

**THE INFRASTRUCTURE COST
PLANNING MODEL: AN INTEGRATED
SOLUTION TO COST EFFECTIVE
DESIGN**

by

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DECLARATION

This dissertation, except where indicated in the text, is the candidate's own work and has not been submitted in part, or in whole, at any other University or University of Technology.

This research was conducted at the Durban University of Technology under the supervision of Dr Dhiren Allopi.

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DEDICATION

*For
Everyone that I Love*

ABSTRACT

Infrastructure project costs are being scrutinised more closely and with greater skill and accuracy as projects have become larger, more complex and more expensive, and clients have become more exacting in their requirements. These and other factors compel engineers to design with greater care and in more detail.

However, public planners spend very little time generating alternative project options, often presenting decision-makers with only a few poorly differentiated alternatives borrowed ad hoc from other projects. Even more disturbing is that they often devote the greatest amount of decision making resources to the development of a single decision rather than a variety of options.

A systematic and iterative analysis of the cost consequences of different design solutions is commonly suggested for infrastructure projects, but rarely happens. There is a growing need to integrate design and costs.

This study concentrates on the issue of cost optimisation of infrastructure projects (particularly at the design stage of the project) and applies construction economics, cost planning, cost optimisation and value engineering techniques to the design of such projects.

The methodology proposed in this study for the optimisation of cost and design planning is the Infrastructure Cost Planning Model. This model divides the planning of a project into four stages and utilises twelve Cost Report Forms across these stages.

The Cost Report Forms define in a comprehensive, precise and verifiable manner the essential characteristics of a deliverable component. They are used to measure, quantify, verify and audit the different design options.

By means of the Cost Report Forms, the Infrastructure Cost Planning Model enables the client to select a combination of alternatives and evaluate a number of possible design options – with their cost implications – at each stage of the design process. This

promotes transparency and accountability, and enables consultants and clients to have greater control over the planning process and overall costs.

Two case studies on infrastructure related projects were conducted and confirm that the Infrastructure Cost Planning Model can reduce costs.

This study demonstrates that it is possible to overcome the problem of over expenditure by introducing cost effective design decisions prior to the infrastructure design approval process. The Infrastructure Cost Planning Model can improve infrastructure standards and procure design in a cost effective, equitable, competitive and transparent manner.

This study contributes to the underdeveloped area of cost planning and forecasting of infrastructure projects.

The findings are relevant to the South African government's infrastructure service delivery programme and the general issue of affordable infrastructure services.

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CHAPTER 1
INTRODUCTION

CHAPTER 1: INTRODUCTION

1.1 Challenges

Due to the housing and infrastructure industry's rapid growth, cuts in the infrastructure budget, poor forecasting techniques and insufficient research, the danger of cost overruns, wastage and insufficient control of budgets is increasing substantially.

While there are numerous political, social and economic aspects of the infrastructure problem that need to be considered, there is also a great need for appropriate technical solutions.

The lack of available financing is often cited as a major reason for the delay or failure of many projects. However, inappropriately high service levels and technical standards can result in unnecessarily high costs.

Many attempts have been made during the last decade to reduce the cost of infrastructure projects, but have often resulted in projects of poor quality.

Infrastructure projects to date have been characterised as costly, inflexible and inefficient. In order to overcome limitations such as cuts in the budget, insufficient funds, inaccurate forecasting and poor quality there is undoubtedly a need to fundamentally transform the existing infrastructure sector. Current practice and procedures tend to favour only single solutions and do not adequately evaluate the use of various design options for infrastructure projects.

1.2 Justification of this study

There is a need for tools to assess infrastructure costs at the design stage, where costs are influenced the most.

There is a need to create a cost effective infrastructure design management system that encourages and promotes the use of more than one level of service option. This would improve infrastructure standards and procure design in a cost effective, equitable, competitive and transparent manner.

By utilising improved optimum-seeking cost methods, this study demonstrates that it is possible to overcome the problem of over expenditure by introducing cost effective design decisions prior to the infrastructure design approval process. This increases overall competitiveness by bringing a whole new class of productive solutions to problems while at the same time adding a fresh perspective to the traditional infrastructure design process.

In general, poor service delivery and the housing backlog justify any relevant effort to improve those indicators.

1.3 Aims

In view of the inadequacy of infrastructure cost forecasting, the aims of this research are as follows:

- To create an infrastructure budgetary control tool that links design to cost;
- To provide accurate forecast of cost at any stage in the design process, thereby reducing the over/under budgeting of projects and cost overruns;
- To enhance consultants' decision making capacity thereby achieving value for money of public expenditure by enabling cost informed choices on technical options;
- To give confidence to the client with regard to the cost of the project;
- To address bottlenecks in infrastructure planning by promoting effective and accountable management of infrastructure;
- To ensure good quality service without additional funds;
- To optimise the client's budget, particularly at inception stage where cost is influenced the most, thereby enhancing service delivery.

1.4 Objectives

The overall aim of the study can be interpreted in terms of a number of supporting objectives:

- To develop an interactive decision making tool that assists consultants and clients by showing the cost implications of different options on infrastructure projects;
- To develop a method for comparing a range of possible design alternatives at any stage in the design evolution, and forecasting the economic effects resulting from the change of different variables;
- To develop a single integrated cost control system which contains the functions of cost planning, cost control, value management and quality management on infrastructure projects;
- To develop Cost Report Forms that allow consultants' decisions, clients' objectives and project requirements to be clearly articulated and readily measured in infrastructure projects.

1.5 Terminology

Cost Target

The cost target indicates the overall cost that the client can reasonably expect the project to be.

Elements

This is used to denote the basic components of infrastructure services such as water supply, sewers, roads and stormwater drainage.

Cost Limit

The sum of money which the client considers to be the maximum that they are able and/or willing to pay for the project, based on the amount that can be raised by grants, loans or other resources.

Cost Analysis

A cost analysis enables the designer to determine how much has been spent on each element. It is a systematic breakdown of costs and assists in the estimation of overall cost.

Cost Plan

This is a statement of the proposed expenditure related to each section or element.

Cost Check

A process of checking the estimated cost of each section or element of the project as the detailed designs are developed against the cost targets set in the cost plan.

1.6 Overview of Chapters

A brief overview of the chapters is presented below:

Chapter 1 – Introduction

This chapter provides the background to the study. It includes the challenges facing infrastructure projects, the research aims, objectives, needs for the study, and a brief overview of the chapters.

It also deals with the need to implement appropriate cost optimisation techniques and decision support systems in order to promote optimal decision making on infrastructure projects.

Chapter 2 – Literature Review – constitutional requirements: the need for economic evaluation

This chapter gives an overview of the legislative requirements for infrastructure projects, with respect to ensuring cost effectiveness of the project. It examines the role of government and municipalities in ensuring the cost effectiveness of projects and the provision of services at an affordable level.

This chapter also identifies the need to implement a system to support decision making processes for the client.

Chapter 3 – An overview of context and challenges facing infrastructure practice

This chapter gives an overview of the growing complexity of infrastructure issues and the cost overruns that occur on infrastructure projects. A literature review of current practice reveals that there is a lack of alternative design option assessment on infrastructure projects and clients and engineers tend to be biased towards single solutions.

Further, the literature review reveals that there is a need for tools and forecasting techniques to assess the cost of different options available for infrastructure and housing projects.

Chapter 4 – The influence of early design decisions on cost

This chapter looks at the need for co-ordinating design decisions and costs. This chapter gives an overview of the link between design decision and costs. It shows that the most significant cost reductions are achieved during the inception stage of the project and that as the project develops, the ability to change costs decreases rapidly. It also shows the declining influence of cost reduction.

Chapter 5 – Current practice: the need for cost planning techniques on infrastructure projects

This chapter presents the literature review that was conducted on the concepts of cost planning, construction economics and value engineering with a view to incorporating these concepts into the planning of infrastructure projects and creating tools that can assist users to make cost informed decisions on infrastructure projects. This chapter also describes the concept of cost planning and shows how it can be applied to infrastructure projects, as well as the advantages of using this concept.

Chapter 6 – The Infrastructure Cost Planning Model

The proposed Infrastructure Cost Planning Model is discussed in this chapter. The model evaluates a number of possible design options with their cost implications at each stage in the design process. The purpose of the model and the detailed description of the Infrastructure Cost Planning Model are described in relation to the various project design stages. The application of the Infrastructure Cost Planning Model and its benefits to consultants and clients is discussed.

Chapter 7 – The Cost Report Forms

This chapter focuses on the Cost Report Forms within the Infrastructure Cost Planning Model. A description of the Cost Report Forms is presented and their functions are explained, as well as how continuous monitoring and control of costs can be achieved with the aid of the proposed forms.

Chapter 8 – The Infrastructure Cost Planning Model can ensure value and quality management on projects

In response to the challenges mentioned in Chapter 3, this chapter shows how the model can maximise the quality and function of the project, without undue costs. The chapter shows how the Infrastructure Cost Planning Model incorporates design quality and value management techniques. The various Cost Report Forms compliment the value analysis process and create opportunities for design improvements.

Chapter 9 – The Infrastructure Cost Planning Model can ensure accuracy of project estimates

This chapter shows how the Infrastructure Cost Planning Model can improve the accuracy of estimates. Cost Report Forms can increase the accuracy of projects at the various stages and help reduce the element of surprise during the bidding process or the need for cost cutting later in the construction stage.

Chapter 10 – Case studies

This chapter describes two case studies conducted by the researcher comparing the traditional method of economic analysis with the proposed Infrastructure Cost Planning Model. It demonstrates that the Infrastructure Cost Planning Model is more effective than the traditional model at controlling cost on infrastructure projects at a number of different stages in the design process.

Chapter 11 – The study's contribution to designing and delivering infrastructure projects

The primary purpose of this chapter is to show how the Infrastructure Cost Planning Model can contribute to infrastructure projects in various ways.

This chapter discusses how the Infrastructure Cost Planning Model promotes accountability and affordability in line with legislative requirements, and can help achieve sustainable service delivery. It shows how the Infrastructure Cost Planning Model can be used as an instrument for economic project planning and describes its benefits.

Chapter 12 – Conclusion and Recommendations

This chapter enumerates the limitations and general conclusions of the study, and outlines the scope for future research. The Infrastructure Cost Planning Model gives rise to various recommendations, all of which seek to promote affordable infrastructure services.

1.7 Summary

This chapter gives an overview of the research study including the challenges faced by designers, the research aims and objectives, and an overview of the chapters. The aims and objectives are aligned with the search to overcome limitations such as cuts in the budget, insufficient funds, inaccurate forecasting and poor quality due to insufficient funds.

Issues such as poor service delivery and the housing backlog more than adequately justify this study.

There is undoubtedly a need to fundamentally transform the existing infrastructure sector in order to respond to the needs of the client. There is a need for more effective methods of assessing various decision making options on infrastructure projects in order to promote the provision of affordable infrastructure services.

CHAPTER 2

LITERATURE REVIEW – CONSTITUTIONAL REQUIREMENTS: THE NEED FOR ECONOMIC EVALUATION

CHAPTER 2: LITERATURE REVIEW – CONSTITUTIONAL REQUIREMENTS: THE NEED FOR ECONOMIC EVALUATION

2.1 Introduction

In this chapter the Constitution and Government legislation pertaining to infrastructure is briefly examined. The role of the public sector in providing services and its ability to meet the challenges facing South Africa is highlighted. An attempt is made to understand the government's obligations with regards to the provision of infrastructure services. It analyses the infrastructure policies in terms of achieving economic projects.

This chapter makes recommendations regarding the need for design planning, enhanced cost optimisation and accountability at the design stage of infrastructure projects.

2.2 Government's commitment to service provisions

While there are numerous political, social and economic aspects of the housing problem that need to be considered, there is also a great need for appropriate technical solutions.

Government needs to effectively monitor the housing process from beginning to end instead of just allocating money. Therefore, a different approach is needed to housing.

2.2.1 Constitutional provisions in relation to service provision

The Government is committed to ensuring that public infrastructure and services are delivered in a cost effective manner and to adopting transparent processes to facilitate accountability. They are ultimately responsible and accountable for all project expenditure and decision making of projects.

The Constitution gives municipal councils the obligation to ensure that services are delivered to their municipalities in a sustainable way (Joseph, 2002).

Government has made an explicit commitment to improving the quality and quantity of South Africa's infrastructure. Inevitably, therefore, the task of transforming infrastructure development presents an enormous challenge for both the government and the construction industry (Zuma, 2009).

2.2.2 The need for economic service provision within municipalities

The real issue facing each municipality is to find the most appropriate combination of options which can most effectively lead to the achievement of its policy objectives.

Municipalities and councillors should embrace innovative new approaches to delivering core municipal services. The need to strategically assess and plan the most appropriate forms of service delivery is of utmost importance. Municipalities need to be geared to implement the chosen delivery options in the most effective manner and so ensure maximum benefit to communities (Joseph, 2002).

The economic and financial viability of infrastructure services receives little attention during planning and budgeting. Consequently the services are normally not integrated and co-ordinated, and this leads to duplication of activities and inefficient application of resources (Mhango, 1999).

This situation, therefore, calls for a pragmatic approach to planning and budgeting, and to the pricing of infrastructure services by municipalities. Realistic pricing of services helps to ensure that the services not only yield societal benefits but are also financially viable.

The eThekweni Procurement & Infrastructure Cluster Committee requires infrastructure to be cost effective and sustainable (Procurement & Infrastructure Cluster Committee, 2003).

The competing demands that are made on limited municipal operational budgets (and

staff and other resources) severely constrain the proper management of services infrastructure.

Some research work has already been done in the area of public sector infrastructure asset management in South Africa.

Consultants offer a variety of skills and services including infrastructure management manuals and (IT and other) systems.

CSIR Boutek identified that, whereas these manuals and systems are very useful to the better-resourced municipalities, they are much less useful to the great majority of municipalities. Also, it would appear that a great deal more than manuals and systems is needed, if infrastructure management is to be adequate -- inter alia: a suitable legislative framework; convincing those responsible for budgetary allocation (without the political will to allocate adequate budgets, the beneficial impact of any consultants' services or of manuals or systems will be limited); skills training, skills retention, and mentorship; the buy-in by national government and other big spenders on or funders of public infrastructure; alternative delivery models and delivery agents for infrastructure management; and the determination of norms, standards, levels of service, and key performance indicators (Wall, 2005).

2.2.3 Municipal Infrastructure Grant Programme (MIG)

The MIG programme requires that consultants assess alternative solutions on infrastructure projects but has no mechanisms, systems or tools in place to control, monitor and cost optimise design solutions during the various stages. It does not provide for adequate exploration of alternative design options during the various stages of the project.

This has resulted in the following phenomenon:

- A succession of stereotyped solutions;
- A rigid method of approaching projects, which may exclude potentially more beneficial approaches;
- A single view of the problem.

2.3 Recommendations

From the literature review carried, it is found that there is a lack of accountability, poor design management, low-quality services, and little promotion of alternative infrastructure delivery options. In the light of this finding, the following recommendations are proposed:

- Promote and support a range of delivery options based on service levels;
- Develop mechanisms for allowing engineers and clients to make cost informed decisions and adopt cost control measures during the design stage;
- New approaches to cost reduction and exploration of cost saving measures;
- Examine means of incorporating value engineering in design;
- A growing need to find ways to enhance cost optimisation on infrastructure projects.

2.4 Summary

The chapter reviews the need for economical service provision within the context of what the Constitution allows. A literature review of current practice reveals that no cost optimising systems or tools are used by clients and consultants to assess the cost of different options available for infrastructure developments. The conclusion of this chapter is that there is a need for more effective methods of assessing design options and promoting cost optimisation on infrastructure projects.

CHAPTER 3

AN OVERVIEW OF CONTEXT AND CHALLENGES FACING INFRASTRUCTURE PRACTICE

CHAPTER 3: AN OVERVIEW OF CONTEXT AND CHALLENGES FACING INFRASTRUCTURE PRACTICE

3.1 Introduction

This chapter provides an overview regarding the current status of infrastructure projects. It highlights the deficiencies of current infrastructure projects, cost overruns and the lack of design options or cost optimisation on infrastructure projects.

From the review carried out on current infrastructure practice, it is clear that there is a need for more systems and tools to be in place to facilitate infrastructure service delivery.

3.2 Enhancing infrastructure service delivery

Standardisation in procurement documentation, design specifications, procurement, pricing, contracting and targeting strategies within particular infrastructure programmes can also bring about significant efficiencies in the time and cost of the delivery of projects, and improvements in project outcomes, all of which will significantly reduce the internal and external professional inputs required to deliver projects.

An alternative approach to alleviate many of the perceived skills deficits in infrastructure delivery at local, provincial and national government is needed. Systems are needed that can manage the infrastructure design, procurement and delivery process. Such processes would dramatically reduce the risk of poor delivery and at the same time better utilise scarce expertise within the public sector (Didiza, 2007).

3.3. The growing complexity of infrastructure issues

Today it is widely acknowledged that the complexity of infrastructure planning and realisation is growing, and on many levels – technical, legal, political, social and financial. The technical complexity of infrastructure planning and decision making has increased as a result of several factors, including:

- Technological developments;
- The growing scarcity of resources;
- The growing construction costs;
- The needs of clients;
- Uninformed design decisions (Meiklejohn *et al.*, 2008).

3.4 Cost overruns on infrastructure projects

Cost management problems start at the initial design stage with feasibility and elemental budgets that can be very inaccurate – inaccuracies which can continue through the design development if costs are not monitored throughout the design phase. Inaccurate early cost estimates can be a catalyst that triggers a series of events that will culminate in overspending.

It may also be triggered when specification changes that affect the final budget are not carried through to the relevant cost report, because of ineffective manual systems. It has been estimated that some 80% of projects are already over budget by the time construction commences on site, but ignorance of that fact allows the projects to go ahead.

Paying more attention to project administration will reduce cost underruns and overruns, thus improving the quality of cost estimates.

One of the aims of good cost budgeting must be to avoid abortive effort and therefore to advise where cost-acceptable solutions are likely to be found (Ferry and Brandon, 1999).

A well implemented cost control system introduced at the conception of the design process and continued through construction will reduce construction problems and cost overruns.

A further role identified for designers is that of optimal interaction with clients, particularly at the design brief stage. This is the most crucial phase for the successful and safe completion of any project.

3.5 The lack of alternative design options on infrastructure projects

At present, municipalities do not have the systems or tools to evaluate and forecast costs of a number of design options on infrastructure projects. Clients such as municipalities do not have cost optimisation techniques to ensure optimal use of the budget achieved. They rely solely on consultants to give them the best choice of design option, at the most economical price.

Traditional estimating methods can result in the designer sacrificing client benefits by selecting what seems to be a cheaper design alternative but in reality is not.

Atkin (1987) contends that there is a tendency for the client and the designer to be biased towards a particular solution and, therefore, only one design is considered. This can result in an unproductive use of infrastructure budgets.

There is a neglected dimension in the planning of projects. Evidence such as the lack of proper cost systems suggests that public planners spend very little time generating alternative policy options, often presenting decision makers with a few poorly differentiated alternatives, borrowed ad hoc from other projects. Even more disturbing is that they often devote the greatest amount of decision making resources to the development of a single decision, rather than a variety of well-spaced options (Byrne, 1995).

Provision of safe water and sustainable sanitation for the urban poor is required as one of the factors to ensure public health, but is challenging for reasons such as insecure

tenure, lack of political will, financing, cost recovery and choice of technical options (Münch, 2007).

There is a need to transform the existing public infrastructure system in order to respond to the current needs of the South African society.

3.6 An evaluation of current practice

A review of the literature reveals a lack of control systems and cost planning techniques on infrastructure projects. It also reveals that there are inadequate controls in place to assess the cost of various options during the design stage which is when the major cost-significant decisions are made.

The following questions arise from the evaluation of current practice:

- How are projects being controlled at the design stage, where construction costs are affected the most?
- What systems are in place to enable optimal decision making processes?
- What sustainable mechanisms should be put into place to ensure cost effectiveness and efficiency?

The following points arise from these questions:

- There has to be a greater effort at improving and controlling the cost of infrastructure design options at the various stages of the project;
- There is a need for generating new ideas and cost optimisation of alternative solutions for projects;
- There is a need for active participation of consultants and clients at the design stages.

It is thus accepted that the systematic evaluation of the design options needs to be a focal point in the project cycle. There has to be a mechanism whereby clients, consultants and government can evaluate the cost of design decisions at the planning stage, where costs are most affected.

3.7 Summary

This chapter reviews the need for economic evaluation of infrastructure service options and the deficiencies in current provisions for infrastructure services practice. It gives an overview of the context and challenges regarding infrastructure projects.

From the literature search undertaken, it is evident that there is a need for design tools and mechanisms that facilitate an optimum use of the client's budget and cost control at the design stage, where cost optimisation can be most readily achieved.

CHAPTER 4
THE INFLUENCE OF EARLY DESIGN DECISIONS
ON COST

CHAPTER 4: THE INFLUENCE OF EARLY DESIGN DECISIONS ON COST

4.1 Introduction

A successful project is managed by taking control of the client's decision making processes as early as possible, to provide the certainty of decision making. This should be done by totally involving clients in the decision making process so that they can appreciate the necessary timing and consequences of the decisions.

This chapter shows the significance of cost decisions made at the early stages of a project. The lack of preliminary planning and design – which includes poor cost forecasts and inadequate design solutions – contribute to construction delays and costs overruns, which in turn contribute to higher per unit cost or over optimistic cost projections. The lack of co-ordination can also lead to abortive design work and may result in unsatisfactory design solutions.

4.2 The need for co-ordination of design and cost

The greatest activity generally occurs during the design stage, when the design process is most complex, as well as being under the most time pressure. When the design process for a project consists of a number of sequential operations, then the management of the whole process is complex. However, because each component is fixed to others, there has to be frequent and detailed interaction between the designers to ensure that the costs are within limit. The sequences and interfaces between designers thus form a network of design activity, which requires cost co-ordination.

Diligent attention to cost issues from the very earliest phases of a project will help guarantee that design quality is "built in" from the beginning.

4.3 The influence of design on cost

As illustrated in Figure 4.1 the designers, though costing the client only 5% of total contract, have a 70% influence on the cost of the contract.

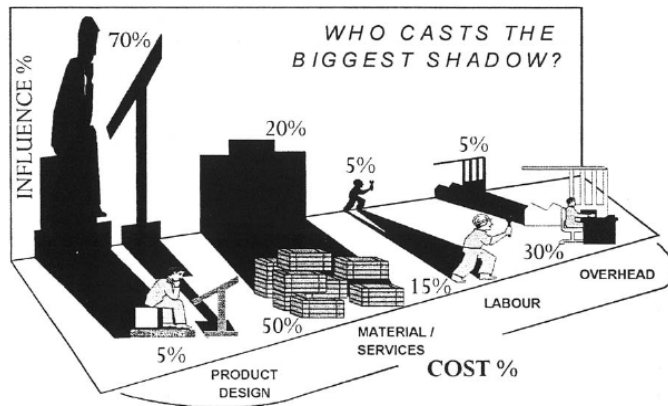


Figure 4.1 Who casts the biggest shadow? (Hubert and Peter, 2007)

4.3.1 Cost-value reductions

Design cost planning is particularly crucial as decisions made during the early stages of the development process have far greater economic consequences than the relatively limited decisions which are made later in the process.

Cost-value savings can be made on a project at any time from inception to completion. However, it is easier to make such changes during the earlier stages of a project than when the project design or the construction phase is nearing completion. Late changes to design are more difficult because of the possible knock-on effects with other aspects of the project. It is also not a good policy to spend more on preparing design changes that result in cost reductions that are less than the administrative costs involved, unless this also achieves some longer term cost savings. Figure 4.2 shows the typical life cycle of a project from conception through to operation and occupation. During the design stage large cost savings can be achieved as the design is flexible enough to incorporate relatively significant changes. Once the project has reached the construction stage, the potential for achieving cost reductions is significantly lower.

The cost reduction potential curve shown in Figure 4.2 graphically illustrates that the most significant cost reductions are achieved during the inception stage of the project.

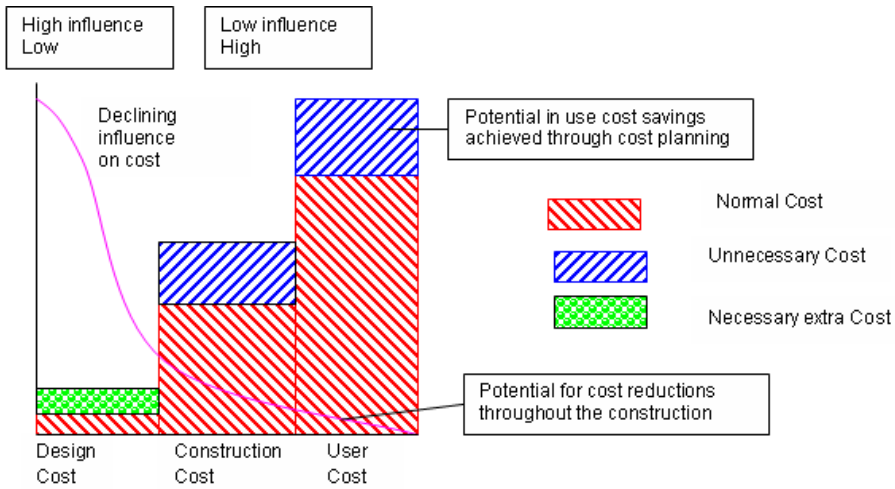


Figure 4.2 The declining influence on cost (Ashworth, 1999)

Figure 4.2 indicates that as the project develops the ability to change costs decreases rapidly during the design stage, and that in general the ability to influence cost decreases during the course of a project (Ashworth, 1999).

Effective cost management requires focusing on the planning, programming, and early design decision making process, where changes can usually be accommodated without major disruption to the project. Figure 4.3 illustrates the relationship between time and degree of change (Dell'Isola, 2002).

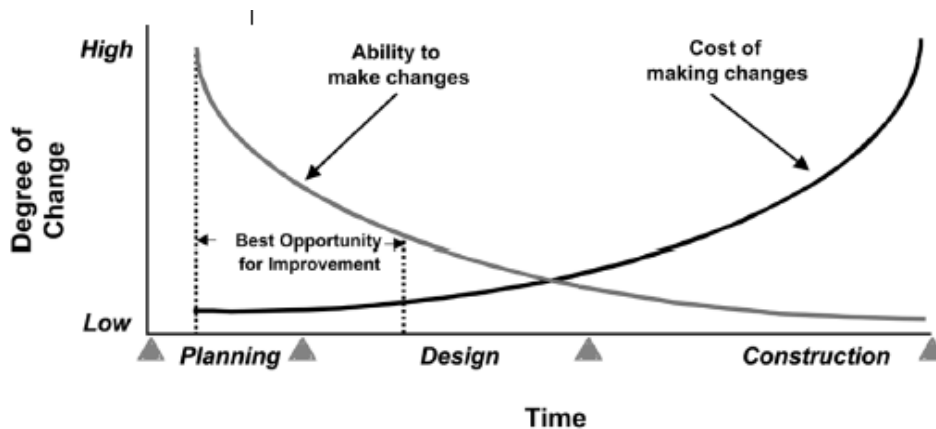


Figure 4.3 Relationship between time and degree of change (Dell'Isola, 2002)

This is not to imply that cost management during the preparation of construction documents is not important, but that the level of focus should be substantially narrowed by design development; otherwise the cost to implement changes may be prohibitive.

4.4 Focusing on cost drivers of a project

It is critical to concentrate on the true cost drivers for any project – there simply is not enough time to “sweat all the details” from a cost perspective. Often, relatively minor decisions can cause substantial ripple effects or may force other decisions not anticipated.

Of a large number of components, a very small number contain the vast majority of cost. This rule is a common thread in cost management approaches. Figure 4.4 illustrates the point in diagrammatic form.

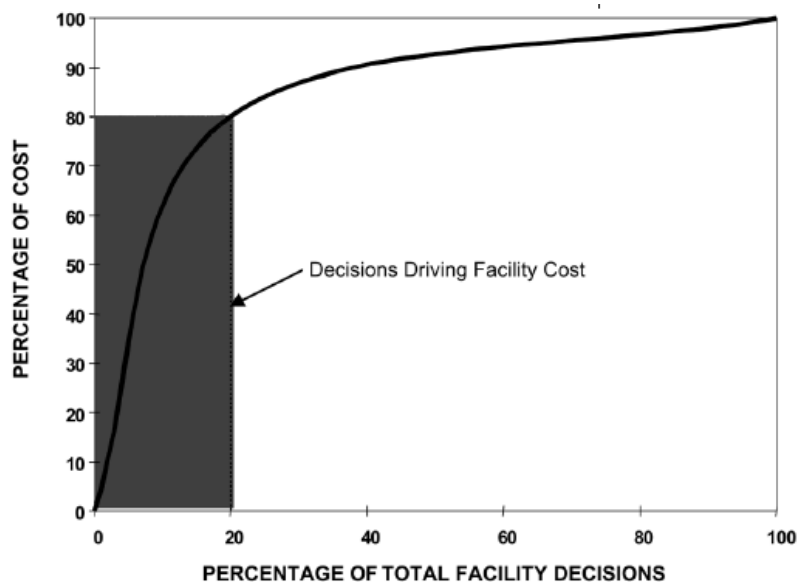


Figure 4.4 Pareto's principle of cost distribution (Dell'Isola, 2002)

Pareto's principle of cost distribution illustrates that by the completion of 20% of a design (sketch design stage), 80% of the costs are committed (Dell'Isola, 2002). Thus, there is already a heavy commitment of cost prior to a sketch design being formalised, and once this stage is completed, there is perhaps only 20% available to actually be 'controlled'. With an improved understanding of the design method it may be possible to input

information prior to the sketch design which will reduce the number of abortive design solutions that need to be produced again (Ferry and Brandon, 1999).

4.5 Summary

Current practice is that early design decisions are being made when not enough data is available thus leading to too many assumptions. Important decisions made very early in the design based on unreliable estimates cannot easily be changed at a later date when more reliable estimates can be made. What is needed is a means of achieving greater estimate reliability in the early stages of design. This chapter gives an overview and link between design decisions and costs. It is accepted that there is a causal link between design decisions and costs. As shown in the figures in this chapter, the degree of influence on costs declines steadily over time.

CHAPTER 5

**CURRENT PRACTICE: THE NEED FOR COST
PLANNING TECHNIQUES ON INFRASTRUCTURE
PROJECTS**

CHAPTER 5: CURRENT PRACTICE: THE NEED FOR COST PLANNING TECHNIQUES ON INFRASTRUCTURE PROJECTS

5.1 Introduction

Clients often want the best possible quality but are not prepared to pay for it. This frequently results in the engineer's major problem being not one of design, but of cost. Cost plays an important part throughout the design process. In the first instance, it influences the size of the project and its general form, and then later it indicates the type of and the choice of services and finishes.

The previous chapter focused on the theoretical effect of design decisions in the early phases of a project. The literature review entailed a search for methods of cost prediction, planning, cost control and other relevant economic theories across all industries, with the aim of applying the insights to infrastructure projects.

Much of the available research on cost forecasting and planning is related to multi-storey buildings and specifically the building industry. The concept of cost planning used in architectural projects encapsulates various methods of controlling costs within a predetermined sum of money. This chapter explores various cost control theories and discusses a way forward for infrastructure projects.

5.2 Need for design evaluation

In addition to the need to ensure that the client's budget is not exceeded, the following factors contribute to the necessity to constantly check the project cost during the design phase:

- Clients have become more exacting and cost conscious for reasons of profitability and accountability. As a result, construction costs are being scrutinised more closely and with greater skill and accuracy;

- Construction projects are now larger and technically more complex and, hence, are more expensive. There is a need for more efficient usage of funds, and higher accountability;
- There is now greater emphasis on a faster pace of the construction process. This creates the need for the development of an optimum design as there is no time to redesign if the lowest tender was excessively high;
- Rising construction costs has introduced a general trend towards greater cost effectiveness and a move to reduce or eliminate waste, where possible;
- Clients have complex requirements and require assessment of the full financial implications before incorporation into a construction project.

5.3 Cost planning: a way forward for infrastructure projects

As one goes through the literature, it is evident that there is a need for sufficient attention to be focused on optimisation of the client's budget and to make confident cost assessment of other options available to the client. These are of prime importance to a client whose aim is to achieve maximum use of the project's allocated funds.

There is a fundamental need to establish cost control at the design stage of infrastructure projects. What is required is a technique whereby estimates can be prepared on the basis of a known and economic standard of construction and finish, early in the design phase. Such a technique is known as cost planning and is the control of cost.

The need for a paradigm shift to focus on cost effectiveness of projects was discussed in Chapter 3. Given the factors described above, it is proposed that there is a need to incorporate cost planning into infrastructure design, in order to improve the practical applications of cost forecasting and planning on these projects.

5.4 Previous research on cost planning theories and techniques

Cost planning is the term used to describe any system of bringing cost advice to bear upon the design process. Another merit of cost planning is that it introduces a positive

checking procedure into the design stage, where previously nothing systematic had existed (Seeley, 1996:123).

5.4.1 Cost planning theories and techniques

The objective of cost planning is to enable the designer to control the cost of a project (within the target) while he/she is still designing. The earlier this process is introduced, the greater the measure of control that can be exercised over ultimate cost, quality and design. Cost planning is a continuous process, with progressive checks being made from time to time in relatively more detail.

Cost planning is interpreted as controlling the cost of a project within a predetermined sum during the design stage, and normally envisages preparation of a cost plan and the carrying out of cost checks (Seeley, 1996:14).

Cost planning is a generic term describing the various methods adopted to shape the construction project's budget progression (Kwakye, 1997: 91).

5.4.2 Cost planning: a three phased approach

Traditional cost planning techniques have been used on buildings and enable the architect to select a combination of alternatives which will satisfy the financial, functional and aesthetic considerations.

Ashworth (1999) describes cost planning as a three phase process for building projects:

- Phase 1: The estimate or establishment of the target cost;
- Phase 2: The cost plan;
- Phase 3: The cost checking.

The first phase involves establishment of a first estimate. The second phase plans how this estimate should be spent among various parts. The final phase is a cost checking process to ensure that various elements can be constructed within the cost plan.

5.4.3 The Royal Institute of British Architects (RIBA) Plan of Work

The RIBA Plan of Work' is a design-tender-construct procedure envisaged from the quantity surveyors' point of view. The 'RIBA Plan of Work', shown in Figure 5.1, represents a suggested set of cost control procedures for architects during each stage of the building project. It incorporates cost planning terminologies such as cost plans, cost checks and cost limits.

At the inception stage of a building contract, the building client considers his/her building requirements and produces a realistic first estimate and a cost limit. At scheme design stage, as the brief is completed the cost plan is formulated, which consists of a statement showing how the design team proposes to distribute the available money over the various elements or parts of the building.

The quantity surveyor carries out cost checks periodically throughout the design stages, to ensure that the architect's proposals are being kept within the total cost limit agreed upon with the building client. Every part of the building is cost checked and design adjusted if necessary. The cost plan is then compared with the cost target for the element and this constitutes a cost check (Seeley, 1996:120).

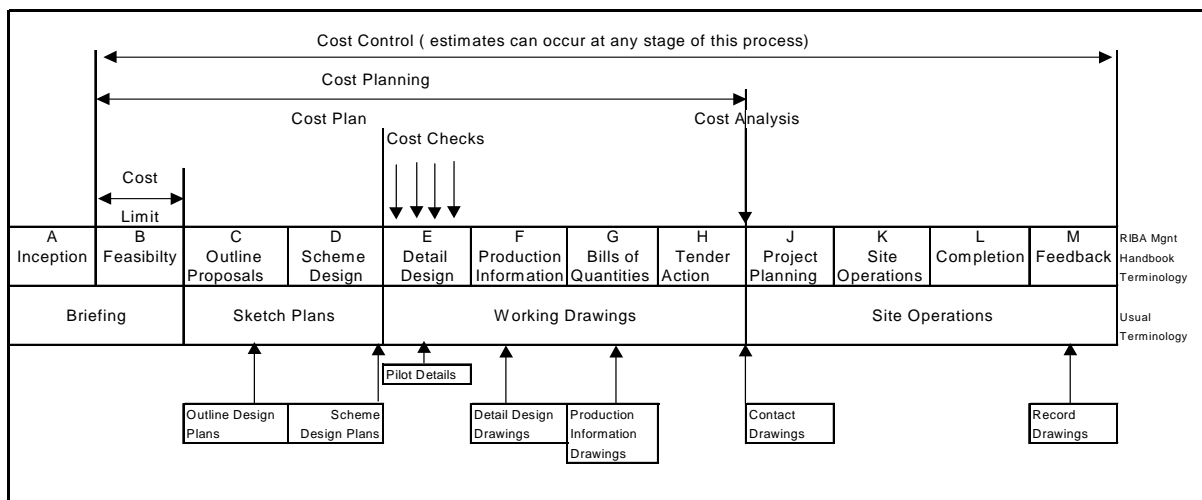


Figure 5.1 The RIBA (Royal Institute of British Architects) Plan of Work (Ferry and Brandon, 1999)

The design is not as straight forward as the RIBA programme seems to imply – there are certain shortfalls. It merely gives an overview of the complete design process on building projects. The pre-tender procedure overlaps in certain procedures and delays letting out of the contract (Ferry and Brandon, 1999).

It does not show the cost implications of decisions at each stage. It indicates the cost of the project only twice in the project lifecycle, as the Cost Limit and the Cost Plan. Whilst it provides an extra dimension to cost estimating, there are the following shortfalls:

- This work plan was created for building projects. However, it becomes very complex too early in the design stage;
- It lacks a method of enforcement due to not having any measurable outputs to enable objective assessment of reliability;
- There are few variables needed to derive a solution and decisions are made when too much data is unavailable;
- It is largely theoretical, laying out the process of design and lacks applicability to everyday projects;
- The methodology does not enforce cost optimisation or value management;
- It focuses only on building process rather than design options and some of the elements are based on guesswork (Atkin, 1987);
- It does not include interaction between client and consultant for client prioritisation;
- Feedback from the client is only proposed at the end, instead of the beginning, where it is the most significant.

5.5 Advantages of using cost planning

The general advantages claimed for cost planning therefore include the following:

- The tender sum is more likely to equate with the approximate estimate;
- It provides a link between design and cost;
- Cost-effective designs are more likely to be achieved;
- It proposes a system of cost control within cost limits;
- Cost planning provides a basis for enforcing cost control of the client's budget;
- It introduces a positive cost checking procedure into the design stage.

5.6 Cost planning: more than just approximate estimating

Cost planning aims at ascertaining costs before many of the decisions are made relating to the design of a project. Cost planning differs from approximate estimating in that approximate estimating aims at providing a preview of the probable tender figure, with the method employed often being influenced by the amount of information available. Cost planning, on the other hand, does not merely estimate the tender sum but probes much deeper into the cost implications of each part of the project, whereby each design decision is analysed and costed. In addition, cost planning permits control of expenditure throughout the design and construction stages.

Approximate estimating plays a largely passive role after the major design decisions have been made, whilst cost planning bears upon the decisions themselves and plays an active part in the formulation of the design.

5.7 Summary

This chapter established an alternative approach to cost estimating on infrastructure projects and infrastructure investment decisions. The cost planning concept could assist planners in developing a least-cost strategy to address infrastructure backlogs, as well as provide sustainable infrastructure services.

Cost planning today should more appropriately be renamed value planning, since the intention is to provide a balanced design and value for money. Although it has been researched in the academic world there is only scant evidence of it ever being used in professional practice (Ashworth, 1983:24).

In order to design a project within the client's cost limit, there is a need to adopt an economic approach to infrastructure project design. Chapter 4 established the need for consultants to evaluate the cost of infrastructure decisions at the planning stage, where costs are most affected. This need can be met by incorporating cost planning theories into infrastructure design, with the aim of optimising the cost of decisions at the planning stage.

This study makes use of traditional cost planning techniques combined with other economic theories such as construction economics, cost optimisation, and value engineering to selectively optimise the value of projects and enhance budget optimisation. A focus on cost optimisation can provide engineers with better tools and techniques for delivering alternative strategies on infrastructure projects.

CHAPTER 6

THE INFRASTRUCTURE COST PLANNING MODEL

CHAPTER 6: THE INFRASTRUCTURE COST PLANNING MODEL

6.1 Introduction

Infrastructure project costs are being scrutinised more closely and with greater skill and accuracy as projects have become larger, more complex and more costly, and clients have become more exacting in their requirements. These and other factors have compelled the engineer to design with greater care and in more detail.

The best choice of appropriate design solutions for infrastructure projects is often complicated by severe financial constraints. A systematic and iterative analysis of the cost consequences of different design solutions is commonly suggested for infrastructure projects, but rarely happens.

The previous chapter focused on the importance of cost planning and applying it to infrastructure projects. This chapter discusses the proposed Infrastructure Cost Planning Model which has been developed to optimise design decisions at each stage in the development of the design.

This model applies construction economics and cost planning, cost optimisation and value engineering to the design of infrastructure projects. This can result in a project of a higher standard, without the need for additional funds, thus improving the design and planning of infrastructure projects.

6.2 Applying cost planning to infrastructure projects

As has been stressed throughout this study, the need to design within cost limits – and to forecast and control costs accurately – arises from the inevitable reality that clients expect value for money. This study uses cost planning theories such as cost limits, cost targets, and cost plans along with construction economics and value engineering to create measurable output reports (Cost Report Forms) that can be used for decision making on infrastructure projects. It combines engineering principles with sound

economic theories and provides tools to facilitate a more organised and logical approach to decision making.

A comprehensive, technically consistent planning method provides an economic framework to assess the cost-effectiveness of infrastructure services options and management strategies, while taking into account all costs.

A successful project is managed by taking control of the client's decision making processes as early as possible to provide the certainty of decision making. This is usually done by totally involving clients in the detailed decision making process so that they can appreciate the necessary timing and consequences of the decisions (Gray and Hughs, 2001:38).

6.3 The Infrastructure Cost Planning Model defined

The Infrastructure Cost Planning Model is shown in Figure 6.1. Through a variety of Cost Report Forms, the Infrastructure Cost Planning Model enables the client to select a combination of alternatives and evaluate a number of possible design options – with their cost implications – at each stage of the design process.

The Infrastructure Cost Planning Model provides a ready guide to design decisions, ensuring progressive, efficient, affordable, economical, and sustainable provision of infrastructure services. It relates the design of infrastructure services to their cost, so that, while taking full account of quality, utility and appearance, the cost is planned to be within the economic limit of expenditure.

One of its aims is to ensure that scarce and limited resources are used to best advantage. It is about ensuring that clients receive the best value for money for the projects that they construct.

THE INFRASTRUCTURE COST PLANNING MODEL

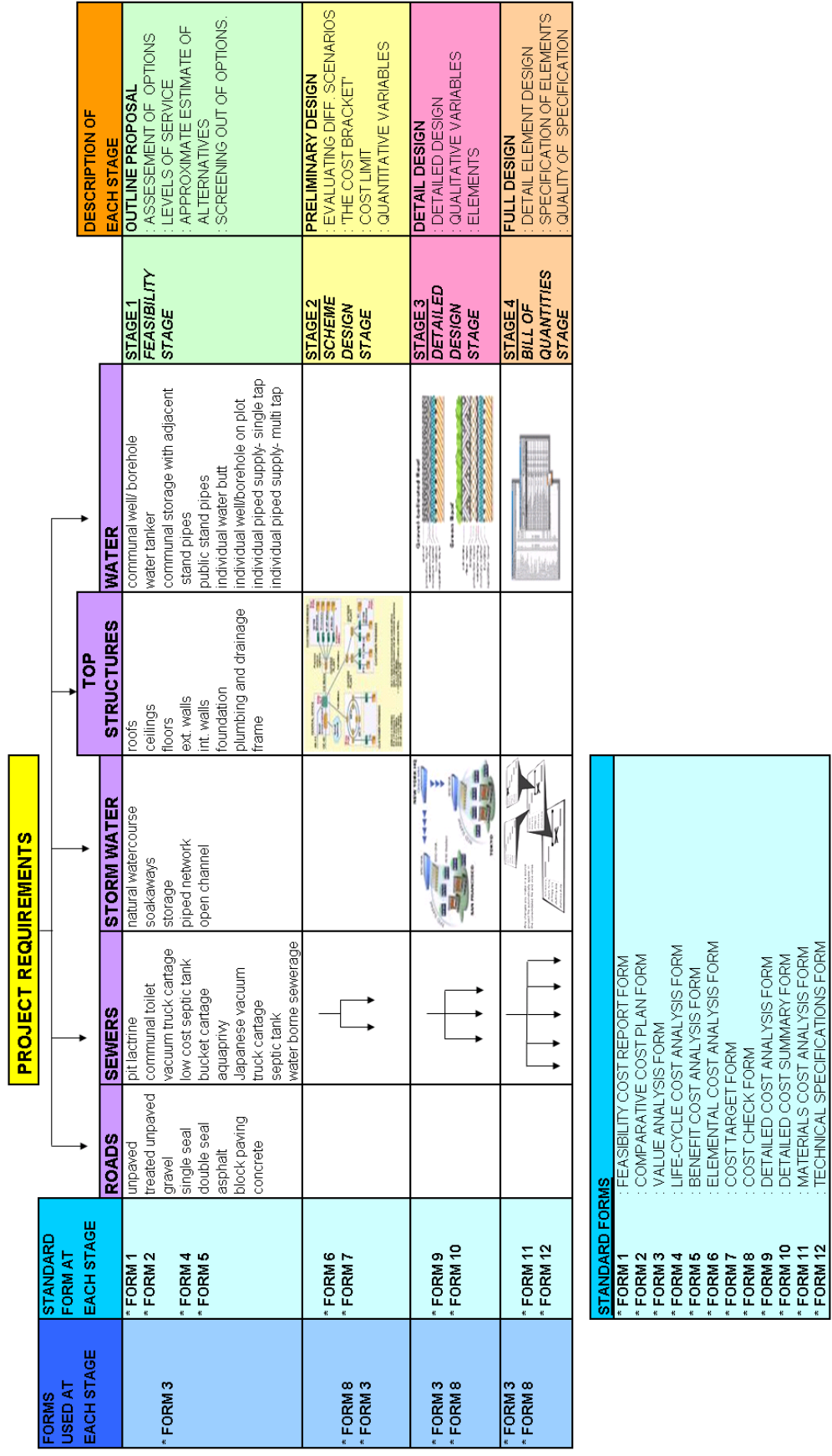


Figure 6.1 The Infrastructure Cost Planning Model

6.4 Purpose of the model

The Infrastructure Cost Planning Model introduces the concept of responsibility for managing cost in all the various stages of the project. The purpose of the model is:

- To provide investors in infrastructure projects with cost information at any stage in the design process;
- To ensure that the work is carried out in a cost effective manner, integrating the design and cost optimising process;
- To use the proposed Cost Report Forms as a cost control mechanism throughout the design process;
- To allow for goals to be set, monitored and evaluated with the aid of the proposed Cost Report Forms, thus allowing for meaningful participation of clients to be obtained;
- To give confidence and economic assurance to the client with regard to the expected cost of his/her project;
- To establish a system for advising the client on cost that is compatible with his/her own build-up of the design, allowing for a meaningful participation of the client;
- To establish a link between the cost control and design so that costs are generated and controlled, while designing.

6.5 The Infrastructure Cost Planning Model methodology

This section describes a methodological approach used to enhance the consultant's decision making process by improving financial optimisation of infrastructure projects. Such improvements would result in lower cost, better specifications; and would translate into more economical projects for clients.

During the briefing stages, (1 and 2), the client and engineer have a joint responsibility of deciding just how much the project should cost, or alternatively of deciding what quality of services can be provided, for a given sum. During the preliminary and detailed stages (3 and 4), the engineer has the responsibility of designing, while maximising the value of the project, so that it will not exceed the client's budget or cost limit.

The Infrastructure Cost Planning Model analyses various design scenarios and levels of services of infrastructure projects and identifies the cost elemental parts of design, which appear to be more or less costly than they might have expected. The fundamental theory of economic analysis, cost planning and value engineering is applied to infrastructure projects.

A range of analytic reports developed for use in the different stages of the project, provide clients and consultants with more control over the economic decisions taken and enable a cost comparison of the options of various engineering solutions. The underlying structure of the Infrastructure Cost Planning Model is based on a hierarchical breakdown of the project into four stages described below:

- Stage 1 – Feasibility Stage;
- Stage 2 – Scheme Design Stage;
- Stage 3 – Detailed Design Stage;
- Stage 4 – Bill of quantities Stage.

6.5.1 Stage 1 – Feasibility Stage

During the first stage, as the brief is considered and developed, some idea of cost has to be established quickly. At this stage the engineer and the client endeavour to establish the client's requirements.

This stage gives greatest opportunity for optimisation of the budget, by determining the most economical levels of services. There may already be a budget limit but if not, the client will need to know what order of cost is likely to be involved i.e. the 'cost bracket'. The cost estimating of alternatives is carried out at this early stage, before the design is developed, to avoid the unnecessary problem of cost cutting into the whole cost-control process.

In this stage a comparison of major design options and selection of the most economical level of service is chosen, allowing the least competitive alternatives to be eliminated. In this way, progressively fewer alternatives are developed to an increasing level of detail, until the final choice is made.

The project is then subjected to technical feasibility studies and cost estimation of various options such as:

- Gravel, concrete, paved or asphalt roads;
- Communal standpipes, communal water-selling kiosks, or individual connections;
- Pit latrines, water-borne septic tank for each property, or full sewerage for every property.

The standard reports that have been developed within the Infrastructure Cost Planning Model are explained in Chapter 7. The cost of alternatives would be computed and tabulated along with other cost combinations in the Feasibility Cost Report Form, which defines the scope of the project.

The Comparative Cost Plan Form involves dividing the project into various components and by a series of cost analyses the various levels of services can be compared with each other to ensure an optimum use of the budget. It allows various solutions to be evaluated and, in consultation with the client, for a decision to be made regarding the most appropriate scheme. This method is developed more with the public sector in mind, which may want to prioritise the services for a particular scheme.

This stage also allows the designer to undertake a life cycle cost and a benefit cost analysis. The Value Analysis Form helps the designer understand the many design choices, which may be made primarily on functional and aesthetic criteria that affect the overall economics of the project.

6.5.2 Stage 2 – Scheme Design Stage

The Scheme Design Stage is essentially a continuation of the feasibility study. It brings the search for the most appropriate approach to a conclusion. The designer can obtain an optimum solution, evaluating the major functional elements of each component at this stage. Work from the initial design stages is analysed and the economic consequences of each element is assessed.

The Elemental Cost Plan Form is a statement showing how the design team proposes to distribute the available money over the various elements of the project.

The engineer translates the design team's decisions on each element into cost targets. The Target Cost Plan Form indicates the final costs, which the client can reasonably expect the cost of the project to be. An allowance for design and price risk, is added to produce cost limits.

The Comparative Cost Plan Form is then compared with the Cost Target Form and this constitutes a cost check. In this way the design team is able to exercise effective cost control. A value analysis can be carried out at this stage as well.

6.5.3 Stage 3 – Detailed Design Stage

At this stage of the design the major items that form the elements (e.g. different types of road layer works) are considered. A more precise estimate is obtained by inputting more detail of the element and choosing additional items that make up the element, where such data is available or known. These items can also be assumed, should the designer require a more detailed analysis.

At the level of detailed design every decision presents a complex trade-off between function, aesthetics and cost.

The Detailed Cost Analysis Form compares various detailed options that can make up the element. Within each element there are many options regarding the choice of materials and layer thickness that are then cost analysed at this stage, provided that it is within the design specification.

At the end of the design, various items are firmed up such as road layers, cut and fill, road surfacing, number and type of manholes, length of chutes, stormwater pipes, etc., which are inputted into the Detailed Cost Analysis Form and the Technical Specifications Form. The engineer checks his/her approximate estimate figure with the provisional target cost figures set down in the Cost Target Form.

The Infrastructure Cost Planning Model introduces a process of checking the estimated cost of each section or element of the project, as the detailed designs are developed, against the target set.

If the cost check process is postponed until the end of the design stage, serious problems such as redesigning and consequent delays might arise. But by undertaking the evaluation process as the design progresses, the design team is able to choose design decisions that are within the client's budget. Design decisions can be made with full knowledge of the financial implications of that decision (Seeley, 1996:13).

6.5.4 Stage 4 – Bill of Quantities Stage

The next stage is the Bill of Quantities Stage, in which the main work items are further broken down into detailed selection criteria of individual minor elements that contribute to the cost of the item and assessed, e.g. type of pipes, bedding material.

With the subdivision of the item into further classifications, more of the total costs become determined and to an extent the range of possible alternatives for remaining stages become limited. By assessing the variations in specification on the Material Cost Analysis Form, it is possible to evaluate the effect on cost savings of using alternative materials. The process involves iterative adjustments to design details, producing either a progressive decrease in costs or an improvement in performance. Only in this stage is the bill of quantities produced. The engineer continues his/her cost checks on the data produced against the Detailed Cost Summary Form. Every part of the project elements is cost checked and adjusted if necessary.

The value analysis carried out at this stage considers the different types of materials.

The following factors are taken into account in a value analysis:

- Is there a more economic use of materials versus quality?
- Will the element last longer or have lower life cycle costs?
- Will there be a more cost-effective use of available funds?

After a detailed selection of these minor elements, further attempts to reduce costs and optimise the budget can be made, but this could result in the budget becoming over simplified. The possibilities are endless but for the purpose of simplicity in this study, just the key items have been chosen.

6.6 Types of cost advice offered by the model

The type of cost advice required will vary depending on the individual circumstances and the nature of the design information available.

The model offers a range of cost advice and value techniques with an emphasis towards value for money. The overarching aim of the proposed Infrastructure Cost Planning Model is to develop a planning tool that encapsulates the following characteristics:

- Application of cost planning;
- Introduction of cost limits and allowances;
- Cost-value reductions;
- Value engineering;
- Pre-tender price estimating;
- Comparative costing of alternative design solutions;
- Elemental target costing for prioritisation;
- Cost analysis of alternative materials.

These techniques not only limit the expenditure but enable the consultant to add value to the design of the project.

6.7 The Infrastructure Cost Planning Model: designing to cost / costing to design

The Infrastructure Cost Planning Model is described as 'designing to a cost' or 'costing to a design.' It provides a disciplined method of forcing the project participants to take regular, careful forward planning and hence enables continuous reporting about goals, design and cost issues.

The use of the Elemental Cost Plan, which is explained in Chapter 7, can also be referred to as 'designing to cost' or 'costing to design', as it involves examining the cost implications of different design variables, as well as ensuring that the project does not exceed the cost target.

However, unless cost is of paramount importance, it should not dictate the approach the designer takes – if the financial tail wags the project dog this will not normally be conducive to the satisfaction of all the client's requirements. The cost adviser should also be aware that striving to achieve optimisation in cost is only a part of the total objective (Ferry and Brandon, 1999:101).

6.8 Application of the Infrastructure Cost Planning Model

6.8.1 The Infrastructure Cost Planning Model enhances financial control within the executing authorities

In order to create a more cost-effective project, the Infrastructure Cost Planning Model aims to overcome the problem of poor design decisions being made by consultants and clients. It will enable executing authorities to have final power over most cost decisions of projects, allowing authorities the opportunity to respond to design decisions. Financial control will then be shifted from the consultant to the authorities and will enhance real accountability to the authorities.

6.8.2 The Infrastructure Cost Planning Model facilitates consultant and client interaction

The Model creates a platform for design decisions to be continuously evaluated by the consultant and the client in the following ways:

- It provides a clear and credible presentation of the cost of different options and their influence on the budget;
- It enhances service delivery within the housing and infrastructure sector by enabling management to make informed cost-effective decisions;
- It makes realistic comparisons of different design options to be used and readily assesses alternatives;
- It provides a graphical method of presenting their results, allowing engineering, practical and financial issues to be easily weighed up against one another;
- It ensures that financial control is shifted from the consultant to the authorities, by giving the local authorities greater freedom to decide the cost and quality of the services they provide;

- It ensuring that clients receive good value for money in design.

The model and its outputs enable executing authorities to have final power over the cost decisions of projects while at the same time enhancing their financial accountability.

6.8.3 Cost limits give value for money

A cost limit is the sum of money, which the client considers is the maximum that they are able and/or willing to pay for the project. The cost limit is established by an additional 20 percent of the cost target or may be established by means of a developer's budget.

As has been stressed throughout this study, the need to design within cost limits and to forecast and control costs accurately arises from the inevitable reality that clients expect value for money. In the absence of cost limits, housing standards and expenditure could reach high and unacceptable proportions.

Cost limits have been used for a large number of public construction projects. Their objective is to establish a system limiting the expenditure on initial construction costs (Ashworth, 1983:52).

6.9 Summary

A formal approach to the management of design decisions of infrastructure projects is essential in order to be able to provide services in the most cost effective manner.

The Infrastructure Cost Planning Model shows how different levels of cost estimates can be prepared in parallel with design development, allowing for the various components of the costs to be estimated at their own discrete level, depending on the level of design information available.

The proposed 'design optimisation model' undertakes a qualitative analysis in the context of infrastructure projects and is concerned with ensuring value-for-money.

The Infrastructure Cost Planning Model optimises the project value by progressively ensuring efficient, affordable, economical and sustainable provision of infrastructure services, which will result in a project of higher standard, without the need for additional funds. The distinguishing feature of this model is that it assists the designer to know, by the initial design stages, the costs of various solutions and what the influence of certain parameters would be. This chapter placed emphasis on the Infrastructure Cost Planning Model and the context in which the process takes place. The Cost Report Forms will be discussed in detail in Chapter 7.

CHAPTER 7
THE COST REPORT FORMS

CHAPTER 7: THE COST REPORT FORMS

7.1 Introduction

The purpose of this chapter is to present the standard outputs of the Infrastructure Cost Planning Model. The output generated by the model compares the cost of various design options and in so doing enhances the ability to reduce the overall cost of projects.

The Infrastructure Cost Planning Model can ensure that projects are completed within budget and to the specified quality, thereby promoting the maintenance of financial discipline within projects. Comprehensive reporting at every stage allows for early identification of problem areas and for immediate intervention and remedial action by the consultant. The Cost Report Forms enable project objectives to be quantified, measured and verified at each stage in the design process.

This chapter describes the Cost Report Forms of the Infrastructure Cost Planning Model, which are cost planning tools which have been developed to improve cost management of infrastructure projects.

7.2 The philosophy

The Infrastructure Cost Planning Model meets a well-recognised need for improved and standardised cost reporting, allowing managers to make realistic budget and cost comparisons from the proposed reports. The Cost Report Forms are developed at the front end of all the phases of a project to facilitate scope definition, maximise cost optimisation, maximise designing, planning, and monitoring and thereby control the cost of infrastructure decisions. They enable the designer to analyse the cost of different options as the design is being developed so as to ensure value for money, simplicity and quality.

The Cost Report Forms can help monitor activities, track progress, and prevent potential overspending. This information is crucial to targeting both high and low areas of costs in

order to determine optimum areas for opportunity. It is also inspired by the desire to improve the quality of client service. The cost planning tools are intended to achieve best value or lowest cost, and to meet a variety of social and economic objectives.

7.3 Purpose of the Cost Report Forms

The standardised Cost Report Forms were developed to:

- Set out the methods by which deliverables may be obtained, quantified and optimised;
- Determine the means by which goals can be quantified at early stages;
- Measure, quantify and verify cost at any stage of design, to ensure a value-added, quality driven, graded approach to infrastructure design management;
- Provide a basis for the consultants and clients to work together on planning and budgeting thereby ensuring comprehensive infrastructure planning with maximum stakeholder involvement;
- Provide a standardised method for the costing and selection of options;
- Achieve the required balance of expenditure, value for money and quality, between the various elements of the project;
- Keep the expenditure within the amount specified by the client;
- Provide a method for designing to achieve prioritisation of services;
- Provide a method to improve efficiency and cost-effectiveness.

The standard forms allow consultants and clients to exchange information with other stakeholders and thereby increases the transparency of their decision making. This in turn will improve consultants' accountability to clients and, as a result, increase the economic efficiency of the project.

The Infrastructure Cost Planning Model together with the practical and standardised Cost Report Forms can translate design decisions into readily definable outputs.

7.4 The Cost Report Forms defined

The Cost Report Forms define in a comprehensive, precise and verifiable manner the essential characteristics of a deliverable component. They are used to measure, quantify, verify and audit the different design options.

Table 7.1 shows the Cost Report Forms at each stage of the Infrastructure Cost Planning Model. The Cost Report Forms are found in Appendices 1 to 12. Cost reports are the foundation for an effective cost evaluation process and are the basis of a design-to-cost approach that contributes to overall cost-control.

Table 7.1 The Cost Report Forms at each stage

STAGE	FORM NO.	FORM NAME
FEASIBILITY STAGE	Form 1	Feasibility Cost Report Form
	Form 2	Comparative Cost Plan Form
	Form 3	Value Analysis Form
	Form 4	Life Cycle Cost Analysis Form
	Form 5	Benefit Cost Analysis Form
SCHEME DESIGN STAGE	Form 6	Elemental Cost Analysis Form
	Form 3	Value Analysis Form
	Form 7	Cost Target Form
	Form 8	Cost Check Form
DETAILED STAGE	Form 3	Value Analysis Form
	Form 9	Detailed Cost Analysis Form
	Form 10	Detailed Cost Summary Form
	Form 8	Cost Check Form
BILL OF QUANTITIES STAGE	Form 3	Value Analysis Form
	Form 11	Materials Cost Analysis Form
	Form 12	Technical Specifications Form

The Infrastructure Cost Planning Model and its outputs is a disciplined effort to produce fundamental decisions in shaping the project cost. The model maximises the

opportunities for improving quality and reducing project costs and enables consultants to use clients money in the most efficient way possible. The tools provide graphical methods for presenting results, allowing for engineering, practical and financial issues to be easily weighed up against one another.

The complementary role of cost reporting within overall project performance can enhance cost containment, productivity, quality and time lines. Through a variety of reports, it provides the clients with opportunities to respond to technical decision making and the successful implementation of projects within their budget. The Cost Report Forms enable informed cost effective decisions by creating a better representation of construction costs and so add value at the design stage.

7.4.1 Form 1 – Feasibility Cost Report Form

During the first stage, as the brief is considered and developed, some idea of cost has to be established quickly. There may already be a budget limit, if not the client will need to know what the order of cost is likely to be, i.e. the 'cost bracket'. This form determines what kind of level of services can be expected considering the client's budget and also what are the trade-offs between quality, value and cost that can be achieved.

Before a client commits himself/herself to a project or to raising finance, the developer needs to know just how much it is going to cost. Sometimes clients may have a clear idea of the project required in terms of its function and size but need to know how much it is likely to cost. The Feasibility Cost Report Form enables the consultant's estimate to be tailored to the client's project requirements and specifications.

On the other hand, a client, particularly one with no experience of construction, may have no idea of how much it will cost to meet his/her requirements and may, in discussion with the engineer, have to adjust his/her brief to make it feasible within the proposed budget (Morton and Jaggar, 1995:18).

This preliminary estimate initially serves to check the consultant's feasibility against the client's original budget or appropriation estimate.

The purpose of this form is to:

- Formulate the budget and test the feasibility of the project;
- Devise and evaluate alternatives in response to the projects goals and objectives;
- Confirm the budget already set.

7.4.2 Form 2 – Comparative Cost Plan Form

The Comparative Cost Plan Form involves undertaking comparative analysis of the different scenarios and options available to the client.

There should be some sort of approximate estimating of alternatives at this early stage before the design is developed, to avoid the unnecessary problem of cost impinging on the whole cost-control process. The purpose of the Comparative Cost Plan Form is to allow comparisons to be made between the costs of achieving various levels of services of infrastructure on a project, with that of achieving an equivalent number of units that it serves. This step involves a systematic comparative analysis, cost performances and sensitivity tests of the elements, so that the user can evaluate different scenarios, options and design schemes.

The development of alternative design solutions takes into account all the consequential effects of decisions on various elements of infrastructure services. It enables the consultant to make rational decisions in the light of individual orders of cost and their cumulative effect on the total cost, before he/she starts developing the design.

The financial analysis translates the financial costs into economic benefits by adjusting the project inputs and assessing its price distortions.

This form of analysis also undertakes a cost-effectiveness analysis of the various options. A cost-effectiveness analysis compares the costs of alternative ways of producing the same or similar outputs.

The Comparative Cost Plan Form does not seek to enforce rigid cost limits for the design of particular elements, but rather to maintain flexibility of choice of a combination of possible design solutions.

The purpose of this form is:

- Generation of options – (e.g. using stormwater pipes instead of open channels);
- Devise alternatives in response to the project's goals and objectives;
- Compare costs, where the scheme has to fit within an overall cost limit.

The advantage of this method is that it provides a methodology or a 'cost strategy' with which the designer explores a range of possible solutions available to him/her in relation to the infrastructure project. It allows the design team to identify a 'least cost' solution, as set out in the methodology, for cost effective infrastructure provisions.

7.4.3 Form 3 – Value Analysis Form

Value analysis helps the designer understand the many design choices which need to be made in relation to functional and aesthetic criteria and their impact on the overall economics of the project. The Value Analysis Form is a coherent and systematic study of these aspects of the design, with the purpose of identifying problems and assessing the project's ability to fulfil specified and stipulated requirements.

It is a formal, documented, comprehensive and systematic examination of a design, to evaluate the design requirements and the capability of the design to meet the requirements as well as to identify problems and propose solutions.

It has been created to ensure that key issues with direct impact on overall design quality are addressed at the earliest stages of the development process. It is an invaluable guide to the key issues that influence the quality of affordable infrastructure projects. The Value Analysis Form contributes to a value-added decision making process and can lead to an improvement in functionality, cost-effectiveness and quality.

7.4.4 Form 4 – Life Cycle Cost Analysis Form

Most civil engineering projects represent major infrastructure investments for the nation and are likely to remain in use indefinitely. Therefore, in addition to initial cost considerations, planning and design decisions need to be based on a consideration of

the long-term performance of the project. Such analysis will enable informed tradeoffs amongst capital outlays, operating and maintenance costs, and non-monetary costs.

There is a general trend towards greater cost-effectiveness and thus a need to examine construction cost not solely in the context of initial costs but in terms of life-cycle costs, or total-cost appraisal (Ashworth, 1999).

Life cycle cost analysis is an indispensable technique that employs well established principles of economic analyses to evaluate long-term performance of competing investment options (Ozbay *et al.*, 2003).

Good design will not always result in the lowest initial capital cost. However, over the period of the contract, a higher initial investment can, when expressed as a discount value, result in the lower whole life costs (HM Treasury, 2003).

The Life Cycle Cost Analysis Form compares the costs of alternative solutions, levels of services and materials by calculating the initial capital costs, the anticipated operating, maintenance, and the future facility capital costs.

7.4.5 Form 5 – Benefit Cost Analysis Form

Benefits and costs of the different levels of infrastructure services should be quantified and monetised for public sector projects. Benefits and costs should be measured and appropriately discounted over the full life cycle of the project.

The basic method for identifying the costs of a project is to compare the costs and benefits that are likely to arise if a specific alternative is implemented to the situation that would prevail if an alternative design decision were implemented.

This method quantifies the net benefits that are likely to be generated by the project alternatives. The financial analysis of different levels of services translates the financial costs into economic benefits by adjusting the project inputs and comparing outputs for price distortions.

7.4.6 Form 6 – Elemental Cost Analysis Form

Once the sketch design has been completed and approved by the client, the task of allocating sums to the various elements can take place.

The Elemental Cost Analysis Form guides decision-makers by altering key design factors and assessing the costs. This decision making tool guides the user to spend money in accordance with the client's requirements, by allocating sums of money to the various major components of the project.

This form enables the user to evaluate different scenarios and change a number of key variables such as length of elements or number of elements, to make more money available for the priority elements, but leaving the overall cost limit unaltered.

Elemental cost planning is often described as 'costing a design'. This method is particularly suited to the public sector. In large infrastructure projects, judgments sometimes have to be made on what proportion of the total sum can be spent on the functional characteristics of particular elements before targets are set. For instance, a municipality may want to prioritise sewer services compared to the stormwater for a proposed scheme.

Elemental cost planning enables the engineer to use money to the best advantage in interpreting his/her design. For example, stormwater pipes cost far more per metre than stormwater open channels and it is worthwhile investigating the results of the different design options, or proportioning the cost of both the design options.

An elemental cost analysis of the functional elements can reveal the cost-sensitive parts of a project which are likely to be the most fruitful areas for cost evaluation. The most productive areas for analysis are the ones that are the most expensive.

The engineer would be able to focus on cost drivers of the project. Improvement of early design decisions could ensure a greater measure of control over the ultimate cost, quality and design.

The sensitivity analysis determines which variables appear to have the most influence on the price.

The functions of the Elemental Cost Analysis Form are:

- To allow for a distribution of costs to be made among the various functional elements on the project as appropriate to the needs of a project. For example, the sanitation component of a project may be a far more critical issue than the stormwater issues faced in the area, so it would not be sensible to specify an expensive stormwater level of service;
- To provide a balanced design expenditure throughout the construction project, thus giving the client value for money in terms of functional elements;
- To reveal the cost drivers of a project from within its elements, which is useful to both designers and clients;
- To determine the probable cost of each element of the project.

7.4.7 Form 7 – Cost Target Form

Clients will always seek to impose some expenditure limit on the costs of construction projects.

The Cost Target Form indicates the target cost of each element. As the design develops and the details begin to firm up, the Elemental Cost Analysis Form can be used to establish cost targets for each element of the project. In this way the cost targets established should confirm the budget established at the feasibility stage. The engineer can then translate the cost target into a cost limit.

Because of the investigation and preparation of the individual targets, the processes of elemental cost planning will automatically show at a very early stage whether the final costs will remain within the budget. This is reassuring to the client and the design team.

Objectives of cost targets:

- To ensure that the sum of money which the client sets out to spend on the construction project is not exceeded;
- To ensure the correct allocation of funds to the functional element ;
- To control the cost within a predetermined sum of money.

The above objectives are of importance to the client. If, for instance, the client's development budget is exceeded, it may be found rather difficult to raise the additional finance needed to complete the project. Moreover, when placed in an additional borrowing situation, the client's expected margin of profit in the development might shrink to almost nothing and all investment efforts would then be wasted.

7.4.8 Form 8 – Cost Check Form

This form is used to track the cost of the project as well as notifying the consultant of significant changes in cost. This form can also be called the 'Budget Tracking Form'.

The engineer will need to carry out cost checks between the Feasibility Cost Report Form, the Elemental Cost Analysis Form, the Cost Target Form and the Detailed Cost Summary Form at each stage of the design, to ensure that the proposals are being kept within the total cost limit agreed with the client.

The Cost Check Form is vital to the performance of a budget, as it provides the means by which the cost is monitored and controlled. It addresses how the actual cost will be tracked to the budgeted cost, how corrective actions will be implemented, and is compared with the Cost Target Form.

If at some later stage the design has to be revised because it exceeds the funds that are available, this can be both expensive and time-wasting. The aim of budget tracking is to avoid this happening.

As the design moves into the detailed stage and final decisions are made, the system of cost-checking is used to confirm the cost targets of each element.

The advantage to the client of this process is an awareness of the cost implications of all the design decisions, and a reasonable assurance that their budget estimate will not be exceeded (Ashworth, 1999:277).

When a cost check reveals a difference from the target cost of the element, the engineer must be informed accordingly and may then choose to proceed in one of the following ways:

- Redesign the element so that the target cost and the project is not changed;
- Approve the change in the element's cost. In order that the total cost of the scheme remains unchanged, re-examine other elements in order to produce cost-saving measures;
- Change the specification;
- Seek an alternate solution;
- Alter the design of the element so as to bring the cost within the cost target;
- As a last resort, raise the cost target for the element.

If the design solution for an element shows a saving, the surplus money can be fed into the reserve or spent to improve the remaining elements. The quality of the specification of the element can be increased to bring the cost up to the cost target. Whatever decision is taken, the client must be informed accordingly.

7.4.9 Form 9 – Detailed Cost Analysis Form

This form attempts to identify the relationship between quantity and cost and identifies potential areas for changing items and thereby improving performance.

The object of cost analysis is to provide a method for comparing the cost of alternative detailed design options. The Detailed Cost Analysis Form is the process of breaking down the project into its component parts and identifying different and hopefully more effective methods of achieving the desired result.

It is essential for the planning team to test how such variations will affect the cost of the project. Apart from the quantitative variables there are also qualitative variables that affect the viability of a project option.

7.4.10 Form 10 – Detailed Cost Summary Form

The Detailed Cost Summary Form contains the results from the Detailed Cost Analysis Form. It shows how the design team proposes to distribute and allocate the available money among the major elements of the project.

The Detailed Cost Summary Form can achieve a balanced design by increasing the quality of the specification of the element to give the client good value for money rather than merely distributing money between the various elements.

This enables the engineer, within his/her cost terms of reference, to use the money to the best advantage in interpreting his/her design. This strategy attempts to spend money in accordance with the client's requirements by allocating sums of money to the various major components of the project.

It enables the designer to determine how much has been spent on each element and to show where reductions could be most beneficially made should the estimate prove to be too high. This improves cost control.

The purpose of a Detailed Cost Summary Form is to show the distribution of the cost of a project among its elements or main functional parts in a way which is meaningful to both designers and clients. The Detailed Cost Summary Form can be used to fulfil four main purposes:

- To enable clients and designers to appreciate how cost is distributed among the functional components of a project (appreciation);
- To enable clients and designers to develop ideas as to how costs could have been allocated, to obtain a more balanced design (judgment);
- To allow remedial action to be taken on initial over estimation, by revealing the sources of over-expenditure (belated remedial action);
- To help with the cost planning of future projects (planning).

7.4.11 Form 11 – Materials Cost Analysis Form

The Materials Cost Analysis Form evaluates the effect on cost savings of using alternative materials. The process involves iterative adjustment being made to the design details, to produce either a progressive decrease in costs, quality or an improvement in performance. This form shows that cost savings can still be achieved even after the detailed design is complete.

7.4.12 Form 12 – Technical Specifications Form

The Technical Specifications Form is required to ensure that the specifications proposed are appropriate and feasible with respect to technical considerations and specifications. Technical specifications are used to define the product and to set out acceptance criteria and resource specifications in order to define quality. These specifications not only define the deliverables which are to be realised in the process of delivery, but also set out the manner in which they can be achieved, measured and monitored.

The function of this form is to check that the project will meet the specified requirements and the verification of the compliance with specifications. The cost analysis, supplemented with specification notes, ensures that non-conforming materials are quarantined or otherwise prevented from being used.

Specification and design notes give the requirements of the element and the specification notes describe the form of construction and quality of material sufficiently to explain the costs in the analysis (Seeley, 1996:147).

Specifications provide the criteria by which to assess and assure the required quality.

7.5 Monitoring the cost of the project with the aid of Cost Report Forms at the design stage

Generally, clients wish to know only in general terms the anticipated total financial commitment at various milestones on the project, but in practice this rarely happens.

The importance of monitoring of cost is given significant emphasis in the previous chapters. The proposed model makes provision for checking on a comprehensive basis, to ensure that the most cost effective decisions are taken at each stage in the design process.

The Cost Report Forms readily measure, audit and verify design decisions on a project entailing a thorough and critical examination of each cost component.

The Cost Report Forms therefore seek to forewarn the client and designer of any future possible increases or decreases in the costs of a project, at each stage of the design process.

7.6 Cost Reports Forms – an acceptance plan in the design delivery

The Cost Report Forms can form part of a sequential acceptance plan in project design delivery. They can be described as a plan for acceptance of the project deliverables for the client and consultant.

Decisions affecting cost typically are made incrementally as the design evolves. Therefore, as these decisions are made, their consequences (economic and otherwise) should be clearly understood by the designers.

During the process the Cost Report Forms become in effect an acceptance plan in aspects of scope, quality, and performance to maintain the project within the overall budget.

The Infrastructure Cost Planning Model can be seen as an important tool for improving the cost management process. These Cost Report Forms provide creative input and a comprehensive review of all decisions and become progressively more detailed as the design develops.

7.7 Summary

Given the documented impact of cost overruns, there is need for a multi-stakeholder approach to 'the influence of designers on the cost of engineering decisions'.

The Cost Report Forms control the design by means of verification of the cost of design elements at each stage in the development of the design, for the benefit of the client.

This chapter describes the various reports which engineers can use to perform qualitative and semi-quantitative analysis of the designs.

Throughout the project, the proposed model quantitatively measures the cost effectiveness of the design options and acts as an early warning system to diagnose major cost problems, so that remedial measures can be taken to ensure that the project is still within the client's budget.

The standardised Cost Report Forms referred to in the Infrastructure Cost Planning Model serve to support decision making and management functions. They are distinguished from the textbook definitions in that they are more practical in application.

Cost Report Forms have been developed to provide a more cost-effective project, permitting the project objectives to be quantified, measured, verified and audited.

Thus it will improve the quality of life, by providing sustainable services to more communities, with the same budget.

CHAPTER 8

THE INFRASTRUCTURE COST PLANNING MODEL ENSURES VALUE AND QUALITY MANAGEMENT ON PROJECTS

CHAPTER 8: THE INFRASTRUCTURE COST PLANNING MODEL ENSURES VALUE AND QUALITY MANAGEMENT ON PROJECTS

8.1 Introduction

Too often in the past, value management has been applied too late in the project.

In these days of ever-increasing costs the majority of clients are insisting on projects being designed and executed to give maximum value for money. One of the principal objectives of any design solution for a civil engineering project is to provide value for money for the clients through more carefully considered design solutions that fully meet the client's objectives.

The Infrastructure Cost Planning Model ensures that project designs are more carefully examined, and that alternative design solutions are developed to ensure the client's objective of value for money. The model uses cost limits on public sector projects to help to eliminate wastage in design and to reduce construction costs, while still maintaining standards of quality.

Value engineering is traditionally applied in the later stages of design or construction, when cost overruns occur. However, the Infrastructure Cost Planning Model introduces value management from the time the developer communicates with the consultant and most particularly in the early stages of design where cost reductions are most beneficial.

Another important outcome of the Infrastructure Cost Planning Model is improved quality. A project's quality depends upon the consultant's control over his/her design. Application of the model ensures a level of quality that will assure satisfactory performance of the included elements, but again without undue cost overruns.

In response to the concerns highlighted in Chapter 2, this study has been developed to maximise the quality and value of projects, yet do so without undue costs.

8. 2 Value management techniques incorporated into the model

Value analysis identifies and removes unnecessary costs without compromising the quality and reliability of the design.

Value management is a service which maximises the functional value of a project by managing its evolution and development from concept to completion by means of the comparison and audit of all decisions (Kelly and Male, 1993:10).

One of the aims of the proposed Infrastructure Cost Planning Model is to offer a client improved value for money in the design, which has a measurable output.

8.2.1 Emphasising value management early in the design process

Figure 8.1 illustrates the opportunities to revise or make changes to the design of a project. These opportunities reduce over the life cycle of a project. Figure 8.1 also illustrates the costs involved to implement changes – a reminder that cost reduction can

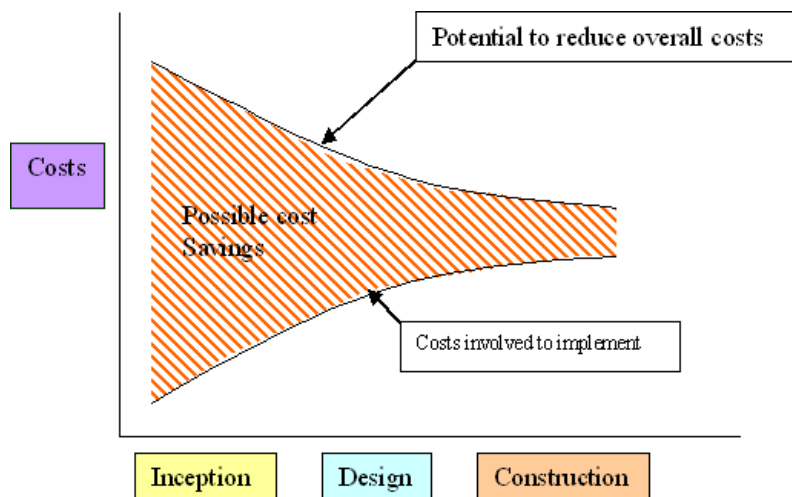


Figure 8.1 Opportunity to change a design (Ashworth, 1999:8)

also have a cost increase effect due to the cost of implementation. These implementation costs increase over the life cycle of a project. Costs include necessary alterations to documentation (drawings, specifications, bills of quantities, schedules, etc). During the early stages of project design, changes are unlikely to result in significant document revisions, particularly prior to the production of detailed drawings. More documentation needs to be produced and the potential for disruption is increased during subsequent stages of the project's life cycle. During the later stages of the project life cycle the saving potential diminishes as the two curves converge. Thus, some changes may not be implemented if the net effect on total cost is nil or negative.

8.2.2 Cost-value reductions offered by the model

Cost-value savings can be achieved on a project at any time in the project; however, it is easier to make such changes during the earliest stages of a project than when the project design or the construction phase is nearing completion.

The value analysis approach is incorporated into the proposed Infrastructure Cost Planning Model and readily monitored with Cost Report Forms, so that value management and quality control is achieved. The Materials Cost Analysis Form in Appendix 11 is directed at analysing the cost of materials, for the purpose of achieving required functions at the lowest total cost.

The Value Analysis Form, as discussed in Chapter 7, analyses the elements by systematically developing the answers to such questions as:

- What is it?
- What does it do?
- What must it do?
- What does it cost?
- What other material or method could be used to do the same job without sacrificing required performance or degradation to safety, reliability, or maintainability?

8.2.3 The Infrastructure Cost Planning Model compliments the Value Analysis process

The components of the Value Analysis (VA) process, also referred to as the Miles Job Plan (Kelly and Male, 1993: 10), are covered in the proposed Infrastructure Cost Planning Model. The correlations are as follows:

- Investigation Phase – The proposed model's Feasibility Cost Report Form offers technical input, functional analysis and assesses its objectives, as required in the VA process;
- Speculation Phase – The proposed model considers alternative solutions;
- Evaluation Phase – The Cost Report Forms within the proposed model assess the cost of various alternatives;
- Development Phase – Throughout the project, the proposed model provides economic supporting data to prove the feasibility of the desirable concepts or design solutions;
- Presentation Phase – The various Cost Report Forms within the proposed model present the project costs and recommendations at the various stages;
- Implementation Phase – The alternatives are given a fair and thorough evaluation;
- Audit Phase – The Cost Report Forms within the proposed model are a record of the decisions taken at each stage.

8.3 Designing for quality

An important outcome of the Infrastructure Cost Planning Model is improved quality. A project's quality depends upon the consultant's control over his/her design.

The designer wants a level of quality that will assure satisfactory performance of the element, but again without undue cost overruns. In the design phase the Infrastructure Cost Planning Model assesses the impact that higher standards of quality and tighter tolerance limits have on costs. One of the easiest ways to drive up the costs of a project unnecessarily is to specify high design standards of quality that are inappropriate to the intended function. For example, to specify concrete finish standards on buried pipelines or other unexposed surfaces is setting standards too high. On the other hand, specifying

cheap and failure-prone materials may provide lower initial costs but will drive up overall costs in the long run.

Designing for quality implies a design solution which meets the client's requirements in terms of function, aesthetics and external attributes.

In all infrastructure sectors quality is crucial, as is the need to make adequate provisions for operation and maintenance when allocating resources.

The Infrastructure Cost Planning Model continuously ensures quality through the various Cost Report Forms.

8.3.1 The Infrastructure Cost Planning Model can contribute to quality management and assurance

Planning authorities wish to have more influence on the quality of infrastructure to achieve their improvement objectives. Each of the Infrastructure Cost Planning Model's reports contributes to the quality of the project.

The Comparative Cost Plan Form compares the various alternatives and identifies the optimum level of service that can be achieved with the client's budget. This ensures that quality services are achieved for a given cost.

The Detailed Cost Analysis Plan Form explores the opportunities for design improvements that might be achieved through the analysis of alternative design options. It also measures the relationship between the cost, quantity and value of quality. By trial inputs in the detailed cost analysis, the optimum level of quality can be achieved.

The Materials Cost Analysis Form evaluates the effect on cost savings by using alternative materials. The process involves iterative adjustments being made to the design details to produce either a progressive decrease in costs, quality or an improvement in performance.

The Infrastructure Cost Planning Model optimises costs for a given quality of design. It seeks to minimise the direct construction costs and maximises the quality-control, as well as considers life cycle cost of materials. The Life Cycle Cost Analysis Form ensures that the best life cycle choice is measured and optimised.

In this way, the Infrastructure Cost Planning Model compares the various alternatives and identifies the optimum level of quality at various stages in the design phase, as shown in Figure 8.2.

The level of quality control offered by the model enables the consultant to identify the close relation between design, cost and quality.

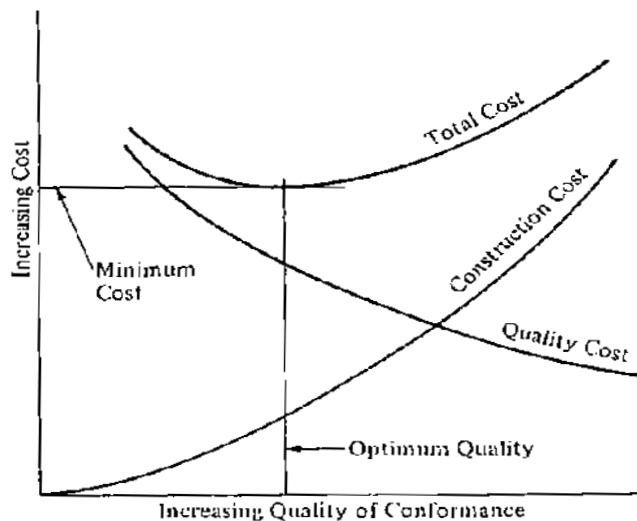


Figure 8.2 Economics of Quality of Conformance (McGraw-Hill Inc, 1978:313)

8.4 Benefits of using a value and quality management approach

The value and quality management approach represents a natural progression for the search for alternative technical options and presents them as evaluated and costed design solutions. The benefits of adopting value management techniques, are listed below:

- Reduced project costs;
- Improved design efficiency;
- Optimised value for money;

- Advanced design decisions;
- Improved ways to comply with the brief;
- An independent functional review;
- Examination of function and cost;
- Opportunity for options to be considered and concentrated design effort;
- Improved technical and more cost effective solutions;
- Accommodation of design changes at minimal cost to project.

8.5 Summary

Planning authorities wish to have more influence on the quality of infrastructure to achieve their improvement objectives. Each of the Infrastructure Cost Planning Model's reports contributes to the quality of the project, by comparing the various alternatives and identifying an optimum level of service that can be achieved with the client's budget. This will ensure that quality services are achieved for a given cost.

The various Cost Report Forms contribute to quality control, quality assurance, as well as quality management on the project.

This chapter described the value engineering and quality management principles that are encapsulated in the Infrastructure Cost Planning Model. The model continuously involves the evaluation of alternatives and the resulting improved value for money, in all stages of the project.

This value for money approach is more than merely a way of minimising construction costs – equal and explicit attention is also given to the important aspects of operational performance and quality. The utilisation of various Cost Report Forms during the design phases proactively links quality and value management to cost and enables the designer to assess the cost of increasing the quality of various items.

CHAPTER 9

**THE INFRASTRUCTURE COST PLANNING MODEL
CAN ENSURE ACCURACY OF PROJECT
ESTIMATES**

CHAPTER 9: THE INFRASTRUCTURE COST PLANNING MODEL CAN ENSURE ACCURACY OF PROJECT ESTIMATES

9.1 Introduction

Theoretically, preliminary feasibility studies normally estimate costs within a margin of error of 15-20%, and detailed engineering studies estimate costs within a margin of error of 5-10%. However this rarely happens in practice.

One of the first questions asked by a client who wants to construct is 'How much will it cost?' If the client is wise, the next question will be 'How accurate is this figure?'

The first indication of the cost of the proposed project is often the amount most remembered by the client. Perhaps the single most important criterion of an estimate is its accuracy. An early price estimate which is too high may discourage the client from proceeding. Alternatively, if the estimate is too low it may result in an abortive design, dissatisfaction on the part of the client or even litigation (Ashworth, 1999:244).

It can be argued that construction cost estimating on major infrastructure projects has not increased in accuracy over the past 70 years. The underestimation of cost today is in the same order of magnitude that it always has been (Flyvbjerg *et al.*, 2002).

Cost estimation practices need to improve for many reasons. Projects are often cut in scope or cancelled altogether due to other projects exceeding their budgets. This persistent cost underestimation reflects poorly on the industry in general, but more specifically on engineers (Silverstein, 2004).

9.2 The accuracy of the Infrastructure Cost Planning Model

9.2.1 The importance of accurate cost estimates on projects

- Accurate cost reports add credibility and reality to the project estimates and design decisions.
- They also substantially reduce the need for cost cuts during later phases of the development, ensuring that original design concepts and objectives are achieved.
- Accurate estimates are critical for ensuring the reliability of the project feasibility study.
- Accurate cost reports presented at all phases of the development help to reduce or eliminate surprises during the bidding process.

9.2.2 The Infrastructure Cost Planning Model can improve accuracy

- Design and cost implications can be recorded at all stages on the project.
- It establishes effective communication of cost within the project team.
- All assumptions can be checked and confirmed with clients and consultants and formal feedback for design and estimating activities is established.
- It uses a more rigorous method of estimating and quantifying the effects of alternative design options.
- It increases cost planning and control activities during all the stages of the design.
- It provides a method of selection and adjustment of design decisions.
- The continuous cost reporting would help improve the estimating accuracy.

9.3 Summary

Cost management problems start at the initial design stage with feasibility and elemental budgets that can be very inaccurate, and can continue through design development if costs are not monitored throughout the design phase. Insufficient information leads to more assumptions being made, and to the production of 'loaded' estimates to cater for higher risk due to unknown elements in the design.

The importance of accurate cost estimates is given significant emphasis in the previous chapters. The proposed model makes provision for checking on a comprehensive basis, to ensure that the most cost effective decisions are taken at each stage of the project.

The Cost Report Forms readily measure, audit and verify design decisions on a project and result in a thorough and critical examination of each cost component.

The Infrastructure Cost Planning Model ensures that accurate forecasting is carried out at all the phases using the Cost Report Forms.

CHAPTER 10
CASE STUDIES

CHAPTER 10: CASE STUDIES

10.1 Introduction

Infrastructure design is generally carried out in an environment of a limited budget with a need to stretch financial resources as far as possible. For this reason designers are placed under considerable pressure to minimise costs through changes to, and often downgrading of, their designs.

This chapter presents two case studies that were undertaken by the researcher using the Infrastructure Cost Planning Model. A systematic and iterative analysis of the cost consequences of different design solutions was carried out on the selected infrastructure projects. As will be seen, the Infrastructure Cost Planning Model forced project participants to make regular, careful forward planning by means of continuous reporting on design and cost issues.

10.2 The economic analysis of infrastructure projects

The proposed model uses techniques such as construction economics, cost planning, cost optimisation and value engineering, to the design of infrastructure projects. The model aims to achieve a project of a higher standard, without the need for additional funds.

The economic analysis involves undertaking various cost analyses of the various project options, to assess their economic viability. Sensitivity analysis is undertaken to determine how the viability of the proposed project will be affected by variations in selected design options.

During the process, the Cost Report Forms provide the basis for an acceptance plan in aspects of scope, quality, and performance, in order to maintain the project within the overall budget. The tools provide an output in each phase of the project and provide a comprehensive review of all decisions, as the design develops.

10.3 Case Studies

Two pilot studies were undertaken to ensure a representative assessment of the model. The case studies engaged with active projects to enable a comparative measurement of the actual versus projected costs.

10.3.1 Pilot Study 1

10.3.1.1 Background

Pilot Study 1 engaged with the Farm Berrel project. This project involved the provision of infrastructure services to 1419 houses. The initial estimate envisaged a cost of 66.2 million Rand, however at the detailed design stage, the bill of quantities revealed the project cost to be 92.7 million Rand and 49% over budget. Due to the insufficient funds, the project scope and the level of infrastructure services had to be reduced drastically, to fall within the project budget. This frequently happens on infrastructure projects – consultants produce inaccurate cost forecasts, resulting in a project of poor quality or being over-budget, due to the original inaccurate estimates. This project was picked deliberately to be a Pilot Study as it is representative of most public service infrastructure projects.

Table 10.1 shows the initial estimates which were determined by means of traditional methods of cost estimating on infrastructure projects.

Table 10.1 Pilot Study 1: Cost estimates using the traditional methods

STAGE OF PROJECT	INITIAL ESTIMATES	ACTION
Feasibility stage	R66 232 000.00	Cost based on previous projects
Design stage	R92 724 804.20	Design and completed bill of quantities
Design stage	R67 413 204.05	Redesign and redo bill of quantities

10.3.1.2 Evaluating the results of the Infrastructure Cost Planning Model

The Infrastructure Cost Planning Model was introduced to the project at the design stage. Prioritisation of services was done using the Elemental Cost Analysis Form. This strategy seeks to spend money in accordance with the client's requirements. The project was then redesigned to fit within the budget limit. Table 10.2 presents the revised estimates using the Infrastructure Cost Planning Model.

Appendices 13 to 15 show the Comparative Cost Plan Form, the Elemental Cost Analysis Form and the Detailed Cost Summary Form for Pilot Study 1.

The Comparative Cost Plan Form compared the various levels of services that could be achieved with the client's budget, thereby identifying alternative and more effective methods of achieving the desired result. The Elemental Cost Analysis Form was carried out to proportion the cost of the project. This showed that the cost could have been ascertained at the preliminary design stage, rather than at the detailed design stage, thereby avoiding redesign.

The Detailed Cost Summary Form showed how the design team proposed to distribute and allocate the available money among the major elements of the project.

Table 10.2 Pilot Study 1: Revised estimate using the Infrastructure Cost Planning Model

DESCRIPTION	COST REPORT FORMS USED	REVISED ESTIMATE VALUE	% DEVIATION FROM ACTUAL
Preliminary stage	Comparative Cost Plan Form	R66,226,369.06	6.0%
Preliminary stage	Elemental Cost Analysis Form	R65,698,854,00	5.3%
Design stage	Detailed Cost Summary Form	R66,497,758.61	6.40%
Tender stage	Tendered stage	R62,231,003.00	

10.3.2 Pilot Study 2

10.3.2.1 Background

Pilot Study 2 engaged with the Sunnyside Park project. This project involved the provision of infrastructure services to 1221 houses. This study was conducted in conjunction with the traditional method of estimating, to show how major cost savings can be achieved during the design stage using the Infrastructure Cost Planning Model's various Cost Report Forms. The initial estimates were up to 32% under budget. The final tender value was the benchmark on which the Infrastructure Cost Planning Model was measured against.

Table 10.3 shows the initial estimates where the costs were determined using the traditional method of cost estimating on infrastructure projects.

Table 10.3 Pilot Study 2: Cost estimates using the traditional methods

DESCRIPTION	INITIAL ESTIMATES	% DEVIATION FROM ACTUAL VALUE	METHOD OF CALCULATION
Feasibility stage	R 25,500,030.32	-31.19 %	Cost based on previous projects
Preliminary stage	R 28,003,000.00	-24.4 %	Bill of quantities
Design stage	R 28,500,050.23	-23.1 %	Bill of quantities
Tender stage	R 37,058.000.19		Bill of quantities

10.3.2.2 Evaluating the results of the Infrastructure Cost Planning Model

From the Feasibility to the Tender stage, the Infrastructure Cost Planning Model undertook various alternative analyses in search of identifying cost effective design options for achieving the optimum use of the client's budget. Table 10.4 presents the revised estimate using the Infrastructure Cost Planning Model.

Table 10.4 Pilot Study 2: Revised estimate using the Infrastructure Cost Planning Model

DESCRIPTION	COST REPORT FORMS USED	REVISED ESTIMATE VALUE	% DEVIATION FROM ACTUAL
Feasibility stage	Comparative Cost Plan Form	R 39,240,202.91	-5.9 %
Preliminary stage	Elemental Cost Analysis Form	R 39,318.706.35	-6.1 %
	Cost Check Form	R 39,318.706.35	-6.1 %
Design stage	Detailed Cost Analysis Form	R 39,262.370.91	-5.9 %
	Detailed Cost Summary Form	R 39,262.370.91	-5.9%
	Material Cost Analysis Form	R 67 116.00 SAVING	
	Revised Detailed Cost Summary Form	R 39 195 254.91	-5.8 %
Tender stage	Tendered value	R 37,058.000.19	

The results showed that from Feasibility to Tender stage, there was less than 7% deviation from the actual Tendered value.

Appendices 16 to 22 show the Infrastructure Cost Planning Model's reports for Pilot Study 2. The Comparative Cost Plan Form compared the various levels of services and their price distortions. The Elemental Cost Plan Form refined the cost, thereby setting the Cost Target Form and Cost Limit Form. Another objective of the study was to show that alternative materials can be investigated even after the detailed design stage, using the Materials Cost Analysis Form. The case study shows how the costs were optimised and monitored at each phase of the project.

10.4 Summary

This chapter has described two case studies undertaken using the Infrastructure Cost Planning Model to show the validity and reliability of the Cost Report Forms.

The model was used to optimise the cost of various options for two infrastructure projects. Pilot Study 1 shows that the cost could have been ascertained at the

preliminary design stage and thus allow for a prioritisation of services in terms of costs, before the design is commenced. The Elemental Cost Analysis Form proportions the cost in terms of the design reference, thereby avoiding redesigning services to suite the budget.

The accuracy of the model was also validated in Pilot Study 2. This pilot study showed that cost savings can be achieved even after the detailed design is complete, utilising the Materials Cost Analysis Form.

From the results achieved, it can be seen that the Infrastructure Cost Planning Model optimises project value by progressively ensuring efficient, affordable, economical, and sustainable provision of infrastructure services resulting in a project of higher standard without the need for additional funds.

The model is currently being tested more extensively on various infrastructure projects and the results indicate that the model can produce major cost savings for clients.

CHAPTER 11

THE STUDY'S CONTRIBUTION TO DESIGNING AND DELIVERING INFRASTRUCTURE PROJECTS

CHAPTER 11: THE STUDY'S CONTRIBUTION TO DESIGNING AND DELIVERING INFRASTRUCTURE PROJECTS

11.1 Introduction

Design is generally carried out in an environment of limited budgets, with a need to stretch financial resources as far as possible. For this reason designers are placed under considerable pressure to minimise costs through changes, and to generally downgrade their designs.

The infrastructure challenges and the need for cost planning on infrastructure projects was outlined in previous chapters. Inefficient use of resources for infrastructure can place a major burden on public finances.

The primary purpose of this chapter is to show how the Infrastructure Cost Planning Model can overcome the challenges put forward in the previous chapters.

The proposed model is used to address infrastructure planning and project management bottlenecks. It allows consultants to make cost informed design decisions on projects and to improve the co-ordination of infrastructure planning.

As mentioned in Chapter 4, it is during conceptual planning and design phases that the decisions have the greatest impact on cost and on the ultimate sustainability of a project.

This chapter discusses the various contributions offered by the Infrastructure Cost Planning Model, such as improved accountability, sustainability, affordability and cost control.

11.2 The Infrastructure Cost Planning Model helps promote accountability

Accountability means being willing to account for one's decisions and actions. The model allows for consultants' decisions to be transparent and creates opportunities to account for public expenditure, by using the various Cost Report Forms.

The standard Cost Report Forms developed in the model serve various functions, including:

- Being documents that set out the client's requirements;
- Being a channel of communication conveying instructions, decisions, and information between a client and consultants, providing collective 'thinking' throughout the project;
- Being a record of decisions and a tool for evaluating the cost of design alternatives.

11.3 Sustainable service delivery with the Infrastructure Cost Planning Model

One of the Infrastructure Cost Planning Model's aims is to focus on basic community services as well as to address the challenge of economic infrastructure development and delivery. It pursues the provision of affordable infrastructure options, in order to support the achievement of more sustainable and economical provision of services to communities.

Life cycle costing, benefit cost analysis and value analysis of design options is recognised as being supportive of sustainable development. Value analysis and material cost analysis directly affects the ultimate performance of an element.

The Infrastructure Cost Planning Model approach seeks to optimise the budget through the analysis of the costs of different levels of infrastructure options, therefore providing the required level of service at the least cost.

The Infrastructure Cost Planning Model was developed to address bottlenecks in infrastructure projects so as to promote effective co-ordinated assessment of design options, thus promoting efficiency and accelerating infrastructure services delivery. Integration of economic theories and cost reporting on the milestones of a project can

result in a design delivery system that is efficient and effective. Improved cost efficiency can have a considerable positive impact on municipalities' budgets.

The Infrastructure Cost Planning Model facilitates the provisions for infrastructure services in the following ways:

- Accelerated provisions for infrastructure services delivery through co-ordinated design efforts;
- Alleviation of key deficiencies in current provisions for infrastructure services practice, namely inaccurate cost forecasts, cost overruns, etc.;
- Cost planning awareness for more economical projects;
- Creating an environment towards stringent cost control of economical infrastructure design options;
- Incorporating value engineering, cost benefit analysis, life cycle analysis, etc. to infrastructure projects.

11.4 The Infrastructure Cost Planning Model – facilitating the provision of affordable infrastructure services

By far the most important factor influencing the choice of service is affordability. The enormous costs involved have forced Government to formulate ways of stretching its limited resources as far as possible. However, the choice of level of service and design must be within the affordability constraints.

Municipalities and consultants must work together to ensure efficient and effective provision, operation and maintenance of the services at an affordable cost.

Affordability is measured in terms of both capital costs and ongoing operation and maintenance costs, in the Life Cycle Cost Analysis Form.

The model aims at achieving a performance improvement in service delivery as well as service provision, which better meets the needs of the client. The development of the client focused Infrastructure Cost Planning Model aims to achieve the most economical design decisions, as well as improved levels and standards of service.

The Infrastructure Cost Planning Model has a higher level objective, which considers the trade-off between cost efficiency, functionality on the one hand and quality on the other. It can be seen as a strategy which achieves improvements in efficiency and accessibility without degrading quality.

This study describes the Infrastructure Cost Planning Model tools that can help increase infrastructure affordability, by reducing user financial costs for infrastructure options.

11.5 The principles of the Infrastructure Cost Planning Model compliment legislative requirements

Financial sustainability – The Infrastructure Cost Planning Model ensures that services are provided at levels which are affordable, and that municipalities are able to recover the costs of service delivery.

Effective and efficient resource use – Economic resources are scarce and should be used in the best possible way to reap the maximum benefit for local communities. However, there are no mechanisms available to ensure that municipal decisions will indeed lead to an effective allocation of resources. Efficiencies in public spending and resource allocation will ultimately increase the access of the poor to basic services. The Infrastructure Cost Planning Model can allow for the effective allocation of money by giving the client an opportunity to make informed decisions in the design process, thus facilitating cost effective projects.

Accountability, transparency and good governance – Municipalities should be held responsible and accountable to local taxpayers for the use of public funds. In order to achieve the above objectives, the model ensures accountability for both the client and the consultants regarding the design decisions made on projects.

11.6 The Infrastructure Cost Planning Model: shifting control to the local authorities

Effective cost management enables all involved in a project to respond to project challenges and to understand the interrelationships that result from various decisions about costs (Dell'Isola, 2002).

The Cost Report Forms play an important role in providing information and control systems that help toward the optimum use of the client's budget, at various stages of the project. The cost control tools enable the client to be kept fully informed of the cost implications of all his/her design decisions.

The model has been developed to provide clients and consultants with more control over the economic decisions taken in each design stage, enabling a comparison of the cost of various engineering solutions.

The measurable outputs give the executing authorities the opportunity to respond to cost of design decisions on the project. Control is shifted from the consultants to the municipality and the Government. This approach is in line with the emphasis on assessing outputs and outcomes. This shift will enhance accountability at government level.

11.7 Summary

The Infrastructure Cost Planning Model gives value for money in the public sector with the use of various cost planning tools. Construction economics, value analysis, cost planning, and other economic tools have been incorporated and developed into measurable outputs. Their objective is to establish a system limiting the expenditure on construction costs, but at the same time achieving the required quality and value.

The absence of a systematic and co-ordinated approach to infrastructure projects denies the stakeholders, and especially municipalities, synergetic benefits and optimum use of the infrastructure budget.

The key objective of the Infrastructure Cost Planning Model is to enhance decision making regarding different options in all the key stages of the project cycle, resulting in a more economical project.

This study supports Government's commitment to sustainable services. This study also supports industry by having developed decision support tools to help the industry make informed decisions for a sustainable infrastructure sector. The model can be used interactively by engineers and clients working together testing various design scenarios and arriving at a realistic, sustainable infrastructure project. The reports ensure the acceleration and improvement of service delivery and economic development, while not compromising quality. At the same time, the model ensures that consultants' designs are financially viable.

CHAPTER 12

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 12: CONCLUSIONS AND RECOMMENDATIONS

12.1 Introduction

As projects become more complex and clients more exacting in their requirements, so it becomes more necessary to improve and refine cost control tools. Rising prices, restrictions on the use of capital and high interest rates have caused clients to demand that their professional advisers should accept cost as a central element in design and that they should ensure suitably balanced costs throughout all parts of the projects.

Owners are demanding that designers relate more strongly to their financial and economic objectives and demonstrate more effective cost management in the delivery of projects.

The duties of engineers have changed over the past few years. This has been largely due to clients expecting better performance from both designers and contractors and their need to be certain of the final outcome of their projects. Clients have also sought greater control over their projects and an increased involvement in decision making.

This study emphasises the need to design within cost limits, and to forecast and control costs accurately. This arises from the inevitable reality that clients expect value for money.

12.2 Adhering to design standards when using the Infrastructure Cost Planning Model

It is generally recognised that any cost information system must be in line with design standards. However, unless cost is of paramount importance, it should not dictate the approach the designer takes – if the financial tail wags the project dog, this will not normally be conducive to satisfaction of all the client's requirements. The consultant should also be aware that striving to achieve optimisation in cost is only a part of the total objective.

12.3 Sustainable infrastructure provisions

Infrastructure is a key element for realizing sustained economic growth and sustainable development.

The model aims to provide sustainable infrastructure solutions. Using the various tools such as the life cycle cost analysis, value analysis and materials analysis, For an infrastructure project to be sustainable throughout its life-cycle, designers must understand all of the constraints including economic, environmental, social, as well as technical. It is imperative that development is strategic from the outset. Cutting-edge, cost-effective, and cleaner technologies must be promoted over conventional designs.

12.4 Recommendations

The following recommendations are offered for consideration and implementation.

- Cost planning, value engineering, construction economics, etc. should be incorporated into the traditional method of estimating the cost of infrastructure projects. Consultants should endeavour to integrate cost planning strategies into design.
- Engineering designers should undertake more cost optimisation during the design phases, namely concept design and preliminary design, where costs are affected the most.
- The Infrastructure Cost Planning Model should be implemented on projects to monitor the optimal use of the budget. Currently there are no uniform or co-ordinated monitoring and control procedures in place to measure the impacts and effectiveness of design options in the industry. It is recommended that the Cost Report Forms as explained in Chapter 7 be implemented to monitor and control project costs and ensure that the process of delivery is efficient and cost effective.
- Clients do not have full understanding of the design and the cost implication of certain design parameters or their decisions on a project.

- Local authorities need to be given an opportunity to respond to design decisions.
- Clients need to insist that consultants adopt value and quality management in infrastructure design.
- There is a need for continuous cost reporting to assess the relationship between cost and quality.
- There is a need to explore new delivery mechanisms, as mentioned in Chapter 3. The Infrastructure Cost Planning Model is a system that promotes cost effectiveness of design decisions.

12.5 Scope for further research

Developing cost planning software

With the increased sophistication of programming ability, it is likely that the Infrastructure Cost Planning Model could be programmed to run in a software package.

The software would enable clients to standardise the way their cost estimates are prepared and submitted. A database of elemental rates would allow for a range of estimates to be prepared in a few minutes, merely by typing in a few variables.

The Cost Report Forms that are generated from the software would ensure that clients have access to information regarding the costing of the project. The introduction of an electronic cost planning system would facilitate the communication between consultants and clients.

12.6 Summary

Due to the stringent financial controls proposed by the model, effective cost management can be achieved by consultants, engineers and project managers. This model ensures ongoing monitoring and accurate, timeous financial reporting which are key factors in effective cost planning and management of infrastructure projects. The benefits of using the model are revealed by the benefits that accrue from informed technical decisions made as a result of using the various Cost Report Forms of the Infrastructure Cost Planning Model.

Although cost planning has been partly researched in the academic world, particularly in the building industry, there is only scant evidence of it ever being used in professional practice.

Finally, the Infrastructure Cost Planning Model is about improving living standards and increasing and optimising the use of the infrastructure budget. If the aforementioned recommendations are implemented it will bring about major savings on projects. This will

no doubt have a tremendous impact on service delivery and contribute to delivering quality services to its end users.

This model enables Government to make use of private sector expertise in the most effective way possible and enables executing authorities to have final power over most cost decisions and contributes to the service delivery strategy.

In order to create a more cost-effective project, the Infrastructure Cost Planning Model was developed to be consistent with and promote the transformation of South Africa. The proposed model is more than just a tool, it is a systematic model intended to promote the concept of '**affordable infrastructure services**'.

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APPENDICES

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COMPARATIVE COST PLAN FORM

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VALUE ANALYSIS FORM

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APPENDIX 23

LIST OF PUBLICATIONS, CONFERENCE PRESENTATIONS AND POSTER PAPERS

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Journal Publications

Journal of the Institution of Municipal Engineering of Southern Africa

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