A COST MODEL FOR THE EVALUATION OF DIFFERENT OPTIONS IN TOWNSHIP INFRASTRUCTURE PROJECTS

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ABSTRACT

Minimum cost has become a critical performance criteria for most engineers in subsidised provisions of township infrastructure service schemes.

Government needs to effectively monitor the design process from beginning to end instead of just allocating money and that a different approach is needed in the provisions of infrastructure service schemes. While there are numerous political, social and economical aspects of the infrastructure services problem, there is a great need for appropriate technical solutions.

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

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.

As one goes through the procedural framework, it is intended to draw up some generic cost estimation from the different design scenarios and levels of services for roads, storm-water, sewer and water on infrastructure projects.

The proposed decision tool, with the use of process guidelines, assists in the levels of services option, quantitative and specification selection processes and will prove very useful for consultants and clients.

It uses a systems' thinking approach to identify and cost elemental parts of design, which appear to be more or less expensive than they might have expected.

This model takes the problem of inaccurate cost prediction and provides a methodology for forecasting the total cost for the project in various stages of the project by mapping the choices of design in the form of a decision tree in which all scenarios can be demonstrated and evaluated.

The goal for continuous improvement in the infrastructure sector can be achieved through the proposed framework and sound management practices at design stage. This, together with basic values and principles of cost planning and construction economics can

contribute to the concept of **"affordable township infrastructure**" and will result in a delivery system that becomes more efficient and effective.

1. INTRODUCTION

The best choice of appropriate design solutions for infrastructure projects is often complicated by the severe financial constraints and by many practical problems. A systematic and iterative analysis of the cost consequences of different design solutions is commonly suggested for infrastructure projects, but never happens.

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. (Byrne, 1995)

First a brief review of the principles of the cost planning on infrastructure projects and the cost consequences of different design solutions, as they relate to this type of problem, is given and some of the techniques used in the analysis are described.

In order to enhance service delivery within the housing and infrastructure sector, the research aims to put into place a cost model, in order to enable management to make informed cost-effective decisions and enhance the delivery and quality service. The best choice of an appropriate design for infrastructure services is often complicated by the severe financial constraints.

In essence, the model was designed to reduce the cost on housing and infrastructure projects with objectives of developing interim strategies that can be adopted and implemented within the project planning stages to reduce the cost of financial decisions.

The output generated by the model is visualised in terms of the functions, applications, and techniques of cost planning.

An analysis is then carried out to determine whether the costs are within limits. If not, a trial adjustment has to be made to the design and a new analysis carried out in the search for a feasible solution. Analysis plays a comparable role in a planning problem.

By using a systems thinking approach it organizes goals into strategies, that is addressed from the moment the developer communicates with the engineer. It is never too early to integrate strategy into the infrastructure design, scheduling specifications and construction process.

For the reasons of brevity, this paper only addresses the cost planning model and its components are presented. The outputs of the model will be addressed in subsequent papers.

2. PRE-TENDER PRICE ESTIMATING

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 purpose of the model is to provide an indication of the probable costs of construction.

Perhaps the single most important criterion of the 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. It should be accepted, however that early price estimate is an approximation and will therefore include some amount of uncertainty.

3. THE INFLUENCE OF DESIGN ON COST

It has been accepted that there is a causal link between design decision and costs. This is based on research conducted, which concluded that 35% of cost overruns were caused by falls that could have been reduced through early design decisions.

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.

Deviation from it at a later stage, resulting in variation orders can be the catalyst that triggers a series of events from the designer that will culminate in overspending.

Consequently, the designers need to make sufficient design related information available at pre-project stage to facilitate budgeting. (Flanagan and Tate, 1997).

The model and its output forms are used to check the costs of the design as it develops. They ensure that the tender sum comes within the forecasted cost.

4. INFRASTRUCTURE COST PLANNING

4.1 The cost planning model defined

The cost planning model is a systematic guide with procedures and outputs that evaluates a number of possible design options with their cost implications at each stage in the design.

Cost modelling is a technique that can be used to estimate cost of a proposed construction project. Although cost planning has been heavily researched in the academic world there is only scant evidence of it ever being used in professional practice.

This research aims at remodelling these cost planning techniques, by creating systems, decision-making processes and output forms and applying it to infrastructure projects.

4.2 The cost planning model: How it works in Practice?

The cost planning model is brought into the project cycle process in the first stages of design. Through a variety of techniques, the cost planning model maps out processes and evaluates a number of possible design options with their cost implications at each stage in the design and provides those who may not have all the necessary resources, capacity or expertise to make accurate cost decisions.

5. OBJECTIVES

The cost model will enable decision–making of different options in all the key stages of the project cycle so as to reap the benefits of a more economical project.

In view of the inadequacy of housing and infrastructure cost forecasting, the objectives of this research are as follows:

- To develop a model for assessing various decision-making options on infrastructure and housing projects.

- To develop the model as a decision making tool. The model should be an interactive tool, assisting in showing the implications of decisions as part of the process. The model must be clear and understandable without compromising the technical quality.

- To develop a system of comparing a range of possible design alternatives at any stage in the design evolution and the forecasting of the economic effects upon the change of different variables or elements.

- To develop a system of forecasting the cost of the total project, which the client will pay at any stage in the design process.

- To develop a single integrated control system, which incorporates the functions of cost planning, cost control, value management and scope management on projects.

- Promote social and economic development and continue to achieve good value for money in public expenditure.

- Reduce costs while retaining quality and standards.

- To increase the volume of services available to the poor and to enhance the budget utilisation.

6. METHODOLOGY

6.1 Methodology summary

The proposed model maps out processes and evaluates a number of possible design options with their cost implications at each stage in the design. The Cost Planning Model is illustrated in Annexure 1

The first stage involves dividing the project into various components (its main elements/ objectives / requirements), as discussed with the client in the brief. In this stage a comparison of major design options and selection of the most economical system and components is done

The second stage involves evaluating the major functional elements of each component.

One then goes through a detailed design and detailed items would be assessed.

This stage allows for elemental, sub-elemental and unit breakdown of components of the project to be identified.

Work from the initial design stages will be analysed and the economic consequences of each element will be assessed.

A more precise estimate can be obtained by inputting more detail of the element and choosing additional items that make up the element.

Further evaluations of detailed specification options are reviewed in stage 4.

In the early design stages, design information is scarce, and so assumptions have to be made. Later these assumptions are replaced by information concerning the actual design decisions made.

The distinguished 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.

6.2 The cost planning model methodology

This model describes a methodological approach used to enhance management's decision-making processes by mapping the choices of design options and subsequently increasing financial optimisation on infrastructure projects

As one goes through the procedural framework, it is intended to draw up some generic cost estimation from the different design scenarios and levels of services on infrastructure projects. The model helps to identify and cost elemental parts of design, which appear to be more or less expensive than they might have expected.

The model consists of process guidelines, which define an elemental breakdown of the project and of standard forms in which various cost planning and analysis functions are carried out.

Annexure 1 illustrates the conceptual model for cost forecasting at the different stages of design as well as standard forms for the analysis of the various options.

The model was developed to provide clients and consultants with more control over the economic decisions taken in each design stage enabling a rapid comparison of the options under consideration and the cost of various engineering solutions as well as cost implications of certain parameters. The underlying structure for cost modelling is based on a hierarchical breakdown of the project into five stages described below:

Stage 1 – Feasibility Stage
Stage 2 – Scheme Design Stage
Stage 3 – Detailed Design Stage
Stage 4 – Production Design Stage
Stage 5 – Bill of quantities Stage

The procedural framework is described below:

Stage 1 – Feasibility Stage

The first step in cost planning is to determine the project requirements or objectives.

In this stage a comparison of major design options and selection of the most economical system and components is done.

A progressive approach is usually appropriate; whereby the concepts are first developed to an initial stage, which allows the least competitive alternatives to be eliminated. The development is then carried to a more detailed stage.

In this way, progressively fewer alternatives are developed to an increasing level of detail, until the final choice is made. This stage allows for elemental, sub-elemental and unit breakdown of components to be identified in the project.

The project will be subjected to technical feasibility studies and cost estimation. The feasibility studies will attend to various options, e.g.

- Tarmac roads, gravel roads, or dirt/earth roads.
- Standpipes, communal water-selling kiosks, or individual connections.
- Pit latrines, water-borne septic tank for each property, or full sewerage for every property.

These feasibility studies will define the scope of the project, and will produce preliminary designs and cost estimates. Fully detailed engineering designs and cost estimates will not, however, be done at this stage.

At this stage the engineer and the client are busily endeavoring to establish the client's requirements.

Often the client is pressing for an assessment of cost before any drawings have been produced. He will make allowance for such factors as differences of location, site conditions, market conditions and quality of work, and so arrive at a provisional estimate on a comparative or interpolation basis.

The preliminary planning and design step is essentially a continuation of the feasibility study. It brings the search for the most appropriate approach to a conclusion. Each of the alternative approaches short listed in the feasibility study is investigated in turn and details are worked out to the extent necessary to enable them to be compared and ranked by means of the measures of effectiveness.

This stage gives greatest opportunity for optimisation of the budget (e.g. determining the most economical levels of services).

It involves dividing the project into various components and their various levels of service. By a series of cost analysis the various levels of services can be compared with each other to ensure the optimum use of the budget. A feasibility study can be carried out using a combination of criteria. The cost of alternatives could also be computed and tabulated along with other cost combinations.

The preferred option will devise further set of alternatives of different elements in the next stage.

Elemental cost analysis

By whatever means the total cost of the element has been obtained in this stage, it should always be expressed in a per metre length, for the following two reasons:

- For a comparison of reasonableness with other design options, if stormwater pipes (for instance) are costing far more per metre than stormwater open channels or proportioning it over the project cost, it is worthwhile investigating the results of the different design options.
- The elemental price per square metre enables the importance of any extravagance or economy to be judged in a way that is not possible when considering unit prices only.

Stage 2 - Scheme Design Stage

The preliminary planning and design step is essentially a continuation of the feasibility study. It brings the search for the most appropriate approach to a conclusion. The designer must strive to obtain an optimum solution. Each of the alternative approaches is short-listed in the feasibility study.

The client's requirements have now been definitely established and confirmed to be viable, the site has been surveyed and the engineer begins to consider the various alternative ways in which the project can be designed and constructed.

Some drawings will be produced at this stage and the quantity surveyor will be in a position to give general guidance on costs and, in particular, to evaluate the financial effect of different solutions to any specific design problem, and often prepares an outline cost plan.

These steps translate these broad characteristics into functional elements. This stage allows for elemental, sub-elemental and unit breakdown to be identified.

Work from the feasibility stage will be analysed and the economic consequences of each element will be assessed.

One can go on to stages 3 and 4 assuming certain materials and items to be used; the initial budget can also be checked. A broad outline of the specification and the brief is developed even further

With a preliminary design it would by now be possible to forecast the cost of these elements quite reliably.

As the amount of information that is available to the engineer, it should enable him to allocate target costs more accurately.

It is anticipated that this kind of optimisation process would take place prior to design and therefore the level of detail required for the geometric model would be rather sceptical.

Stage 3 - Detailed Design Stage

In order to obtain an accurate cost estimate and a detailed estimate of the effectiveness of a possible approach, a great deal of planning and design work needs to be undertaken, which can be costly. If the engineer goes into too much detail in the preliminary planning and design, in order to compare and rank the alternative approaches, this step becomes unnecessarily expensive and time consuming. On the other hand, if alternatives are eliminated on insufficient information, the most appropriate alternative may not be chosen.

At this stage of the design the major items that form the elements (e.g. different types of layer works) would then be considered. A more precise estimate can be 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.

The ‘outline specification form’ and the ‘elemental cost plan’ form can be finalized at this stage. A full design would then be carried out and decision made about certain variables. At the end of this stage, a cost plan is drawn up.

“By setting out the budget based on these elements, budgetary control procedures can be adopted that will allow monitoring and correction of the design, should it go outside the cost constrain” (Cited by Ferry *et* al, 1999). Sketch plans are now finalized and some working details are prepared.

The engineer checks on his approximate estimate figure and, with the aid of extensive cost information, reappraises the initial cost plan with provisional target cost figures set down. The engineer may adopt an elemental approach, a comparative technique or a mixture of both.

Stage 4 - Production Design Stage

The last step of the selection procedure is the production information stage. The main work items can further be broken down into a detailed selection criteria of individual minor elements that contribute to the cost of the item and assessed (e.g. class of pipes, depth categories)

However, within each there are many options regarding the choice of materials and layer thickness. The detailed design is more refined in this stage with detailed drawing.

The use of different materials will be considered here, provided that it is within the design specification and the subdivision of the item into further classifications

After a detailed selection of these minor elements, attempts of reducing the cost and optimising the budget can de done even further.

Further breakdown of work structure will result in the budget being oversimplified and a greater cost implication to the consultant. It can also lead to too many assumptions made in the earlier stage and a greater cost implication to the client.

This step can also include a checklist to ensure that nothing is left out and that all materials are within design specification.

The final working drawings (production drawings) will now be prepared from which bills of quantities can be produced. The engineer continues his cost checks on the data produced against the final cost plan.

Stage 5– Bill of Quantities Stage

The items in the bill will be broken down into various zones illustrated on plans to simplify the job and the contraction work sequence in this stage. It will attempt to measure costs the same way they are incurred on site.

The following factors will be taken into account in this stage: -

- A more economic use of materials verses quality,
- Will the element last longer or have lower life cycle costs?

- Will there be a more cost-effective use of available funds?

This will lead to a more cost-effective design. The possibilities are endless but for the purpose of simplicity in this research, just the key items were chosen.

Each element should be cost checked and drawings done to the quality that is necessary for the production of the bill of quantities.

7. COST REPORTS

Cost reports is a document that defines in a comprehensive, precise and verifiable manner, the cost of a project. It is used to measure, quantify, verify and audit the different design options.

The foundation for an effective evaluation is laid down in these precise reports

The following standardized output forms have been developed accompanying the model and is listed in Table 1.

Table 1: The output forms at each stage

Stage	Form No.	Form Name
FEASIBILITY STAGE	FORM 1	COMPARATIVE DEVELOPMENT SCENARIO OPTIONS
	FORM 2	FEASIBILITY COST REPORT FORM
SCHEME DESIGN STAGE	FORM 3	ELEMENTAL COST ANALYSIS
	FORM 4	COMPARATIVE COST PLAN
	FORM 5	PREFERRED DESIGN ALTERNATIVE FORM
	FORM 6	OUTLINE COST PLAN
	FORM 7	DESIGN APPROVAL FORM
	FORM 8	COST CHECK FORM
DETAILED DESIGN STAGE	FORM 9	DETAILED COST ANALYSIS
	FORM 10	DETAILED COST PLAN
	FORM 11	SPECIFICATION AND DESIGN NOTES FORM
PRODUCTION	FORM 12	COST TARGET FORM/COST LIMIT FORM
	FORM 13	CHECKLIST
	FORM 14	PROJECT BUDGET TRACKING FORM

8. APPLICATION OF THE COST MODEL

8.1 The cost model within the municipality

The pre planning of projects to date has been characterised as excessively rules driven, inflexible and inefficient. The cost model's aim is to overcome this over centralisation of

public service administration and will enable executing authorities to have final power over most cost decisions of projects.

This framework will enable authorities with the opportunity to respond to design decisions. Financial control is shifted from the consultant to the authorities and provincial Parliaments. This approach is in line with the emphasis on assessing outputs and outcomes, rather than focusing on whether managers follow correct procedures, irrespective of the results. This shift will enhance real accountability to the authorities.

Management in the municipalities will have to redesign their process, to be in pace with the cost model.

8.2 The model will assist consultants and client in the following ways

- Cost information can be provided more quickly, and changes in the design can be easily cost updated.
- More information is generated from the use of the computer, so that more informed decisions could be made.
- To make realistic comparisons of different items and design options to be used and readily assessing alternatives.
- Plan and cost infrastructure projects using simple templates and guides to formulate effective programme implementation plans.
- Manage planning and the design of projects.
- The tools used in the model provide a graphical method of presenting their results. It allows engineering, practical and financial issues to be easily weighed up against one another e.g. in the case of roads, the cost of pavements with cemented bases can be found to be cheaper or equivalent to granular bases.
- The correct pricing of infrastructure services.
- Clear and credible presentation of options and of costs and benefits;

9. BENEFITS

The key benefits of the model are as follows:

- It is a structured tool that will allow the consultant/decision maker to evaluate alternate decision strategies.
- The model will improve design quality in terms of increasing decision correctness; enhancing consultants decision confidence and reliability for the final decision.
- It reduces decision difficulties in making judgements in uncertain environments.
- It provides a search for alternative feasible technical solutions and presenting them as evaluated and costed options. This can be done within a structured framework of skills and techniques.
- It provides the design team with ideas and solutions to a problem and puts forward suggestions which is backed up by calculations and costing.
- A thorough sensitivity analysis of each element or option of the desired choice, irrespective of the stage of design.

10. CONCLUSIONS

The paper highlights one specific deficiency in the infrastructure projects practice; namely inaccurate cost forecasts and lack of the use of cost planning techniques.

There has to be a mechanism whereby clients, consultants and government can evaluate the cost of decisions at planning stage, where costs are most affected.

This paper shows how different levels of cost estimate can be prepared in parallel with design development. The system allows for the various components of the costs to be estimated at their own discrete level, depending on the level of design information available.

As the project moves to tender stage the estimate, which will be in elemental sections can be sorted into various sub elements. This data then appears in summary form in the anticipated cost report as a cost. The detailed level of the system can then be used to produce tender schedules for the bill of quantities.

It should be clear that all these proposed model and procedures cannot be developed without the client and consultant adopting a vigorous approach to implement this framework.

This research has outlined a theoretical approach to the cost forecasting methodology for the analysis of different options and their related cost effects. By developing this generic framework, an optimum use of the client's budget can be achieved, thus facilitating the growth and development of South Africa.

This cost planning approach makes cost effective decisions just one of the criteria relevant to the project planning.

This paper places emphasis on the cost planning model and the context in which the process takes place.

11. REFERENCES

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ANNEXURE 1 : THE COST PLANNING MODEL

PROJECT REQUIREMENTS

PROCESS INVOLVED AT EACH STAGE	STANDARD FORM AT STAGE	ROADS	SEWERS	STORM WATER	TOP STRUCTURES	WATER		DESCRIPTION OF EACH STAGE
* APP 1 * APP 2 * APP 7 * FORM 14	* FORM 1 * FORM 2	unpaved treated unpaved gravel single seal double seal asphalt block paving concrete	pit lactrine communal toilet vacuum truck cartage low cost septic tank bucket cartage aquaprivy Japanese vacuum truck cartage septic tank water borne sewerage	natural watercourse soakaways storage piped network open channel	roofs ceilings floors ext. walls int. walls foundation plumbing and drainage frame	communal well/ borehole water tanker communal storage with adjacent stand pipes public stand pipes individual water butt individual well/borehole on plot individual piped supply- single tap individual piped supply- multi tap	**STAGE 1** *FEASIBILITY* *STAGE*	**OUTLINE PROPOSAL** : ASSESEMENT OF OPTIONS : LEVELS OF SERVICE : CONSTRAINTS : SCOPE OF WORK IDENTIFICATION
	* FORM 3 * FORM 4 * FORM 5 * FORM 6 * FORM 7 * FORM 8						**STAGE 2** *SCHEME* *DESIGN* *STAGE*	**PRELIMINARY DESIGN** : FUNCTIONAL UNITS : MAJOR ELEMENTS : SKETCH PLANS
* APP 2 * APP 3	* FORM 9 * FORM 10 * FORM 11 * FORM 8						**STAGE 3** *DETAILED* *DESIGN* *STAGE*	**DETAIL DESIGN** : DETAILED DESIGN : PRELIMINARY DRAWINGS : ELEMENTS
* APP 4 * APP 5	* FORM 12 * FORM 13						**STAGE 4** *PRODUCTION* *INFORMATION* *STAGE*	**FULL DESIGN** : DETAIL ELEMENT DESIGN : SPECIFICATION OF ELEMENTS : DETAIL DRAWINGS
* APP 6							**STAGE 5** *BILL OF* *QUANTITIES* *STAGE*	ITEMS ARE SEPARATED INTO DIFFERENT WORK ZONES AND THE WAY COSTS ARE INCURRED ON SITE.

STANDARD FORMS

* FORM 1	: COMPARATIVE DEVELOPMENT SCENARIO OPTIONS
* FORM 2	: FEASIBILITY COST REPORT FORM
* FORM 3	: ELEMENTAL COST ANALYSIS
* FORM 4	: COMPARATIVE COST PLAN
* FORM 5	: PREFERRED DESIGN ALTERNATIVE FORM
* FORM 6	: OUTLINE COST PLAN
* FORM 7	: DESIGN APPROVAL FORM
* FORM 8	: COST CHECK FORM
* FORM 9	: DETAILED COST ANALYSIS
* FORM 10	: DETAILED COST PLAN
* FORM 11	: SPECIFICATION AND DESIGN NOTES FORM
* FORM 12	: COST TARGET FORM/COST LIMIT FORM (FINAL PRODUCTION)
* FORM 13	: CHECKLIST
* FORM 14	: PROJECT BUDGET TRACKING FORM

STANDARD PROCESSES

* APP 1	: OUTLINE OF COST PLANNING PROCESS
* APP 2	: OUTLINE OF COST CHECKING PROCESS
* APP 3	: OUTLINE OF DETAILED DESIGN PROCESS
* APP 4	: OUTLINE OF ELEMENTAL COST ANALYSIS PROCESS
* APP 5	: OUTLINE OF MATERIALS SELECTION AND EVALUATION PROCESS
* APP 6	: OUTLINE OF COST DATA VERIFICATION PROCESS
* APP 7	: OUTLINE OF VALUE ANALYSIS PROCESS