participate in this survey titled

"Designing for Maintenance"

The data researched would be most valuable to the NMMU when future buildings would be designed and built as the focus of the study is around tertiary buildings. Funding at tertiary institutions is becoming scarcer every year. The expenses where funds are cut back are always wrongly on the maintenance budgets. As long as we construct buildings, there will be maintenance costs. An attempt would be to have future buildings designed in a fashion that will have the cost of maintenance on these buildings kept to an absolute minimum.

Please take note of the following:

- There are 39 questions.
- There are no right and wrong answers in this survey.
- There are no foreseeable risks associated with this project.
- DFM – abbreviation for the title of this survey – can be read as "designing to make maintenance easier or cheaper".
- For the purpose of this survey the word 'Architect' may refer to all Architectural Professionals.
- Should you feel uncomfortable with any of the questions please feel free to skip them or withdraw from the survey at any point, however your participation and honest opinion is appreciated.

Please feel free to forward this survey to any other individual that you feel may contribute greatly to the topic. All responses are treated with absolute confidentiality. Data will be handled with coding and not with names. The data researched will be treated on an aggregate reporting.

Should you have any queries regarding this survey please feel free to email me (melvin.syce@nmmu.ac.za) or call me on 083 264 6820.
Thank you.

DFM Questionnaire (Designing for Maintenance)

Guide: Make your choice by clicking inside the cute little box. Aim - **x** . A cross will appear. Select only one answer per question.

1. This topic is a part of the curriculum in Architectural schools.

   ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

2. The focus of this topic should only be applied to certain buildings.

   ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

3. I request feedback from building owners or maintenance personnel from buildings designed for use in future designs.

   ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

4. We request input from maintenance personnel when we design buildings.

   ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

5. Maintenance is always kept in mind during the design stages of our buildings.

   ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

6. Maintenance is unimportant at design stages of a building.

   ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

7. DFM is worth the design cost implications.

   ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

8. Owners should compile lists of design criteria and a team of design evaluators to criticize designs in order to get more DFM friendly designs.

   ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

9. Controlling design by legislation could kill architectural creativity.

   ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

10. Today's computer technology can greatly assist with the visualization of maintenance aspects while designing.

    ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

11. Clients normally request that the design should be as maintenance free as possible.

    ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

12. I always bring up the topic of maintenance while designing.

    ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

13. DFM should be part and parcel when designing buildings.

    ☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

14. DFM are very important when designing buildings.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

15. I see the advantages in considering DFM in building design.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

16. Architectural Practitioners are highly aware of DFM.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

17. Most Architectural Professionals are highly committed to applying DFM.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

18. Decisions affecting DFM is usually made at a higher level.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

19. Authority to make these types of decisions is usually delegated to lower ranks.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

20. Teamwork is used to get things done, rather than hierarchy.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

21. We always brainstorm when we design new buildings.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

22. Information is shared so that everyone can get the information when needed.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

23. DFM is part of the ongoing education and involves all Architectural Practitioners.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

24. The Professionals in the Built Environment always work as if part of a team.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

25. Within this team, Architects are solely responsible for the selection, use and application of materials.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

26. The relationships between the BE professionals are of utmost importance to achieving the DFM goal.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

27. Projects are structured in a manner that shows clearly all the roleplayers responsibility within the DFM framework.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

28. There is a clear and consistent set of values that is applied when designing buildings that governs a favorable DFM outcome.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

29. Maintenance is never a topic of discussion in our office when designing.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

30. We should assume that Architects do consider maintenance while designing.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

31. There is a clear agreement about the right way and the wrong way of applying materials.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

32. Trend plays a big role in deciding what material is used when designing.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

33. Post Occupation Evaluation should be encouraged among Architectural Practitioners to broaden their DFM experience.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

34. Age.

☐ 20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60

35. In what field of Architecture are you strongest.

Designing

36. In what field do you aspire to be stronger.

Designing

37. My years of experience in Architecture.

☐ 1 Yr ☐ 5 Years ☐ 10 Years ☐ 20 Years ☐ 30 and above

38. My highest professional level that I can register with SACAP.

☐ Draughtsman ☐ Technologist ☐ Senior Technologist ☐ Architect

39. Please enter any information that you feel may be relevant to this survey and topic of research.

Place cursor inside box and start to type normally.

You're a winner.

Thank you for your time in completing this survey.

Upon completion please email this back to melvin.syce@nmmu.ac.za.

C

Summary of Questionnaire results

Summary of Questionnaire results

Question Number	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	27%	13%	33%	27%	0%
2	0%	27%	13%	53%	7%
3	0%	33%	7%	47%	13%
4	13%	13%	27%	27%	20%
5	7%	20%	20%	47%	7%
6	7%	53%	27%	13%	0%
7	0%	7%	7%	67%	20%
8	7%	20%	13%	40%	20%
9	0%	20%	13%	27%	40%
10	0%	20%	20%	60%	0%
11	0%	27%	47%	20%	7%
12	0%	33%	27%	40%	0%
13	0%	7%	27%	67%	0%
14	0%	20%	13%	67%	0%
15	0%	20%	20%	53%	7%
16	0%	27%	33%	33%	7%
17	7%	20%	47%	27%	0%
18	0%	13%	33%	53%	0%
19	0%	53%	7%	40%	0%
20	7%	20%	20%	53%	0%
21	0%	53%	7%	20%	20%
22	0%	40%	13%	33%	13%
23	0%	20%	47%	27%	7%
24	0%	53%	27%	20%	0%
25	0%	20%	40%	40%	0%
26	0%	7%	13%	67%	13%
27	0%	13%	27%	60%	0%
28	0%	27%	20%	53%	0%
29	7%	40%	27%	27%	0%
30	0%	33%	27%	40%	0%
31	0%	20%	40%	40%	0%
32	0%	33%	13%	47%	7%
33	0%	7%	13%	47%	33%