4. COST ESTIMATION

PURPOSE OF THE ESTIMATE

4.1 The objective of the estimate is to provide the most realistic prediction possible of the total cash expenditure and time that will be necessary to complete the project ready for operation. Cost estimates provided for road prdjects in developing countries in the past have generally proved to be wildly inaccurate, with two main results:

- Tendered contract bids have often proved to be considerably higher than the engineer's feasibility study estimate
- Considerable cost overruns have occurred during projection execution.

4.2 Traditionally, unit pricing techniques have been used for project costing, but these have been shown to be deficient in several important areas. This section recommends the use of analytical techniques and rigorous procedures of risk management to produce realistic estimates of cost at all stages of the project cycle. Expected values of project costs and construction periods should reflect past experience that actual values achieved have normally been far in excess of those estimated originally, particularly those estimates produced at the early stages of project preparation. It is worth expending considerable effort to produce realistic estimates of cost at all stages of the project.

COST ESTIMATING STAGES

4.3 The stages of a project in which estimates of cost and time may be needed are illustrated in Table 4.1. The result required at each stage and the information normally available are set out. It is appreciated that, in particular projects, some stages may be omitted or be indistinguishable from adjacent stages.

TABLE 4.1

PROJECT STAGES

	Stage					
	Identification	Feasibility	Design	Commitment	Implementation	Operation/ evaluation
Activities	Identification of project	Appraisal of the identified project, including basic requirements, alternative schemes, and recommendation of preferred scheme. Normally requires a cost-benefit analysis.	Definition of preferred scheme including basic design data, conceptual design, technical specifications, construction appraisal, contract strategies and estimate of final cash cost.	Consideration of submission for funding	Implementation of approved project including - detailed design - issue of tender enquiries - assessment of tenders - placing of contracts - construction - completion - commissioning	Operation of new asset by client. Evaluation of project.
Result	Inclusion in forward programme	Recommendation of preferred scheme	Project definition report for use in a subraission for funding	Funding approved for defined project. Basis for cost control	Basis for assessment of tenders and ongoing monitoring of costs and progress against approved estimate	Historical cost and productivity data bank
Available inform-ation for estimate	No design capacity/size only	Preliminary designs of alternatives	Conceptual design	Conceptual design	Tender documents	Completed contract

4.4 It is important to strive for the ideal of evolving a cost history of the project from start to finish with an estimated cash total at each stage near to the eventual achieved cost. This ideal can only be approached throughout the life of the project if the rising level of definition is balanced by reducing tolerances and contingency allowances which are effectively the measure of uncertainty. Each estimate should be directly comparable with its predecessor in a form suitable for cost monitoring during implemention.

4.5 The sequence of estimates throughout the life of a typical project is given below.

1. Preliminary

The quick estimate needed at the project identification stage, with no design available, and only the barest statement of capacity or size.

2. Feasibility

Estimates or alternative schemes under consideration in the feasibility study stage of the project. The essential property of these estimates is that they are directly comparable with each other and therefore base estimates could suffice so long as the same estimating technique and price base data are used. The differences between alternatives will not necessarily be absolute and the danger of their use for forward budgeting must be avoided.

3. Design

The cost estimate for the selected scheme using the design (usually conceptual) and specifications resulting from the design study and forming part of the project definition report. This estimate would provide the figures for capital cost, cash flow and currency requirements which would then be used in viability calculations for the project and in the submission for donor aid, where appropriate. It must be a cash estimate.

4. Commitment

The proposal estimate as modified and approved for financing, together with the associated modifications to the project definition and/or the programme. This must be a cash estimate, and will provide the basis for ~he cost control of the project.

5. Pre-tender

A refinement of the approved estimate in the light of further design work done during the tender period and using the information given in the enquiry documents. This estimate therefore would use the same information as is available to the tendering contractors and should be a good basis for the assessment of bids.

6. Post contract award

A further refinement of the approved estimate in the light of the contract(s) awarded. It includes redistribution of the monies within the approved total to allow more effective cost monitoring of the project to completion.

7. Achieved cost

A record of the actual costs achieved in order to review the cost performance of the project and for project evaluation. It should include a reconciliation of the actual use of contingencies and of the use of tolerance for dealing with major risks.

THE ESTIMATOR

4.6 The estimator must have relevant experience in the type of project envisaged and, wherever possible, in the costs and productivities of construction work at the proposed construction and main supply locations.

4.7 The estimator must have a close working relationship with the project design organisation and will normally be part of that organisation. It is essential that he is able to appreciate the conception and purpose of the project and the intentions of the design, and can easily investigate and clarify any uncertainties with the designers as they arise during the compilation of the estimate. The estimator must also be able to contact the client, the funding agency, visit the site and have access to any local information relevant to the estimate.

4.8 It is highly desirable that the same estimator is used on all the estimates required during the life of the ~roject and is responsible for the subsequent cost monitoring and control. This clearly depends on the continuity achieved in the design organisation. When a new estimator has to be appointed, for whatever reason, or when a check estimate is required from a separate estimator, then it is important to ensure an orderly transfer to him of all relevant information so that the new estimator is able to become accountable for his estimate and the subsequent cost control against it.

4.9 The estimator should be accountable for his estimate and should be involved in the subsequent monitoring of project costs against it. He should be responsible for employing the estimating technique most appropriate for the type of project and the stage of the project. In reaching this decision, he should note the advice on the various techniques, their strengths and weaknesses and their sources of data.

INFORMATION IN THE ESTIMATE

410 The information required by the estimator should include the following:

- The latest description of the intended project including all available drawings, specifications, job descriptions and the site location
- The intended/required start and completion dates and latest programmes
- Latest ideas on method of construction
- Sources of project funding with dates of availability
- Latest ideas on contract strategy and availability of resources together with any prescribed restrictions of choice
- Any papers or reports describing performance and problems encountered on similar projects in similar locations
- Any cost/productivity data relating to the project or current construction projects in the' host country.

4.11 The essential documents to be submitted by the estimator will be:

- Summary of estimate, together with any further documents necessary for explanation
- A list of documents and drawings used in compiling the estimate
- A programme for the project showing key dates.

In all cases the estimator should also be required to submit:

- A method of construction
- A contract strategy report.

4.12 Each section of the estimate should be compiled in the working currency envisaged for that section at prices current at a stated price base date. The consequent base estimates will be converted to cash estimates by the use of inflation indices, selected by the estimator, in conjunction with the project programme. Where a funding agency is involved, all cash estimates should be converted to the currency used by that agency using a stated exchange rate.

ESTIMATING TECHNIQUES

The techniques available

4.13 The four basic estimating techniques available to meet the project needs outlined above are summarised, together with the data required for their application, in Table 4.2.

4.14 The global and unit rate techniques rely on historical data of various kinds. Comments on this aspect of each technique are given under the respective headings, but the associated dangers are so critical that it is worth making the following general warning points about the use of historical data in estimating.

4.15 **Sample size** The data must be from a sufficiently large sample of similar work in a similar location and constructed in similar circumstances.

4.16 **Base date** Cost data needs to be related to a specific historical date, chosen with care. In the case of construction work carried out over a period of time, an appropriate 'mean' date has to be chosen eg two-thirds through the period.

4.17 **Price indices** Having selected the relevant price base date, there remains the problem of updating the price to the base date for the estimate. The only practical method is to use an inflation index, but there may not be a sufficiently specific index for the work in question. If there is not, recourse to general indices is usually made. In any event, there is a limited length of time, which probably does not exceed five years, over which such updating has any credibility, particularly in times of high inflation.

4.18 **Market effects** Overlying the general effect of inflation, is the influence of the 'Market Place'. This will vary with the type of project being undertaken, with the host country and also with the supplying countries. The state of the world economy at the price base date will require careful consideration before historical data can be credibly applied to a later or future date.

Global

4.19 This term describes the 'broadest brush' category of technique which relies on libraries of achieved costs of similar projects related to the overall size or capacity of the asset provided. This technique may also be known as 'rule of thumb' or 'ballpark' estimating. Examples are:

- cost per metre or km of roads
- cost per square metre of bridge deck areas or per cubic metre of mass concrete.

4.20 The technique relies entirely on historical data and therefore must be used in conjunction with inflation indices and a judgement of the market place influence to allow for the envisaged location and timing of the project.

4.21 The use of this type of rolled up historical data for estimating is beset with dangers, especially inflation, as outlined generally above. The following specific dangers apply.

4.22 **Varying definitions of what costs are included**

- engineering fees and expenses by consultants/ contractors/client, including design, construction supervision, procurement and commissioning

TABLE 4.2

ESTIMATING COSTS

	Global	Man hours	Unit rate	Operation
Project Data required	- Size/capacity - Location - Completion date	- Quantities - Location - Key dates - Simple method statement - Completion date	- Bill of quantities (at least main items) - Location - Completion date	- Materials quantities - Method statement - Programme - Key dates - Completion date
Basic estimating data required	- Achieved overall costs of similar projects (adequately defined) - Inflation indices - Market trends - General inflation forecasts	- Hourly rates - Productivities - Overheads - Materials costs - Hourly rate forecasts - Materials costs forecasts	- Historical unit rates for similar work items - Preliminaries - Inflation indices - Market trends - General inflation forecasts - Plant data	- Labour rates and productivities - Plant costs and productivities - Material costs - Overhead costs - Labour rate forecasts - Materials costs forecasts - Plant capital and operating costs forecost

List of potential problems, risks, uncertainties and peculiarities of the project

- final accounts of all contracts including settlements of claims and any other payments
- land acquisition costs
- transport costs of materials
- financing costs
- taxes, duties etc.

4.23 **Varying definitions of measurement of the unit of capacity**

- is a metre/kilometre of road an overall average including pro rata costs of bridges or should these be estimated separately?
- square metre of bridge deck area: including or excluding the cost of abutments?; cubic metre of mass concrete in bridges: height measured from top of ground or top of foundations?

4.24 **Not comparing like with like**

- differing levels of quality such as different pavement thicknesses for different levels of traffic
- different terrain and ground conditions such as roads across flat plains compared with mountainous regions
- different logistics depending on site location
- item prices taken out of total contract prices may be distorted by front end loading eg fob prices for hard currency items.

4.25 **Inflation**

- different cost base dates - it is essential to record the 'mean' base date for the achieved cost and use appropriate indices to adjust to the forecast date required.

4.26 A scrutiny of all these dangers, especially the effects of inflation, must be made before any reliance can be placed on a collection of data of this type. It follows that the most reliable data banks are those maintained for a specific organisation where there is confidence in the management of the data. The wider the source of the data, the greater is the risk of differences in definition.

4.27 However, so long as care is taken in the choice of data, the global technique is probably as reliable as an over-hasty estimate assembled from more detailed unit rates drawn from separate unrelated sources and applied to 'guesstimates' of quantities.

Man hours

4.28 This is most suitable for labour based construction and erection work where there exist reliable records of productivity of different trades per man hour. The total man hours estimated for a given operation are then costed at the current labour rates and added to the costs of materials and equipment. The advantages of working in current costs are obtained.

4.29 The technique is often used without a detailed programme on the assumption that the methods of construction will not vary from project to project. Experience has shown, however, that where they do vary (eg due to the capacity of heavy lifting equipment available), labour productivities and consequently the total

cost can be affected significantly. It is recommended that a detailed programme is prepared when using this technique. The prediction of cash flow requires such a programme.

Unit rates

4.30 This technique is based on the traditional bill of quantity approach to pricing construction work. In its most detailed form, a bill will be available containing the quantities of work to be constructed, measured in accordance with an appropriate method of measurement. The estimator selects historical rates or prices for each item in the bill using either information from recent similar contracts or published information (eg price books for civil engineering), or 'built-up' rates from his own analysis of the operations, plant and materials required for the measured item. As the technique relies on historical data, it is subject to the general dangers outlined earlier.

4.31 When a detailed bill is not available, quantities will be required for the main items of work and these will be priced using 'rolled up' rates which take account of the associated minor items. Taken to an extreme, the cruder unit rate estimates come into the area of global estimates as described above (eg unit rate per metre of road).

4.32 The technique is most appropriate to repetitive work where the allocation of costs to specific operations is reasonably well defined and operational risks are easily manageable. It is less appropriate for civil engineering works where the method of construction is variable and where the uncertainties of ground conditions are significant. It is also likely to be less than successful for engineering projects in locations where few similar schemes have been completed in the past. In these cases, success depends much more on the experience of the estimator and his access to a well understood data bank of relevant 'rolled up' rates.

4.33 Unit rates quoted by contractors in their tenders are not necessarily related directly to the items of work they are pricing. It is common practice for a tenderer to distribute the monies included in his tender across the items in the bill to meet objectives such as cash flow and anticipated changes in volume of work. It is likely that similar weighting is carried out by all tenderers in an enquiry and therefore it is not easily detected. It follows that tendered bill unit rates are not necessarily reliable guides to prices for the work described.

4.34 The technique does not demand an examination of the programme and method of construction and the estimate is compiled by the direct application of historical 'prices'. It therefore does not provide an analysis of the real costs of work, of the kind that would need to be carried out by a tendering contracter, for any but the simplest of jobs. Neither does it encourage consideration of the particular peculiarities, requirements, constraints and risks affecting the project.

4.35 There is a real danger that the precision and detail of the individual rates can generate a misplaced level of confidence in the figures. It must not be assumed that the previous work was of the same nature, carried out in identical conditions and with the same duration. The duration of the work will have a significant effect on the cost. Many construction costs are time related, as are the fees of supervisory staff and all are affected by inflation.

4.36 It is therefore recommended that a programme embracing mobilisation and construction is prepared. This should be used to produce a check estimate in simplified operational forrn where there is any doubt about the realism of the unit rates available.

4.37 Nevertheless, unit rate estimating can result in reliable estimates when practised by experienced estimators with good, intuitive judgement and the ability to assess the realistic programme and circumstances of the work.

Operational (resource-cost)

4.38 This is the fundamental estimating technique since the total cost of the work is compiled from consideration of the constituent operations or activities revealed by the method statement and programme, and from the accumulated demand for resources. The advantages of working in current costs are obtained because labour, plant and materials are costed at current rates.

4.39 The most difficult data to obtain are the productivities of labour and construction plant in the geographical location of the project and especially in the circumstances of the specific activity under consideration. Claimed outputs of plant are obtainable from suppliers, but these need to be reviewed in the light of actual experience. Labour productivities will vary from site to site depending on management, organisation, industrial relations, site conditions, etc and also from country to country. Productivity information is a significant part of the 'know how' of a contractor and will naturally be jealously guarded.

4.40 The operational technique is particularly valuable where there are significant uncertainties and risks. Because the technique exposes the basic sources of costs, the sensitivities of the estimate to alternative assumptions/methods can be investigated and the reasons for variations in cost appreciated. It also provides a detailed current cost/time basis for the application of inflation forecasts and hence the compilation of a project cash flow.

4.41 In particular, the operational technique for estimating holds the best chance of identifying risks of delay as it involves the preparation of a method of construction and a sequential programme including an appreciation of productivities. Sensitivity analyses can be carried out to determine the most vulnerable operations and appropriate allowances included. Action to reduce the effect of risks should be taken where possible.

Suitability of individual techniques

4.42 At the identification stage, the absence of all but the simplest definition of the project means that only the global' technique can be applied. However, estimating organisations which regularly use operational techniques state that even their crudest overall data are recorded in such a way that the effects of the more obvious uncertainties can be allowed for at this early stage. Clearly the availability of a reliable, well managed, global cost data bank together with associated 'broad brush' analyses is an essential requirement for any organisation involved in the early identification of projects for inclusion in a forward financial programme.

4.43 The essential activity in the feasibility stage of a project is the consideration of many alternatives. The most important characteristic of the estimating technique employed is, therefore, reliable comparability between the alternative schemes, which may be numerous. The technique must also be usable with only preliminary data for the schemes, as the conceptual design will normally be in its very early stages. The most appropriate techniques would be:

- Global
- Unit rate, using 'rolled up' unit rates for the main items of work.

4.44 However, if the state of information is good enough and time and funds are available, then the operational technique should be considered even at this stage, especially for plant intensive construction, when the key requirement is to identify the major resources and cost them over their period of required availability.

4.45 As soon as sufficient design detail is available at the appraisal stage, the first preference should be to use the operational technique. Exceptions may be labour based projects, where the man hours technique would be appropriate. In cases where, for whatever reason, there is insufficient time, funds or data available for the operational method, the unit rate technique may have to be resorted to.

4.46 When considering estimating techniques, the following factors should be kept firmly in the foreground:

- For all 'one-off' jobs, there is no credible alternative to operational estimating
- Accuracy in all estimates depends heavily on a clear definition of scope, the extent of use of local information and on the definition of uncertainties and potential problems
- There is considerable merit in using an alternative approach to prepare a 'validation' estimate; any differences between the main and validation estimates must be satisfactorily reconciled.
- An estimate submitted at any stage of a project should be subject to review
- It is recommended that all submitted estimates should include a carefully considered programme for the work; if this is omitted, there is a reduced likelihood that the effects of risk, delay and inflation will be properly considered
- It is vital that any modifications to the estimate are backed up by a depth of study not less than the depth of the original estimator's own investigations.

SOURCES OF DATA

Principal sources

4.47 Estimating data are normally obtained from three principal sources:

- Project-specific data collected for a particular project and therefore related to a specific location and time
- Data banks of previous or current projects collected by an individual estimator or estimating organisation
- Published data.

4.48 It is important that the estimator is directly involved in the collection of these data. This involvement should include visits to the project location and any other appropriate sites. It should also include a search for any significant risks, peculiarities or constraints to which the project may be subject and any factors which might affect the method of construction.

Project specific data

4.49 These data are in two forms:

- current costs of basic inputs to the work
- productivity outputs relevant to the type of work, its location and the particular circumstances surrounding it.

4.50 The basic inputs for which the estimator must collect current cost data include:

- hour wage rates
- other labour costs and overheads
- construction plant purchase prices and/or hire rates

- management, supervisory and administrative salary rates
- prices of materials
- prices of services and utilities
- transport, shipping and freight charges
- import duties
- taxes
- insurances
- interest rates.

4.51 Current cost data should be obtained from the sources closest to the initiation of potential price changes. The estimator must have accurate information on the prices and costs ruling in the market place at the base date assumed for the estimate. The sources must be local to the activity in question and will include:

- Government institutions
- Public works departments
- Contracting organisations ("oth local and experienced offshore)
- Consultants (both local and experienced offshore)
- Aid or development agencies
- Trade missions
- Shipping agencies
- Construction plant and materials manufacturers or importers
- Transport companies, etc.

All these sources are subject to error and the estimator must continually and critically assess their relevance to the specific project.

4.52 Credible productivity data and current cost data of basic inputs are essential information for the compilation of operational and man-hours estimates. They may also be used, with care, to revalidate data for global and unit rate techniques.

4.53 The translation of the base estimate to a cash estimate requires information on inflation and exchange rates which will be normally available from government sources, financial institutions and publications.

Data banks

4.54 Each estimating organisation can be expected to maintain a record of the costs and times achieved in the projects in which it has been involved. In-house data banks are more reliable than data banks collected by others as the management and interpretation of the information is within the control of the organisation and therefore consistency in its application should be assured. However, the reliability of any data bank depends on:

- The size of the sample available
- The acceptance throughout the organisation of standard methods of measurement and definitions of terms
- The recording of any special factors and circumstances which affected the performance of the recorded project
- The applicability of data to the specific circumstances, including location and duration, of the project being estimated.

4.55 Wherever it is necessary to access data banks collected by others, the credibility of the information obtained should be assessed using the same criteria.

4.56 The data recorded should be considered in two basic categories: cost data and productivity data.

4.57 Cost data The majority of these data will be historical, derived from compiled prices, and will include, in increasing order of detail:

- global unit costs related to size of project; eg cost per kilometre of roads
- 'rolled up' unit rates for main items of work
- rates for standard bill of quantity items.

4.58 All types of historical cost data must be related to a date from which the subsequent inflation can be estimated, normally using published indices. In addition, historical data must be assessed against changes in the market place over time. It follows that greater weight should be given to the most recent data available, such as that from current projects.

4.59 These data are for use in the global and unit rate estimating techniques.

4.60 **Productivity data** These data cover outputs and possibly utilisation figures for labour and construction plant. They will be related to specific operations in a known location and in defined circumstances. It is recommended that data are collected in the form of:

- output of work achieved in unit paid time by production units
- utilisation figures for the production units.

4.61 Such data can be collected at several levels, examples of which are given below in increasing order of detail:

a. a histogram of major resources available, coupled with the main quantities of work achieved
b. information of the form 'x number of machines of y capacity were employed for z weeks to remove V m^3 of clay material', together with utilisation figures for the period
c. the output of work achieved on a specific task by a labour gang or item of equipment, together with overall utilisation figures for the production unit.

4.62 As the level of detail increases, so does the importance of clear definition and consistent use of the terms used for productivity measurement. In particular, the distinction and relation between output and utilisation must be recognised.

4.63 It is recommended that levels (a) and (b) are the most appropriate for the initial collection of productivity data. They are the most readily usable for client estimates, since they allow for downtime over a significant period of time. As data are collected from an increasing number of projects, it should become possible to reconcile differences between them. This will be facilitated if a record is kept of the major factors affecting output and utilisation.

4.64 Such productivity data are unaffected by inflation and therefore can be applied in the operational and man-hours estimating techniques, wherever similar circumstances for the operation are foreseen.

Published data

4.65 Wherever required data are not available from in-house resources, or from specific resources related to the project, the estimator may have to resort to published data. Such data must be used with caution and thorough inquiry made into its basis and the circumstances of its achievement. For instance, the unit rates quoted for a common building activity in the United Kingdom in a range of established publications have been found to vary by - 50% to + 150% from the mean. Other studies have shown that equipment outputs as low as 20 per cent to 30 per cent of the manufacturer's published data might be expected, particularly in developing countries. The estimator is responsible for judging the credibility of any published data he may decide to use.

4.66 Some relevant sources of published data are given below, although there are many other useful publications:

- 'Caterpillar Performance Handbook'. Caterpillar Tractor Co. Annual editions.
  The most comprehensive catalogue of plant and its probable performance.
- 'Contractors Plant Association Handbook'. Contractors Plant Association, London. Current UK hire rates and details of selected plant items are given in the current annual edition.
- 'Civil Engineering and Public Works Review' publish a quarterly selection of unit rates for items of civil engineering construction in the UK.

CONTRACT STRATEGY

4.67 The choice of construction contract strategy could have a major bearing on the cost and therefore the feasibility of the project. It is therefore appropriate to consider this choice at an early stage.

4.68 The following four types of contract can be used:

- **Lump sum** payment based on a single price for the total work
- **Admeasure** payment for quantities of completed work, valued at tendered rates in a bill of quantities
- **Cost-reimbursable** payment for actual cost (requires 'open book' accounting) plus fee for overheads and profit
- **Target cost** payment based on actual cost plus fee plus incentive.

Choice of one or other type will be largely dictated by the perception of financial risk.

4.69 **Price based contracts** In lump sum and admeasure contracts, the contractor bears much of the risk and has to price his tender accordingly. When, as may frequently be the case in developing countries, the risks are high, this results in extremely high prices or in offshore contractors being reluctant to tender at all.

4.70 **Cost based contracts** In a cost-reimbursable contract, the client and donor will bear the main risks, whereas the intention of a target cost contract is to price the work excluding risk, the cost of which is borne by the client. Target cost contracts introduce an incentive for the contractor to work efficiently, aligning his objectives with that of the client to achieve the construction cost-effectively. Flexibility is desirable under the uncertain conditions found in many developing countries. Where the contract is managed with 'open book' accounting, this provides the opportunity, in theory, for client, consultant and contractor to discuss design modifications when these may be desirable. However, such methods of contract are very demanding of senior site staff for both consultant and contractor.

4.71 Where there is an active construction industry, tendering mobilises competition to good advantage. However, to be truly successful, the tender procedure also depends on there being a precise, comprehensive specification and a thorough design. Where the above conditions are not met, it is likely that negotiation of a cost-plus form of contract is more likely to be practical. A mixed approach is often adoped with initial tendering followed by negotiation on some aspects of the contract.

4.72 There are strong developmental arguments for using local construction capacity where this is available. Not only will this capacity usually be much less costly to mobilise, but the experience gained will strengthen the industry and help the country to be self-sufficient. There will also often be multiplier effects on other sectors of the economy. Some donors treat local contractors preferentially. For instance, the World Bank will consider local bids acceptable even if they are 15 per cent more expensive than those from offshore contractors.

THE DESIGN PROCESS AND PROJECT COSTS

4.73 For anything other than 'global' cost estimating, it will be necessary to base costs on a design which has been carried out to an appropriate level of detail. The road design process consists of four distinct phases: route location, the structural design of the pavement, the geometric design, and the design of structures including bridges, culverts and earth retaining works.

4.74 Route location applies only to new roads and is discussed in Section 5. It is that stage of the design process where the general positioning of the route or its 'corridor' is determined. The corridor should be chosen to meet the objectives of the project which normally implies a balance between maintaining user benefits by providing the shortest route consistent with engineering constraints of topography, ground conditions, drainage, structures and the location of road building materials.

4.75 The structural design of the road is the process in which the various layers of the pavement are selected so that they are capable of supporting the traffic for as long as required. The principal elements in this process are the choice of materials and their thickness for each pavement layer. This is dealt with in Section 6, where the basic principles of structural design are described and key features pertinent to the appraisal process are highlighted.

4.76 Section 7 covers the topic of geometric design which is the process whereby the detailed layout of the road in the terrain is designed to meet the needs of the road user. The principal elements of this process are the selection of suitable horizontal and vertical alignments and road widths.

4.77 Finally, the design of bridges and structures is concerned with a variety of topics, which include structures which allow the road to cross or be crossed by rivers, water courses, railways and other roads: it is concerned with earth retaining systems, drainage systems and special provisions for erosion control. These issues are discussed in Section 8.

4.78 In general, the four elements of design c an be considered separately although, in some areas, there are overlaps and particular subjects need to be considered under more than one heading. For example, the width of road shoulders has implications for both geometric design and structural design. Other important examples are the consideration of road maintenance and the provision of adequate drainage which affect all three elements of design. Where overlap exists, the requirements can sometimes conflict and compromises are necessary. Topics of this kind are specifically mentioned in the text.

4.79 The relative contribution that each aspect of design makes to the total costs of the project depends mainly on the various design standards adopted and on the type of terrain through which the road passes. To provide a particular geometric standard in hilly terrain requires the construction of cuts and fills involving the movement of earth or rock, much of which would be unnecessary in flat terrain. On the other hand, the quantity of high quality road making material required to provide the necessary structural strength in the pavement will not usually depend on the terrain. The choice of design standards should be based on an economic analysis, but can only be made within practical limits of design, construction and consistency. It is an iterative process and it is not possible to provide general guidelines or r~es of thumb on the relative costs associated with each aspect of design. Each case will need to be assessed on its merits with the objective of optimising the relationship between costs and benefits.

4.80 It is expected that road engineers will already have detailed knowledge of the methods used to design and cost projects at the various stages of their development and implementation. The following four sections on geotechnics, pavement design, geometric design, and drainage and structures are therefore written primarily for transport planners, economists and administrators, and others who may not have experience of practical road engineering.